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C O N T E N T

ASSESSMENT OF PRODUCTION OF UNDERUTILIZED POULTRY SPECIES IN IWO AGRICULTURAL DEVELOPMENT PROGRAMME (ADP) ZONE OF OSUN STATE, NIGERIA

Ayodeji ADEDIRE*, Olaide AKINTUNDE, Timothy AGBOOLA**, Moruff SHITTU***

Osun State University, *Department of Animal Science, Osogbo, Nigeria. ayodeji.adedire@uniosun.edu.ng **Department of Agricultural Economics and Agribusiness Management, Osogbo, Nigeria. E-mails: ayodeji.adedire@uniosun.edu.ng, olaide.akintunde@uniosun.edu.ng, timothy.agboola@uniosun.edu.ng, shittumoruff147@gmail.com

Corresponding author: olaide.akintunde@uniosun.edu.ng

Abstract

The widening supply-demand gap of poultry products in Nigeria calls for urgent attention toward improving the production and productivity of poultry with a special interest in underutilized poultry species. This study was carried out to examine the level of production of underutilized poultry species and the factors influencing it in the Iwo ADP Zone of Osun State. A multistage sampling procedure was adopted to select 150 poultry farmers for the study. Data were obtained through physical interview of the farmers, then analysed using descriptive statistics and ordinary least square (OLS) regression. Results showed higher percentage of males in poultry production and mean age of the poultry farmers was 49.19±12.40 years with a mean length of experience in poultry keeping of 11.0±7.4 years and mean flock size of 68± 17. It was deduced from the study that majority (77.3%) of the poultry farmers had no or limited access to extension services. As determinants of the rearing of underutilized poultry species in the study area, results of multiple linear regressions showed the coefficients of the age of poultry farmers, and length of poultry farming experience was positive and statistically significant (P< 0.01). Household size was also positive and statistically significant (P< 0.05). Based on the findings, the study, therefore recommends the need for an enlightenment campaign and awareness on the importance of rearing underutilized poultry species and strengthening the livestock extension services for effective and result-oriented service delivery to the poultry farmers.

Key words: *poultry, underutilized species, assessment, production, improvement*

INTRODUCTION

Poultry is domesticated avian species that can be raised for eggs, meat, and/or feathers.
The term "poultry" covers a wide range of birds, from indigenous and commercial breeds of chickens to Muscovy ducks, mallard ducks, turkeys, guinea fowls, geese, quails, pigeons, ostriches, and pheasants [16]. Poultry is raised throughout the world, with chickens by far the leading species everywhere [8]. Poultry production can be subdivided into three distinct parts namely, small, medium, and large scale. These are also otherwise known as backyard, semi-commercial, and commercial [20]. The country's standing poultry population is at present 180 million birds, a substantial increase from about 151 million birds, most of which are domiciled in the southern part of the country either in semi-intensive farms or intensive ones [7].
The popularity of poultry in Nigeria is highly significant and this can be as a result of its important role in food security and value chains. [10 and 16] argue that poultry birds are good sources of protein either used as eggs or meat. They further explained that the production of poultry birds is relatively cost-effective, thus, making it possible for low-income farmers to start up the business [10, 16, 17, 18]. More so, the return on poultry investment is relatively high compared to other livestock production and the high level of acceptability of the poultry meat across diverse ethnic backgrounds and religious beliefs broadens the market share and makes the business very viable. In addition to the benefits created by poultry meat, [1] remarked

that poultry eggs are more affordable for low-income earners compared to other sources of protein [1]. This adds to the relative importance of poultry to agriculture.

Extension services have to assure an efficient communication with the farmers regarding the transfer of knowledge and results from the scientific research [4].

The Nigerian poultry sub-sector has great potential for a wide range of reasons. Poultry farming has considerable potential for providing income opportunities, reducing malnutrition, generating employment opportunities, and alleviating poverty, especially for small farmers in Nigeria. Small farmers can start poultry farms at their homestead area at a low cost compared to other livestock farming. In addition, poultry farming also provides opportunities for other industries like feed mills, hatcheries, veterinary drugs, feed ingredients market, and as a market outlet for maize and soybeans farmers [9].

According to the Central Bank of Nigeria [2], the poultry sub-sector is the most commercialized of all Nigeria's agricultural sub-sectors with a current net worth of ₦1.6 trillion. The demand situation is estimated at over 200 million birds, while the demand for eggs and meat is about 790,000MT and 1,500,000MT, leaving a huge demand gap which, unfortunately, is met through smuggling. Thus, there is a need to improve the production and productivity of the poultry sub-sector in Nigeria. As high as the contribution of the poultry sector to the Nigerian economy, Chicken accounted for the majority of the production, followed by turkey production (unpublished source). In 2017, chickens contributed 89 percent of world poultry meat production, followed by turkeys with 5 percent, ducks with 4 percent, and geese and guinea fowl with 2 percent. The rest comes from other poultry species [21]. In recent years, the demand for quail birds and their products in Nigeria is increasing due to their medicinal, nutritional, and economic benefits [14]. According to [22], quail eggs can help to prevent kidney, liver, and gallbladder stones. The nutritional value of quail eggs is much higher than those offered by other eggs as they are rich sources of antioxidants, minerals, and vitamins, and give us a lot of nutrition than other foods [13].

In Nigeria, local ducks are raised on the free range alongside domestic chickens. Though ducks are hardier and more resistant to diseases and environmental hazards, they are fewer than chickens due basically to cultural beliefs which tend to portray ducks as mystique birds. A profitable small backyard poultry project is more feasible with ducks than with chickens because ducks have longer productive (egg-laying) periods. Therefore, the main objective of this study was to assess the level of production of underutilized poultry species (ducks, guinea fowls, turkeys, geese, and quails) in the Iwo zone of the Agricultural Development Programme (ADP), Osun State, Nigeria.

MATERIALS AND METHODS

Study area

The study was carried out in the Agricultural Development Programme (ADP) Iwo zone, Osun State. The zone comprises of seven local government areas namely; Iwo, Irewole, Ejigbo, Ayedire, Ayedaade, Isokan, and Ola-Oluwa.It has an area of 245km^2 and a population of 120,919 [15], and the current population of 5,521,901 composed with the annual population growth rate of 3.3% [3]. The poultry farmers are concentrated in the rural areas of the zone than the other ADPs zone in the state from the available records of the membership register of the Poultry Association of Nigeria (PAN).

Source and type of data

Primary data were used for this study. The Data were obtained through physical interview of the farmers with the aid of a well-structured questionnaire that captured the socioeconomic characteristics of poultry farmers and farm characteristics.

Sampling procedure and data collection

The study was carried out using a multistage sampling procedure to select a representative sample of poultry farmers from the study area. At the first stage, Iwo zone was selected among the three (3) agricultural zones in Osun State, because of the predominance of underutilized poultry species and the availability of a market for poultry products in the study area. During the second stage, three (3) local governments from the study zone were randomly selected, then, two farming communities were randomly selected from each of the selected local government areas, making a total of 6 communities. Finally, twenty-five (25) poultry farmers were randomly selected from each selected farming community to make a total of one hundred and fifty (150) sampled poultry farmers for the study.

Analytical techniques and models

The data obtained were carefully analyzed using descriptive analysis, and multiple linear regression analysis. The descriptive statistics used were frequency, proportion (percentage), mean, and standard deviation while the inferential statistical tool used was multiple linear regression.

Model specification

In estimating the parameters of socio-economic characteristics, descriptive statistics (percentages, frequency distribution, mean, standard deviation) were used to show the description of the socioeconomic characteristics of the respondents. The multiple linear regression models were specified as follows:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + U \text{.........................(1)}$$

where:

Y = determinants of the rearing of underutilized poultry production

X_1 = Age of respondent (years)

X_2 = Sex of the respondent (1= male, 2= female)

X_3 = Household size (number)

X_4 = Level of formal education

X_5 = Length of poultry-keeping experience (years)

X_6 = Access to extension services (1= yes, 2= No)

X_7 = Hired labour

U = Error term

$b_{0,.......}$ b_7 = coefficients of the independent variables

RESULTS AND DISCUSSIONS

Socioeconomic characteristics of keepers of underutilized Poultry species

Table 1 presents the socioeconomic characteristics of the keepers of underutilized poultry species. The table shows that more than half (59.3%) of underutilized poultry farmers were below the age of 50 years while the mean age was 49.19±12.40 years. The results further showed that the majority (72.0%) of the keepers were male, while a few (28.0%) were females. It was revealed that a few (7.3%) of the keepers are single, a large number (78.8%) are married, 1.3% is divorced, 7.3% are a widower and 5.3% were separated.

Table 1 reveals that more than half (56.7%) of the keepers had a household size of 4-6 persons, having a mean household size of 6±4 persons, which implies a large household size. The results indicate that few (7.3%) of the poultry keepers had no formal education; while 17.3% had primary education, 34.7% had secondary education and 40.7% had their tertiary education which determines their exposure and level of adoption of innovation in the field of poultry production.

The results in Table 1 further indicate that a few (32.7 %) of the respondents had less than 5 years of poultry-keeping experience, while 29.3 % had 6-10 years of poultry-keeping experience. The mean length of poultry-keeping experience was 11.0±7.4 years. It was also gathered that the majority (77.3%) of the farmers did not have access to extension services. A larger percentage of those that have access to the extension service (78.0%) had a low connection and (15.3%) had a high connection while (6.7%) had a very high connection.

This study revealed that the majority of our correspondence had little or no access to advisory services (through extension services) or consultancy to aid adequate information on poultry production and disease management; as access to extension services positively influence the management of poultry farms and encourage the farmers to adopt improved farming methods [6]. The keepers depend on long experience in the place of extension services. This long poultry-keeping experience will affect their production practices positively with their reasonable knowledge of poultry production and its problems such that they handle poultry production problems perfectly on their farms just as reported by [19] who observed that years of poultry-keeping positively influence poultry management.

Table 1. Distribution of Socioeconomic Characteristics of Keepers of underutilized Poultry Species

Characteristic	Frequency	Proportion (%)
Age (years)		
≤ 29	14	9.3
30-39	32	21.3
40-49	43	28.7
≥ 50	61	40.7
Mean = 49.19	S.D = 12.40	
Sex		
Male	108	72
Female	42	28
Marital Status		
Single	11	7.3
Married	118	78.8
Divorced	2	1.3
Widow/ Widower	11	7.3
Separated	8	5.3
Household Size		
≤ 3	32	31.3
4 – 6	85	56.7
≥ 7	33	22.0
Mean = 6.0	S.D = 4.0	
Level of Education		
No formal education	11	7.3
Primary	26	17.3
Secondary	52	34.7
Tertiary	61	40.7
Poultry Keeping Experience (years)		
≤ 5	49	32.7
6 - 10	44	29.3
11 – 15	22	14.7
≥ 16	35	23.3
Mean = 11.0	S.D = 7.4	
Access to extension services		
Yes	34	22.7
No	116	77.3

Source: Field Survey Data, 2021.

The literacy levels of the keepers also helped in the absence of extension and consultancy services. The implication of this is that the costs of obtaining new technical and related information for the farmers will be reduced substantially when they can read and understand published materials and simplified farm journals, which are increasingly becoming the modern vehicle for disseminating information through various online media.

Factors affecting the rearing of underutilized Poultry in the study area

Table 2 presents the coefficients of multiple linear regressions for the determinants of the rearing of underutilized poultry species in the study area.

The coefficient of multiple determination (R^2) shows that 70.4 % of the variation in the rearing of underutilized poultry was determined by the included independent variables in the model. The coefficient of R^2 and F statistics which were significant at $p < 0.001$ showed that the exponential model was well-fitted.

The results presented in Table 2 revealed that the rearing of underutilized poultry in the study area was significantly influenced by age, household size, and years of poultry-keeping experience. All these variables had a positive relationship with the underutilized poultry production, except age which had a negative coefficient. The coefficient of age size was 8.62 (P<0.01), implying that a year increase in the age of poultry farmers would increase the rearing of underutilized poultry by 8.6 units. This result confirms that the youthful age of the producer helped to combine more inputs effectively leading to higher levels of gross revenues.

The household size had a positive coefficient of 3.62 (P<0.05), implying that a unit increase in the household size would increase the production of poultry farmers in underutilized poultry by 3.6 units.

The coefficient of years of poultry farming experience was 8.64 (P<0.01), implying that a year increase in the year of poultry keeping would increase the production of underutilized poultry by 8.6 units.

It is believed that longer experience in poultry keeping should translate to better management practices and skills in the exploration of other poultry ventures such as embarking on underutilized poultry production.

This finding on length of experience confirms [5], indicating that the more years they put in the production process the more experienced they become and the more they would increase their flock size, depending on the prevailing circumstances.

Table 2. Multiple Regression Analysis showing determinants of underutilized poultry rearing in the Iwo ADP zone of Osun State

Variable	Coefficient
(Constant)	1.099***
Age	-8.618***
Sex	8.961
Household size	3.620**
Level of Formal Education	1.553
Years of Poultry Keeping Experience	8.638***
Access to Extension	-1.059
Hired Labour	0.821
F Statistics = 2.113 R^2 = 0.7042 Adj R-squared = 0.6894	

Source: Field Survey Data, 2021.
*** Significant at 1%, ** Significant at 5%, * Significant at 10%

Constraints to Poultry production in the study area

The constraints affecting the underutilized poultry production in the study area, is presented on Table 3. Seven major problems were identified (with their respective weight mean score), these are unavailability of the market for stock ready for sale (2.41), inadequate access to extension services (2.05), high rate of mortality (1.97), high cost of feeds (1.94), lack of access to credit facilities (1.85), high cost of medication (1.84), and high incidence of poultry diseases (1.79).

Of these constraints, the unavailability of a ready market was one of the major constraints with 1st rank suffered by the poultry farmers in the area. With pronounced poverty both in the urban and the rural areas [12], demand for these birds became low despite the shift in consumption patterns from the other sources of livestock proteins to poultry products and fish due to changing tastes, costs, and income [11]. Inadequate access to extension services was ranked second. Further investigation revealed that farmers depended on information from fellow poultry farmers and the few that can read got such information from books and related publications. The high rate of mortality ranked third among the problems experienced by the farmers in the study area. High incidence of poultry diseases, lack of access to credit facilities, high cost of medication, and high cost of feeds ranked fourth, fifth, sixth, and seventh, respectively.

Table 3. Distribution of constraints affecting the production of underutilized poultry species in the Iwo ADP zone of Osun State

Factor	Not constraint	Minor constraint	Major constraint	WMS	Rank
Unavailability of a ready market	13 (8.7)	62 (41.3)	75 (50.0)	2.41	1st
Inadequate access to extension services	50 (33.7)	42 (28.0)	58 (38.7)	2.05	2nd
High rate of mortality	34 (22.7)	86 (57.3)	30 (20.0)	1.97	3rd
High incidence of poultry diseases	41 (27.3)	70 (50.7)	33 (22.0)	1.94	4th
Lack of access to credit facilities	50 (33.3)	72 (48.0)	28 (18.7)	1.85	5th
High cost of medication	52 (34.7)	70 (46.7)	28 (18.7)	1.84	6th
High cost of feed	61 (40.7)	59 39.3	30 (20.0)	1.79	7th

Source: Field survey Data, 2021.
*Parentheses are in percentage.

CONCLUSIONS

The factors that were discovered to have a positive effect and significant influence on the rearing of underutilized poultry in the study area included the age of the poultry farmers, household size, and years of poultry-keeping experience.

Based on the findings of the study, the authors, therefore, recommend the following:
-Enlightenment and awareness campaign on the importance of rearing underutilized poultry birds to increase the level of poultry production in the study area.
-The stakeholders in the poultry industry should assist poultry farmers in training on modern practices in the rearing of underutilized poultry birds.
-Government should revitalize the livestock extension services delivery to poultry farmers.

REFERENCES

[1]Aboki, E. A., Jongur, A. U., Onu, J. I., 2013, Productivity and Technical Efficiency of Family Poultry Production in Kurmi local Government Area of Taraba State. Nigeria. Journal of Agriculture and Sustainability, 2013, 4 (1):52-66.
[2]Central Bank of Nigeria, (CBN), 2021, Annual report and statement of account Nigeria. Released on 29th of July, 2021.
[3]City Population, 2020, Osun State, Nigeria – Population Statistics, Charts, Map and Location. https://www.citypopulation.de, Accessed on March 20, 2023.
[4]Chukwudum, E.G., 2019, Effectiveness of agricultural development programme communication methods on broiler production technology adoption among farmers in Anambra State, Nigeria, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.19(4), 53-58. https://managementjournal.usamv.ro/pdf/vol.19_4/volume_19_4_2019.pdf, Accessed on May 22, 2023.
[5]Emaikwu, K. K., Chikwendu, D.O., Sani, A.S., 2011, Determinants of flock size in broiler production in Kaduna State of Nigeria. Journal of Agricultural Extension and Rural Development, 2011, 3 (11):202-211.
[6]Evans, M. M., Samuel, N. N., Samuel, C. M., 2021, Production of indigenous poultry among smallholder farmers in Tigania West Meru County, Kenya. African Journal of Agricultural Research, 17 (5):705-713.
[7]FAO, 2018, Food and Agriculture Organization of the United Nations. Africa Sustainable Livestock 2050: Livestock and Livelihoods Spotlight. Nigeria. Cattle and Poultry Sectors.
[8]FAO, 2020, Food and Agriculture Organization of the United Nations. Gateway to Poultry Production and Products: Products and Processing. Retrieved March 3, 2020 from http://www.fao.org/poultry-production-products/products-processing/en/. Accessed on ????
[9]Hassan, A. A., Ahmadu, H. J., Oseni, Y., Dawang, N. C., Rahman, S. A., AbdulSalam, Z., 2016, Economic Analysis of Poultry Egg Enterprise in Kaduna State, Nigerian J. Anim. Prod. Res., 2016, 28 (1):196-204.
[10]Heise, H., Crisan, A., Theuvsen, L., 2015, The Poultry Market in Nigeria: Market Structures and Potential for Investment in the Market. PhD Student, Post Doc& Professor, Georg August University of Goettingen, Department of Agricultural Economics and Rural Development Chair - Management of Agribusiness, Platz der Goettinger Sieben 5, D-37073 Göttingen, Germany. International Food and Agribusiness Management Review Vol. 18, Special Issue A, 2015.
[11]Ja'afar-Furo, M. R., Balla M. R., Yakubu, B., 2007, Avian influenza (Bird flu) outbreak news scare and its economic implications on poultry enterprises in Adamawa State, Nigeria. Global J. Agric. Sci., 6:61-68.
[12]Kwaghe, P. V., Amaza, P. S., Ja'afar-Furo, M. R., 2009, The relationship between social factors and the poverty experienced by farming households in Bornu State, Nigeria. Global J. Agric. Sci., 8: 119-126.
[13]Lawani, P., 2011, Quail Egg Nutrition. http://www.buzzle.com/articles/quail-egg-nutrition.html. Accessed on 15th April 2012.
[14]Muhammad, L. A., Amolegbe, K. B., Abdulsalam, O. A., 2017, Economics of Quail Production in Ilorin, Kwara State. Department of Agricultural Economics and Farm Management University of Ilorin, Ilorin, Nigeria. Journal of Agricultural Extension, 21 (2).
[15]National Population Commission (NPC), 2006, Analysis of Nigerian 2006 census
[16]Oduntan, O., 2019, Technical effciency of smallholder poultry farmers in Akure South Local Government area, Ondo State, Nigeria, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.19(1), 313-319, http://managementjournal.usamv.ro/pdf/vol.19_1/Art43.pdf, Accessed on May 22, 2023.
[7]Ogbona, S.I., Emerole, C.O., 2018, Analysis of production and profitability of chicken egg farms in Abia State, Nigeria, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.18(3), 275-280, https://managementjournal.usamv.ro/pdf/vol.18_3/volume_18_3_2018.pdf, Accessed on May 22, 2023.
[18]Ogbona, S.I., Emerole, C.O., 2018, Analysis of income and profitability of chicken egg marketing business in Abia State, Nigeria, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.18(3), 281-286, https://managementjournal.usamv.ro/pdf/vol.18_3/volume_18_3_2018.pdf, Accessed on May 22, 2023.
[19]Olorunwa, O. J., 2018, Economic analysis of broiler production in Lagos State poultry estate, Nigeria. Journal of Investment and Management, 7 (1):35-44.
[20]Rimi, N. A., Sultana, R., Muhsina, M., Uddin, B., Haider, N., Nahar, N., Zeidner, N., Sturm-Ramirez, K., Luby, S. P., 2017, Biosecurity Conditions in Small Commercial Chicken Farms, Bangladesh 2011-2012. EcoHealth, 14 (2):244–258.

https://doi.org/10.1007/s10393-017-1224-2. Accessed on the 15th of March 2020.

[21]Sineque, A. R., Macuamule, C. L., Dos Anjos, F. R., 2017, Aflatoxin B1 contamination in chicken livers and gizzards from industrial and small abattoirs, measured by ELISA technique in Maputo, Mozambique. International Journal of Environmental Research and Public Health,14 (9): 951.

[22]Umera, A. E., Ejezie, F.E., Ibegbu, M.D., Ikekpeazu, J.E., Onyekwelu, K.C., Ejezie, C.S., 2018, Effects of quail (*Coturnix japonica*) egg diet on both the blood sugar and the lipid profile of alloxan induced diabetic albino rats. Biomedical Research 29 (9): 3599-3604

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COMPARATIVE ANALYSIS OF SOME MAIZE GENOTYPES - PRODUCTION POTENTIAL AND QUALITY INDICES

Alina Laura AGAPIE[1], Florin SALA[1,2]

[1]Agricultural Research and Development Station Lovrin, Lovrin, 307250, Romania, E-mail: alinamartinig@yahoo.com, florin_sala@usvt.ro
[2]University of Life Sciences "King Mihai I" from Timisoara, Timisoara, 300645, Romania Emails: florin_sala@usvt.ro

Corresponding author: florin_sala@usvt.ro

Abstract

The study comparatively analyzed 15 maize genotypes, under the aspect of production potential and some quality indices. The experiment was organized within the ARSD Lovrin. Eight maize genotypes from Lovrin (L experimental code; L1 to L8) and seven genotypes represented by commercial hybrids (CH experimental code; CH9 to CH15) were considered. The production of maize ears, Y(ears), varied between 6,236.00±570.14 kg ha^{-1} in hybrid L4 and 12,839.33±570.14 kg ha^{-1} in hybrid CH15. The physical grains production, Y(pgp) varied between 5,371.00±524.39 kg ha^{-1} in hybrid L4 and 11,640.00±524.39 kg ha^{-1} in hybrid CH15. The recalculated production (STAS, 14% moisture), Y(STAS) varied between 5,371.00±507.36 kg ha^{-1} for hybrid L4 and 11,579.33±507.36 kg ha^{-1} for hybrid CH15. The protein content (Pro, %) varied between 7.20±0.33% in the CH14 hybrid and 10.60±0.33% in the L3 hybrid. The oil content (Oil, %) varied between 5.20±0.09% in the CH15 hybrid and 6.40±0.09% in the L1 and L2 hybrids. According to PCA (95% confidence), the hybrids from group L were placed associated with the content of protein (Pro) and oil (Oil) as biplot. Hybrids from the CH group were placed associated with the Y(STAS) parameter. PC1 explained 72.693% of variance and PC2 explained 17.704% of variance. For the selection process of genotypes in breeding programs, the genotypes from the CH group (commercial hybrids) are of interest for the production potential, and the genotypes from the L group (Lovrin) are of interest for the quality indices (Pro, Oil)

Key words**:** *agricultural practices, breeding program, comparative analysis, maize, quality indices, yield*

INTRODUCTION

Maize is a crop plant of high importance, with multiple ecological valences and multifunctionality through its use in human food, as fodder but also in industrialization [9, 13, 17].

Maize production has increased constantly in the last decades, through more productive genotypes (more adapted to environmental conditions), through high-performance technologies (irrigation, fertilization, mechanization, plant protection, etc.), as well as through the expansion of cultivated areas [4, 9, 26, 28].

The breeding programs for maize genotypes are increasingly based on the concept and modern techniques of plant breeding [6, 22], biotechnologies [25, 29], informatics [3, 23], machine vision, deep learning, mathematical modeling [11, 27].

The evaluation of different maize genetic resources, their behavior in various climate and soil conditions, culture technologies, nutritional relationships, stress factors, etc. represented a basic concern for the identification of valuable genotypes for crops but also for breeding programs. [1, 7, 10, 24].

In order to obtain new, better performing corn hybrids, it is necessary that genotypes, potential lines in the improvement process, are always tested as well as behavior in climate and soil conditions specific to the area for which the new hybrids will be intended [8].

Maize production and quality indices are closely related to the genotype, but they can also be significantly influenced by agricultural practices, crop management, the level of technology, and various studies have quantified these aspects [4, 5].

The purpose of this study was to comparatively analyze the behavior of some maize genotypes in terms of production and some quality indices, with implications for agricultural practice, but also for the selection

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process of some parents in the improvement process.

MATERIALS AND METHODS

The study evaluated the variation in production and some quality indices in 15 maize genotypes, in order to characterize them for production but also as genetic resources for the breeding process.

The study and field experiments were organized within ARSD Lovrin. Eight genotypes from the ARSD Lovrin collection (L1 to L8) and seven commercial hybrids (CH9 to CH15) were studied.

Genotypes L1, L2 are part of the PAO 320 group, genotypes L3, L4 and L5 are part of the FAO 340 group, and genotypes L6, L7 and L8 are part of the FAO 400 group. All eight genotypes are single hybrid type, with dented grain.

Within the commercial hybrid genotypes, CH9 is part of the FAO 300-320 group, the CH10 genotype is part of the FAO 300 group, the genotype is part of the FAO 320 group, the CH12 genotype is part of the FAO 400 group, the CH13 genotype is part of the FAO 380 group, the CH14 genotype is part of the FAO 420 group, and the CH15 genotype is part of the FAO 350 group.

All the maize genotypes considered in the study were cultivated under identical soil and technology conditions, respectively on a chernozem type soil, weakly glazed, epicalcare, medium clay loam.

The preparation of the land was done classically (plough, disc, combiner), and sowing was done on April 2, 2022.

Fertilization was done with complex (15:15:15) in a dose of 250 kg ha^{-1} and ammonium nitrate 200 kg ha^{-1}. Weed control was done by weeding (Radial, 0.7 l ha^{-1}, Dicoton 0.6 l ha^{-1}). The culture technology was in non-irrigated system. The harvest took place on September 24, 2022. The climatic conditions during the study period are presented in Figure 1.

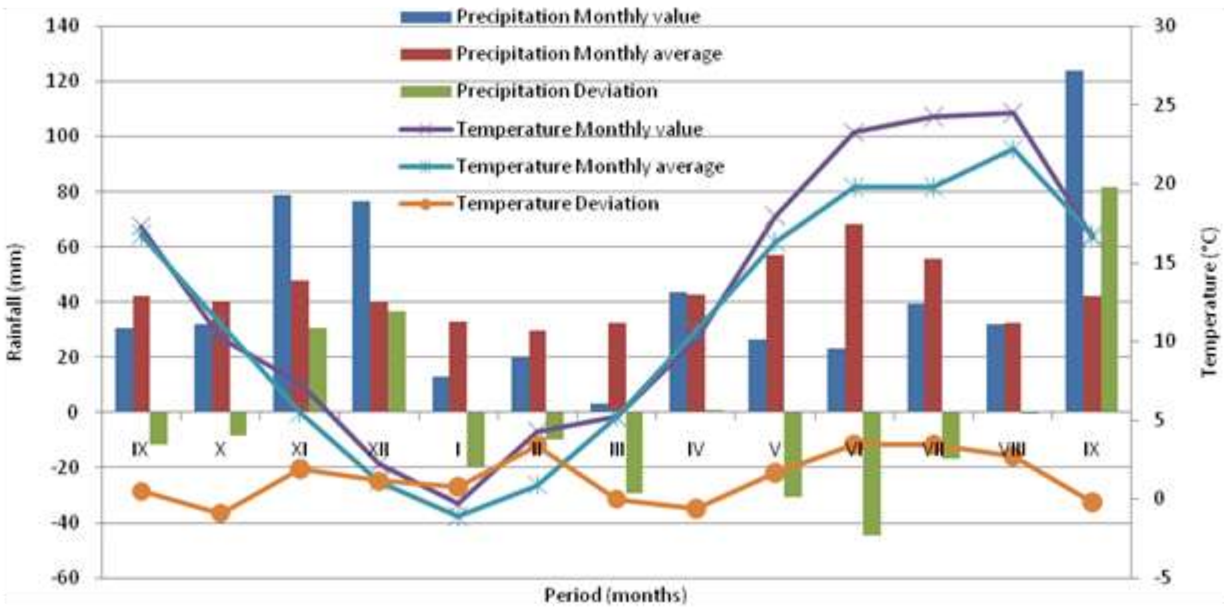

Fig. 1. Climatic conditions during the study period
Source: Original data, ARSD Lovrin Weather Station.

For the comparative analysis of the corn genotypes considered in the study, the production of maize ears Y(ears), the physical production of grains Y(pgp), the production of STAS, Y(STAS), the yield G(Y), the moisture (Mstr), the protein content (Pro) and the oil content (Oil) were determined.

The production parameters were expressed in kg ha^{-1}, and the quality parameters were expressed in %.

The recorded experimental data were analyzed to reveal the differences between the two groups of genotypes (L, and CH), and for this, appropriate mathematical and statistical tools were used [14, 15].

RESULTS AND DISCUSSIONS

The production of maize ears, Y(ears), varied between 6,236.00±570.14 kg ha^{-1} in hybrid L4 and 12,839.33±570.14 kg ha^{-1} in hybrid CH15. The physical production of grains varied between 5,371.00±524.39 kg ha^{-1} in hybrid L4 and 11,640.00±524.39 kg ha^{-1} in hybrid CH15. The recalculated production (STAS, 14% moisture), Y(STAS) varied between 5,371.00±507.36 kg ha^{-1} for hybrid L4 and 11,579.33±507.36 kg ha^{-1} for hybrid CH15. The yield (GY) varied between 83.20±0.51% for the L2 genotype and 90.70±0.51% for the CH15 genotype. The protein content (Pro, %) varied between 7.20±0.33% in the CH14 hybrid and 10.60±0.33% in the L3 hybrid. The oil content (Oil, %) varied between 5.20±0.09% in the CH15 hybrid and 6.40±0.09% in the L1 and L2 hybrids. The complete set of recorded data is presented in Table 1.

Table 1. Production data and quality indices for the maize genotypes studied

Myze genotype code	Y (ears)	Y (pgp)	Y (STAS)	GY	Mstr	Pro	Oil
	(kg ha^{-1})			(%)	(%)	(%)	(%)
L1	9,238.00	7,817.67	7,881.00	84.60	13.53	10.10	6.40
L2	7,057.33	5,873.67	5,936.00	83.20	13.03	10.20	6.40
L3	6,835.00	5,981.67	6,003.00	87.50	13.63	10.60	6.10
L4	6,236.00	5,278.67	5,371.00	84.70	12.47	9.30	6.30
L5	8,715.67	7,432.33	7,316.67	85.30	15.23	10.00	5.90
L6	6,338.67	5,448.33	5,611.33	86.00	11.33	10.40	5.90
L7	8,000.00	7,008.00	7,015.00	87.60	13.93	9.60	6.30
L8	10,352.67	8,856.33	8,910.33	85.50	13.50	10.30	5.90
CH9	11,222.33	9,888.00	10,027.67	88.10	12.80	7.90	6.20
CH10	11,949.33	10,377.00	9,793.33	86.80	18.87	7.80	6.20
CH11	12,694.67	11,059.67	11,026.00	87.10	14.30	8.80	6.00
CH12	9,867.33	8,783.67	8,727.33	89.00	14.57	7.30	5.50
CH13	9,596.67	8,484.33	8,599.67	88.40	12.80	7.80	5.50
CH14	10,231.33	9,035.00	9,141.33	88.30	12.93	7.20	5.80
CH15	12,839.33	11,640.00	11,579.33	90.70	14.47	7.30	5.20
SE	±570.14	±524.38	±507.36	±0.51	±0.44	±0.33	±0.09

Source: original data, recorded from the experiment

The Anova test confirmed the safety of the recorded experimental data, as well as the presence of variance in the data set (Alpha=0.001; F>Fcrit, p>0.001).

Table 2. Anova test

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.9E+09	6	3.17E+08	172.768	8.15E-50	4.1149
Within Groups	1.8E+08	98	1837381			
Total	2.08E+09	104				

Source: original data, resulted from the calculation.

The values of the Anova test are presented in Table 2.

The correlation analysis led to the values in Table 3. Very strong, positive correlations were recorded between Y(pgp) and Y (ears), r=0.997***, between Y(STAS) and Y(ears), r=0.992*** and between Y(STAS) and Y(pgp), r=0.996***. Moderate correlations were recorded between Pro and Y(pgp), r=-0.702**, between Pro and Y(STAS), r=-0.703, between Pro and GY, r=-0.742 and between Oil and GY, r=-0.741. Correlations with weak intensity were also recorded, under statistical safety conditions (* $p < 0.05$; ** $p < 0.001$; *** $p < 0.001$), Table 3.

According to PCA (95% confidence), the diagram in Figure 2 resulted, in which the two groups of maize hybrids studied (L, CH) were differentiated. The hybrids from group L were placed associated with the content of protein (Pro) and oil (Oil), as biplot. The hybrids from the CH group were placed associated with the Y(STAS) parameter. PC1 explained 72.693% of variance, and PC2 explained 17.704% of variance.

Table 3. Correlation table

	Y(ears)	Y(pgp)	Y(STAS)	GY	Mstr	Pro	Oil
Y(ears)							
Y(pgp)	0.997***						
Y(STAS)	0.992***	0.996***					
GY	0.559*	0.620*	0.634*				
Mstr	0.515*	0.497	0.424	0.140			
Pro	-0.668**	-0.702**	-0.703**	-0.742**	-0.291		
Oil	-0.427	-0.476	-0.494	-0.741	-0.009	0.568*	

Source: Original data.

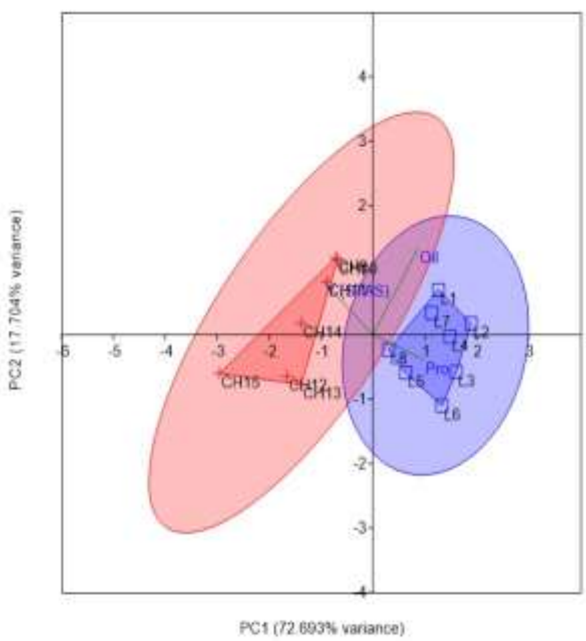

Fig. 2. PCA diagram regarding the distribution of the maize hybrids studied; blue color – ARSD Lovrin hybrids; red color – commercial hybrids
Source: Original figure.

In the framework of the Cluster analysis, based on the production parameters Y (STAS), and quality (Pro, Oil), the dendrogram from Figure 3 resulted, in conditions of Coph corr. =0.740.

The grouping of the analyzed hybrids in two distinct clusters was found. A C1 cluster included hybrids from the CH group (commercial hybrids) and a hybrid from the L group (L8 hybrid) with high yields and lower protein and oil content.

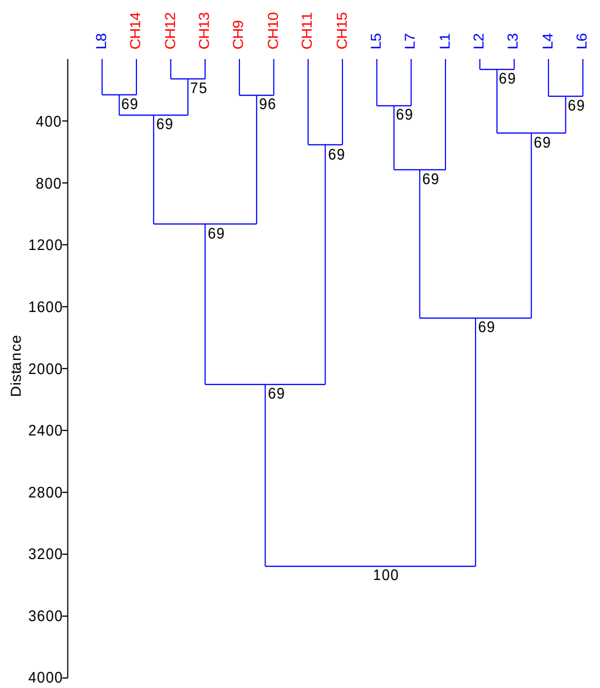

Fig. 3. Dendrogram of the maize hybrids studied, in relation to production and quality indices (Pro, Oil)
Source: Original figure.

Hybrids from group L (Lovrin hybrids), except L8, were associated in cluster C2. In cluster C2 there are hybrids with high protein and oil content.

In cluster C1 a high level of similarity was recorded between CH12 and CH13

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(SDI=127.66), and in cluster C2 a high level of similarity was recorded between hybrids L2 and L3 (SDI=67.002), which was the highest level of similarity at the level of the experiment.

The differences in protein and oil content were calculated, in relation to the average of the experiment.

In the case of the protein content (Pro, %), the average value was Pro=8.97%, and in relation to the calculated average value, certain hybrids (commercial hybrids, CH) had a lower content, and other hybrids (hybrids from group L, Lovrin) a higher protein content. The graphic representation is given in Figure 4.

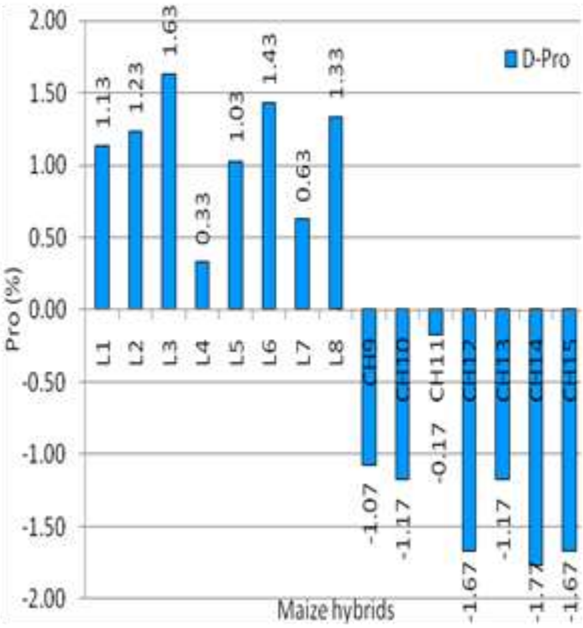

Fig. 4. The distribution of the differences regarding the protein content in the maize hybrids, in relation to the average of the experiment
Source: Original figure.

In the case of the oil content (Oil, %), the average value calculated at the experimental level was Oil=5.97%, and in relation to the average value calculated, it was found that certain hybrids had a lower oil content, and other hybrids a higher oil content. The graphic representation is given in Figure 5.

Hybrids from experimental group L (Lovrin) were highlighted by quality indices with higher values (Pro, Oil).

In relation to the production, the commercial hybrids (CH9 to CH15) presented higher values compared to the group of genotypes from Lovrin (L1 to L8). However, genotype L8 ensured production at the level of three of the commercial genotypes (Table 1), respectively at the level of genotypes CH12, Ch13 and CH14. This level of production was recorded both in the case of Y(ears), as well as in T(pgp) and Y(STAS), respectively.

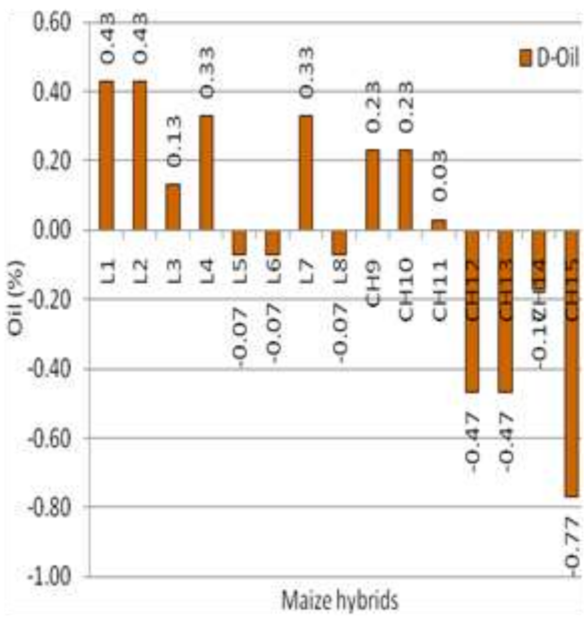

Fig. 5. The distribution of the differences regarding the oil content of the maize hybrids, in relation to the average of the experiment
Source: Original figure.

At the level of the L (Lovrin) hybrids group, the average production value was Y(ears)=7,846.67±526.26 kg ha^{-1}, Y(pgp)= 6,712.08±449.50 kg ha^{-1}, Y(STAS)= 6,755.54±438.26 kg ha^{-1}.

At the level of the group of commercial hybrids (CH), the average production value was Y(ears)=11,200.14±506.35 kg ha^{-1}, Y(pgp)=9,895.38±452.47 kg ha^{-1}, Y(STAS)=9,842.10±429.11 kg ha^{-1}.

In relation to the studied quality indices (Pro, Oil), the group of genotypes L (Lovrin) showed higher values than the group of genotypes CH (commercial hybrid).

In the case of the protein content (Pro), at the level of the L hybrids group (Lovrin), the calculated average value was Pro= 10.06±0.15%. Genotypes L1, L2, L3, L6 and L8 had values above the average.

At the level of the commercial hybrids group

(CH), the calculated average value of the protein content was Pro=7.73±0.21%. The CH9, CH10, CH11 and CH13 genotypes were above average.

In the case of the oil content (Oil), at the level of the hybrid group L (Lovrin), the calculated average value was Oil=6.15±0.08%. Genotypes L1, L2, L4 and L7 had values above the average.

At the level of the commercial hybrids group (CH), the calculated average value of the oil content was Oil=5.77±0.15%. The CH9, CH10, CH11 and CH14 genotypes were above average.

Katsenios et al. (2021) [16] used PCA to evaluate the relationship between production and quality indices (e.g. protein, fiber) in certain maize genotypes in relation to soil properties. Amegbor et al. (2022b) [2] studied the protein content of different maize lines in order to improve the nutritional value of maize genotypes in the context of Southern Africa conditions.

Langyan et al. (2022) [18] studied the nutritional diversity and quality indices in native germplasm identified and collected from different ecosystems in India, in order to identify valuable genetic sources adapted to environmental conditions.

An extensive and complex study on corn quality indices (protein quality) was conducted by Maqbool et al. (2021) [21] for the purpose of genetic characterization and establishment of breeding strategies.

Appropriate genetic methods were used by Lu et al. (2022) [19] to explain the protein content of maize grains in relation to the genetic basis.

Similar studies have been carried out to explain the variation of oil content in corn kernels (especially high values of oil content), especially in relation to the genetic basis, but also to influencing factors [12, 20].

Depending on the interest in the productive level or the quality indices, the appropriate maize genotypes can be chosen, in relation to the intended purpose. For production, Y(STAS), hybrids from the CH group (commercial hybrids) are of high interest, and for quality indices the genotypes from the L group (Lovrin) are of greater interest.

For the selection process of genotypes in breeding programs, the genotypes from the CH group (commercial hybrids) are of interest for the production potential, and the genotypes from the L group (Lovrin) are of interest for the quality indices (Pro, Oil).

CONCLUSIONS

The two groups of maize genotypes (L, CH) behaved differently in the study conditions, in relation to the production potential and considered quality indices (Pro, Oil).

The genotypes represented by commercial hybrids (CH) showed higher production potential, manifested by high production values, with a higher average production value compared to hybrids from group L (Lovrin).

The genotypes from Lovrin (L) presented better values for quality indices (Pro, Oil) with higher average values for both quality indices compared to the other group of hybrids (CH).

For high levels of production and yield, tested commercial hybrids (CH) present an advantage for crop, as well as as a genetic source for breeding programs, in terms of productive potential.

For quality indices, protein and oil (Pro, Oil), the genotypes from Lovrin (L) present an advantage for breeding programs, in terms of quality indices.

In order to obtain maize hybrids with high production potential and to improve the values of the quality indices (Pro, Oil), the base of genotypes studied in the present study and parental forms used for the transfer of valuable traits can be considered.

For production, for practical crop management purposes, the more balanced genotypes from the two tested groups can be taken into account, which ensure more balanced high productions but also quality indices at a good level.

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REFERENCES

[1]Amegbor, I.K., Abe, A., Adjebeng-Danquah, J., Adu, G.B., 2022a, Genetic analysis and yield assessment of maize hybrids under low and optimal nitrogen environments, Heliyon, 8(3), e09052.

[2]Amegbor, I., van Biljon, A., Shargie, N., Tarekegne, A., Labuschagne, M., 2022b, Identifying quality protein maize inbred lines for improved nutritional value of maize in Southern Africa, Foods, 11(7):898.

[3]Atanda, S.A., Olsen, M., Burgueño, J., Crossa, J., Dzidzienyo, D., Beyene, Y., Gowda, M., Dreher, K., Zhang, X., Prasanna, B.M., Tongoona, P., Danquah, E.Y., Alaoye, G., Robbins, K.R., 2021, Maximizing efficiency of genomic selection in CIMMYT's tropical maize breeding program, Theor. Appl. Genet., 134:279-294.

[4]Boldea, M., Sala, F., Rawashdeh, M., Luchian, D., 2015, Evaluation of agricultural yield in relation to the doses of mineral fertilizers, J. Cent. Eur. Agric., 16(2):149-161.

[5]Božović, D., Popović, D., Popović, V., Živanović, T., Ljubičić, N., Ćosić, M., Spahić, A., Simić, D., Filipović, V., 2022, Economical productivity of maize genotypes under different herbicides application in two contrasting climatic conditions, Sustainability, 14:5629.

[6]Crossa, J., Fritsche-Neto, R., Montesinos-Lopez, O.A., Costa-Neto, G., Dreisigacker, S., Montesinos-Lopez, A., Bentley, A.R., 2021, The modern plant breeding triangle: optimizing the use of genomics, phenomics, and enviromics data, Front. Plant Sci., 12:651480.

[7]Dossa, E.N., Shimelis, H., Mrema, E., Shayanowako, A.I.T., Laing, M., 2023, Genetic resources and breeding of maize for Striga resistance: A review, Front. Plant Sci., 14:1163785.

[8]Erawati, B.T.R., Hipi, A., Makkulawu, A.T., Azrai, M., 2020, Evaluation of hybrid corn genotype on productivity improvement to support national food availability, IOP Conf. Series: Earth Environ. Sci., 484:012026.

[9]Erenstein, O., Jaleta, M., Sonder, K., Mottaleb, K., Prasanna, B.M., 2022, Global maize production, consumption and trade: trends and R&D implications, Food Sec., 14:1295-1319.

[10]Ezin, V., Kpanougo, C.M.I., Ahanchede, A., 2022, Genetic diversity and environmental influence on morphological and yield parameters of maize in Benin, Heliyon, 8(6):e09670.

[11]Fan, X., Bi, Y., Zhang, Y., Jeffers, D., Yin, X., Kang, M., 2019, Improving breeding efficiency of a hybrid maize breeding program using a three heterotic-group classification, Agronomy, 110(4):1209-1216.

[12]Fang, H., Fu, X., Ge, H., Zhang, A., Shan, T., Wang, Y., Li, P., Wang, B., 2021, Genetic basis of maize kernel oil-related traits revealed by high-density SNP markers in a recombinant inbred line population, BMC Plant Biol., 21:344.

[13]Gul, H., Rahman, S., Shahzad, A., Gul, S., Qian, M., Xiao, Q., Liu Z., 2021, Maize (*Zea mays* L.) productivity in response to nitrogen management in Pakistan, Am. J. Plant Sci., 12:1173-1179.

[14]Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001, PAST: Paleontological Statistics software package for education and data analysis, Palaeontol. Electron., 4(1):1-9.

[15]JASP Team, 2022, JASP (Version 0.16.2) [Computer software].

[16]Katsenios, N., Sparangis, P., Chanioti, S., Giannoglou, M., Leonidakis, D., Christopoulos, M.V., Katsaros, G., Efthimiadou, A., 2021, Genotype × environment interaction of yield and grain quality traits of maize hybrids in Greece, Agronomy. 11:357.

[17]Klopfenstein, T.J., Erickson, G.E., Berger, L.L., 2013, Maize is a critically important source of food, feed, energy and forage in the USA, Field Crop. Res., 153:5-11.

[18]Langyan, S., Bhardwaj, R., Kumari, J., Jacob, S.R., Bisht, I.S., Pandravada, S.R., Singh, A., Singh, P.B., Dar, Z.A., Kumar, A., Rana, J.C., 2022, Nutritional diversity in native germplasm of maize collected from three different fragile ecosystems of India, Front. Nutr., 9:812599.

[19]Lu, X., Zhou, Z., Wang, Y., Wang, R., Hao, Z., Li, M., Zhang, D., Yong, H., Han, J., Wang, Z., Weng, J., Zhou, Y., Li, X., 2022, Genetic basis of maize kernel protein content revealed by high-density bin mapping using recombinant inbred lines, Front. Plant Sci., 13:1045854.

[20]Luo, M., Lu, B., Shi, Y., Zhao, Y., Liu, J., Zhang, C., Wang, Y., Liu, H., Shi, Y., Fan, Y., Xu, L., Wang, R., Zhao, J., 2023, Genetic basis of the oil biosynthesis in ultra-high-oil maize grains with an oil content exceeding 20%, Front. Plant Sci., 14:1168216.

[21]Maqbool, M.A., Issa, A.B., Khokhar, E.S., 2021, Quality protein maize (QPM): Importance, genetics, timeline of different events, breeding strategies and varietal adoption, Plant Breed., 140(3):375-399.

[22]Matova, P.M., Kamutando, C.N., Warburton, M.L., Williams, W.P., Magorokosho, C., Shimelis, H., Labuschange, M., Day, R., Gowda, M., 2023, New techniques for breeding maize (*Zea mays*) varieties with fall armyworm resistance and market-preferred traits for sub-Saharan Africa, Plant Breed., 142(1):1.11.

[23]Santantonio, N., Atanda, S.A., Beyene, Y., Varshney, R.K., Olsen, M., Jones, E., Roorkiwal, M., Gowda, M., Bharadwaj, C., Gaur, P.M., Zhang, X., Dreher, K., Ayala-Hernández, C., Crossa, J., Pérez-Rodríguez, P., Rathore, A., Gao, S.Y., McCouch, S., Robbins, K.R., 2020, Strategies for effective use of genomic information in crop breeding programs serving Africa and South Asia, Front. Plant Sci., 11:353.

[24]Shrestha, S., Niraula, D., Regmi, S., Basnet, S., Chhetri, S.T., Kandel, B.P., 2023, Performance evaluation and genetic parameters estimation of multi-companies maize hybrids in Lamahi Dang, Nepal, Heliyon, 9(3):e14552.

[25]Simmons, C.R., Lafitte, H.R., Reimann, K.S., Brugière, N., Roesler, K., Altbertsen, M.C., Greene, T.W., Habben, J.E., 2021, Successes and insights of an industry biotech program to enhance maize agronomic

traits, Plant Sci., 307:110899.
[26]Şimon, A., Ceclan, A., Haş, V., Varga, A., Russu, F., Chețan, F., Bărdaş, M., 2023, evaluation of the impact of sowing season and weather conditions on maize yield, AgroLife Sci. J., 12(1):207-214.
[27]Xu, P., Tan, Q., Zhang, Y., Zha, X., Yang, S., Yang, R., 2022, Research on maize seed classification and recognition based on machine vision and deep learning, Agriculture, 12:232.
[28]Yan, X., Chen, X., Ma, C., Cai Y., Cui, Z., Chen, X., Wu, L., Zhang, F., 2021, What are the key factors affecting maize yield response to and agronomic efficiency of phosphorus fertilizer in China?, Field Crop. Res., 270:108221.
[29]Yassitepe, J.Ed.C.T., da Silva, V.C.H., Hernandes-Lopes, J., Dante, R.A., Gerhardt, I.R., Fernandes, F.R., da Silva, P.A., Vieira, L.R., Bonatti, V., Arruda, P., 2021 Maize transformation: From plant material to the release of genetically modified and edited varieties, Front. Plant Sci., 12:766702.

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THE ASSESSMENT OF SUSTAINABLE DEVELOPMENT FACTORS IN THE RURAL AREAS - A CASE STUDY FROM AZERBAIJAN

Fariz ALAKBAROV[1*], Sait ENGINDENIZ[2], Ramina MUSTAFAYEVA[1], Muhammad ALAKBAROV[1**]**

[1]Azerbaijan State Agricultural University, *Faculty of Agronomy, [**]Faculty of Agricultural Economics, Ganja-Azerbaijan, E-mails: alekberovfariz@yahoo.de, raminamustafayeva0206@gmail.com, alekberovmuhammed@mail.ru
[2]Ege University, Faculty of Agriculture, Izmir-Turkey, E-mail: sait.engindeniz@ege.edu.tr

Corresponding author: alekberovfariz@yahoo.de

Abstract

Rural development is the effort to ensure the economic, social, and cultural development of these communities in a democratic way, by first creating a sense of need for individuals and communities living in rural areas and making their living from the agricultural sector or similar rural occupations. For improving and optimizing Sustainable Development Goals (SDGs) approaches for rural livelihoods, it is essential firstly to monitor and evaluate the current situation on SDGs in target villages and its achievements, also to identify the challenges and opportunities in this area. The purpose of study is to conduct surveys for assessment of current situation on SDGs and identifying opinions and understandings of farmers/producers and extension providers/input suppliers on this issue in farms located in Tovuz, Agstafa, Gadabay and Tartar districts in Azerbaijan. In the study, primary clients were farmers and secondary clients were extension providers/input suppliers including different representatives from the public and private sectors. During study, we identified the main pre-conditions, such as the technical, finance and economic problems, natural resources and hazards that farmers face in agriculture, as well as main difficulties faced by farmers in accessing agricultural extension services/trainings, also annual production volume and income on the farm and other difficulties faced by farmers for achievement of SDGs in farms. In the study, data were collected by face-to-face survey method from 47 farmers and 5 extension providers selected by random sampling from Tovuz, Agstafa, Gadabay and Tartar districts. Simple statistical methods were applied in the evaluation of the data obtained, and average and percentage calculations were performed. According to the results, farmers are facing some challenges preventing the achievement of SDGs such as finance and economic problems, natural resources and hazards, and technical issues in agriculture. To eliminate the negative effects of urbanization in target villages, there is a great need to improve rural income sources and promote employment for people in rural areas.

Key words*: *sustainable agriculture, sustainable development goals, rural livelihood, rural economy

INTRODUCTION

Sustainability includes the planning and implementation of today and tomorrow to ensure that economic development is sustainable and that the needs of future generations are met without depleting natural resources and disturbing the balance of nature. Sustainability can be divided into three main sections as economic, environmental, and social sustainability. An economically sustainable system must be able to consistently produce goods and services, maintain manageable levels of government and external debt, and avoid excessive sectoral imbalances that harm agricultural or industrial production. An environmentally sustainable system must maintain a stable resource base by avoiding the overexploitation of renewable resource systems and consuming non-renewable resources only to the extent that investment is made as adequate substitutes. This includes maintaining biodiversity, atmospheric stability, and other ecosystem functions that are not normally classified as economic resources. A socially sustainable system should be the provision of adequate social services, including distributional equity, health and education, gender equality and political accountability and participation. Sustainable development is the meeting and development of those who live today and those who will live in the future. To ensure social, economic, and environmental sustainability, educating human resources in rural areas is of strategic importance. Agricultural activities constitute an important part of the basic economic activities in rural areas. Agriculture is the production of vegetal and animal products, increasing quality and efficiency, protection of products in appropriate conditions, processing, and marketing under appropriate conditions. Since the production of vegetal and animal products can be done largely in rural areas, agriculture and rural areas are directly related to each other. Therefore, the development of agriculture means the development of rural areas [34].

The problems facing development in rural areas are of a high complexity, the necessity of a multi-dimensional development approach towards these areas, and the need to change the conceptual framework of rural policies have created common views. It has emerged that the sectoral perspective in the rural area policies is insufficient and therefore it should be transformed into a policy area with both sectoral and spatial dimensions. Attention was drawn to the necessity of using key elements such as diversity in rural economies, the development of small and medium-sized enterprises, new technologies, and rural tourism in sustainable development, and it was concluded that the increase in services, protection of the environment, and increasing the quality of living spaces should also be considered. For a sustainable balanced development, the necessity and importance of rural and urban-related developments have emerged, as rural and the city are integrated [54].

In 2015, the United Nations (UN) and its member states adopted the 2030 Agenda for Sustainable Development to ensure peace and prosperity. The aim of this agenda is to ensure the development of all countries in relation to economic growth. It is also aimed at making improvements in health and education, reducing inequality, and tackling climate change. To achieve these goals, 17 Sustainable Development Goals (SDGs) including different purposes and actions are implemented. These goals are based on a modern understanding of human development that gives importance to health and education and tries to increase welfare based on a continuous economic growth process. The 17 SDGs are interrelated and include issues such as security, production, and consumption for the sustainable development of different human settlements (cities, towns, and villages). The creation of livable human settlements is recognized as a clear indicator of socially and economically sustainable development [8].

Many studies have been carried out on the obstacles to sustainable rural development in rural areas and the development of different solutions in different countries of the world. Some studies present the main problems encountered in the country and examined regional conditions [12, 47, 45, 10, 51, 13]. Some authors specified rural tourism as a solution proposal [44, 32, 5, 29, 22, 1, 48]. The relationship between environment and ecosystem and rural development has been investigated by [41, 31]. The use of digital tools for this purpose has been evaluated by [16, 52]. Some researchers investigated the effects of rural development programs [27], policies applied [50], funding for rural development [49], rural migrations [35], social capital [17], private and family farms [30, 43, 15], agricultural cooperatives [20, 37], farm modernization [26] and Covid-19 [14].

Some researchers have developed different approaches and created models on SDGs and indicators [33, 39, 40, 18, 29, 19]

Today, the government of Azerbaijan performs the dynamic, rapid and advisable programs for achieving Sustainable Development Goals (SDGs) in the country, especially in rural areas [6]. Considering the principles of SDGs, the government of Azerbaijan has implemented different state programs for reducing poverty, promoting rural livelihood, stopping urbanization, and promoting the employment for people in rural areas [7].

Other researchers issued recommendations destined to ensure sustainable development in rural areas in Azerbaijan [4, 23, 24, 21, 2]. This research should be continued and developed by studying the results obtained in different countries.

For solving the problems encountered in rural areas, especially to improve and optimize SDGs approaches for rural livelihoods, it is essential firstly to monitor and evaluate the current situation and to identify the challenges and opportunities in rural areas.

Considering the importance of measuring SDGs in promoting rural livelihood, we conducted surveys for assessment of current situation on sustainable development goals (SDG) in target villages located front-line areas of Tartar, Tovuz, Agstafa and Gadabay districts of Azerbaijan.

The purpose of study is to conduct the research for assessment of current situation on SDGs, as well as to identify the main challenges and the opportunities on this issue in the farms located in Tovuz, Agstafa, Gadabay and Tartar districts in Azerbaijan. In results of the study, we collected reliable data and achieved to describe the original picture of current situation related with SDGs in farms located in target villages, as well as identified the challenges and the opportunities existed in this area and the road for improving SDGs in target districts.

MATERIALS AND METHODS

The study was conducted in four target districts including in Shicheybat and Garalar villages of Tovuz district, in Kohnegishlag village of Agstafa district, in Arabachi, Farzali, Zamanli and Mormor villages of Gadabay district and in Gazyan and Yukhari Gapanli villages of Tartar district during July-September 2022 (Figure 1).

Fig. 1. Districts and cities in Azerbaijan
Source: [56].

The study tools include individual interviews and village level focus group discussion with primary and secondary respondents in target districts and villages. The research materials consisted of results of questionnaires and focus group discussion with different stakeholders.

The framework for assessing the current situation on SDGs in farms located in target districts is described in Figure 2. As illustrated in Figure 2, in general, for assessment of current situation on SDGs, the primary data was collected from main actors consisted of primary and secondary respondents relevant to this issue. In total, we conducted 52 interviews including 47 interviews with farmers and 5 interviews with extension providers. The respondents to be surveyed were informed about the aims of the study, their rights and limitations, their voluntary participation in the study, and the prepared consent form was filled, and the questions were answered.

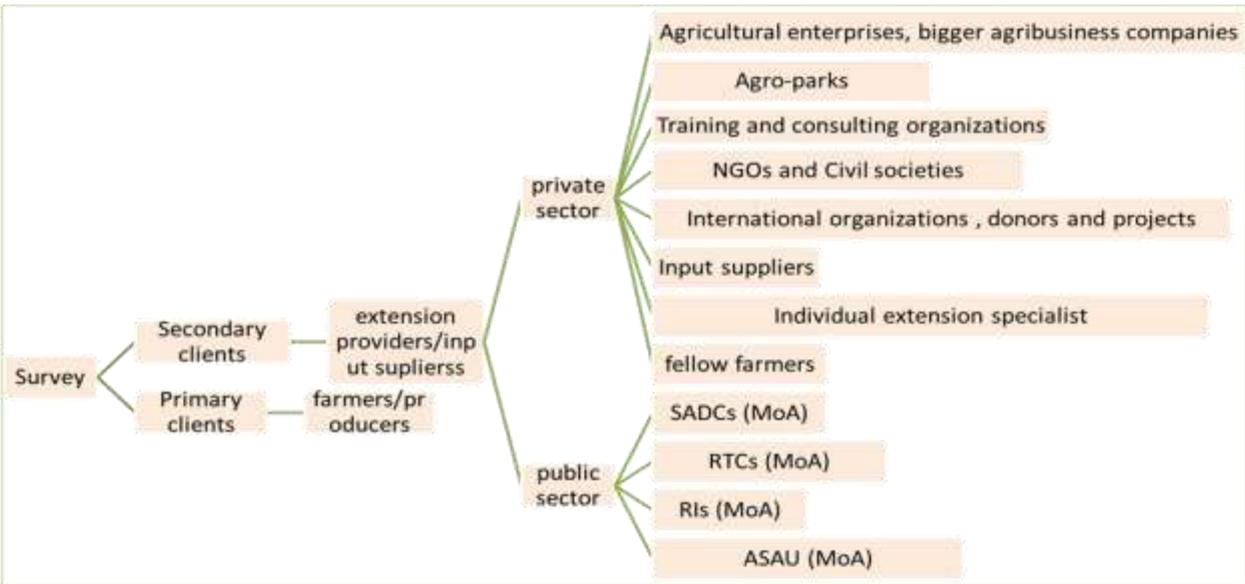

Fig. 2. Framework of assessment
Source: Contribution of authors.
Note: NGOs=None-Governmental Organization, SADCs= State Agricultural Development Centre, RTCs= Research and Training Center, RIs= Research Institute, ASAU = Azerbaijan State Agricultural University, MoA= Ministry of Agriculture

Along with the interviews, we also have conducted the village level focus group discussions with farmers in Shicheybat and Garalar villages of Tovuz district, in Kohnegishlag village of Agstafa district, in Arabachi village of Gadabay district, in Gazyan and Yukhari Gapanli villages of Tartar district, also with extension providers of Tartart Regional Training Centre for rapid assessment of current situation on SDGs and identifying opinions and understandings of farmers/producers and extension providers on this issue.

To collect accurate data and increase the confidence level of surveys we planned to cover all the target villages. Before the survey, the targeted villages were identified according to their social-economic indicators gained by SADCs (State Agriculture Development Centre). In result, we identified the specific villages to conduct the surveys.

But to be on the safe side, we identified the small-scale, medium, and large farmers, as well as poor and vulnerable families depending on their income per capita and involved 1-2 representatives from each above-mentioned group to surveys to cover all of levels of families with different socio-economic indicators in target villages. The respondents were chosen via a simple random sampling method based on their production resources and socio-economic indicators.

As for the number of respondents by districts and villages, 11 respondents including 5 farmers from Garalar village and 6 farmers from Shicheybat village of Tovuz district, 12 respondents including 11 farmers and 1 extension provider from Kohnegishlag village of Agstafa district, 14 respondents including 5 farmers from Arabachi village, 4 farmers from Farzali village, 4 farmers from Mormor village and 1 farmer from Zamanli village of Gadabay district, 12 respondents including 7 farmers from Gazyan village, 4 farmers and 1 extension provider from Yukhari Gapanli village Tartar district, as well as 3 extension providers of Tartart Regional Training Centre were interviewed.

During the surveys, together with vulnerable respondents, we also interviewed leader farmers who are open to innovations to describe the original picture of current situation on SDGs in target villages. In these meetings, we were discussing about the awareness of farmers and extension providers on SDGs, the identification of the special agricultural extension and training needs of farmers and extension providers on SDGs, the staff capacity, especially the updating extension staff with new technologies and Good Agriculture Practices (GAP) approaches used to communicate with farmers, as well as the challenges prevented to achieve SDGs in farms.

During the field survey, the respondents were "face to face" interviewed based on the use of semi-structured questionnaires.

Before conducting the surveys in target villages, the survey forms (questionnaires) containing 11 pages were developed. The questionnaires were designed in such a way that we could obtain the right answers to the questions we are looking for. Questions asked were both open ended and closed. Also, the questionnaires contain both qualitative and quantitative questions. Before collecting actual data, the questionnaire was pre-tested to identify either irrelevant or to add missed part.

During the interview, the following issues were tried to be determined with the questions prepared in advance.

- Identifying financial and economic problems, natural resources and hazards faced by farmers to reach SDGs,
- To determine the level of knowledge of farmers regarding SDGs,
- To determine the knowledge and skills of farmers and their awareness on sustainable natural resource management,
- To identify the main challenges faced by farmers in agriculture.

According to the modern literature, there are different methodological approaches aimed to the socio-economic, ecological (natural) and agricultural aspects of identifying indicators for assessing the sustainable rural development in the regions [55, 28]. Today, most of the researchers prefer to identify and select the important factors with their indicators encouraging and measuring sustainable development of agriculture and the rural areas [9, 25, 20, 42].

[36] used some economic indicators for measuring sustainable rural development such as budget revenues of local or regional self-government units per capita, number of beds in rural tourism in relation to the total population, diversification of sources of income on the farm (additional activities on the farms), diversification of economic activities in the rural area, number of EU-level protected products in each county in relation to the total number of such products in the country, unemployment rate, GDP per capita, productivity of agricultural production, number of entrepreneurs in agricultural and nonagricultural activities in rural areas, education as a prerequisite for using innovation, number of cars per household, internet access- number of connections/number of inhabitants or households, availability of infrastructure facilities connected to agriculture, economic vitality-the number of blocked and newly established companies and land fragmentation-average farmland size.

According to [38], the indicators used by them for assessing the sustainable rural development in the region were coefficient of changes proportionality in the territory's transport, coefficient of changes proportionality in the production infrastructure of the territory infrastructure, coefficient of balance, proportionality and efficiency of changes in the results of using production resource under production subsystem and coefficient of changes proportionality in the parameters of social and household objects under social and household subsystem of rural territories.

[46] stated the village SDGs indicators and targets for measuring achievement of SDGs in rural areas of Indonesia. The authors have pointed out 17 SDGs with their relevant indicators such as: 1.No Poverty (indicator: Income per capita per day); 2. Zero Hunger (indicators: Food menu; Frequency of eating); 3.Good Health and Well-Being (Number of types of disease in 1 family within 1 year); 4.Quality education (Adult household members with good access to education); 5.Gender equality (Women's access to education; Women's access to job opportunities); 6.Clean water and sanitation (Latrine ownership; Source of clean water); 7.Affordable and clean energy (Cooking fuel, Access to electricity); 8.Decent work and

economic growth (Unemployed working-age household members; Diversified livelihoods); 9.Industry, Innovation, and Infrastructure (Ownership of communication tools; Ownership of transportation vehicle; Household access to the internet and other media); 10.Reduced Inequality (Access to agricultural land); 11.Sustainable cities and communities (Building area/house per number of family members); 12.Responsible consumption and production (Commodity history; Garbage disposal location); 13.Climate action (Availability of green open areas at the neighborhood level); 14.Life below water (None; Farmland management level at household level); 15.Life on land (Farmland management level at household level); 16.Peace, justice, and strong institution (Participation in community organizations) and 17.Partnerships for the goals (Household external network level).

Also, as experiences from Norway, [11] has expressed key factors covering financial, technological, knowledge and plan processes, legal-laws and regulation, organizational/institutional, political, and cultural categories which can be identified as facilitating the implementation of the SDGs in Norwegian local and regional planning.

In addition to the above-mentioned approaches, according to the local priorities related with sustainable rural development, our approaches for measuring SDGs in target villages differed from others a little. During study, our surveys have covered the main assessment factors aimed to the technical, finance and economic problems, natural resources and hazards that farmers face in agriculture, as well as main difficulties faced by farmers in accessing agricultural extension services/trainings, also annual production volume and income on the farm and other difficulties faced by farmers for achievement of SDGs in farms.

Simple statistical methods were applied in the evaluation of the data obtained, and average and percentage calculations were performed. The obtained results are presented using figures.

RESULTS AND DISCUSSIONS

Overall overview of agriculture in target districts and surveyed villages

The target villages surveyed are in front-line areas and far from the district center. The target villages are mountainous except Gazyan and Yukhary Gapanli villages of Tartar district. Shicheybat and Garalar villages of Tovuz district are in the lowlands. Mountainous and foothill zones, where positive and negative relief forms are shifted. Kohnegishlag village of Agstafa district, Arabachi, Farzali, Zamanli and Mormor villages of Gadabay district are characterized by hills, mountainous and foothill areas. Gazyan and Yukhari Gapanli villages of Tartar district are in the plain area.

Land use is mainly characterized by irrigation farming in Gazyan and YukhariGapanli villages of Tartar district. Kohnegishlag village of Agstafa, Farzali, Zamanli and Mormor villages of Gadabay district, as well as Shicheybat and Garalar villages of Tovuz district are known for dry farming and rain crops are cultivated in these areas. But, today, the results of our research show that these lands have lost the status of non-irrigated areas due to decrease of precipitation/rain fall.

The agricultural employees make up approximately more than 50% of the labor force of the target districts. Agriculture is considered as a basic priority area in these target districts and villages. In the target districts, favorable climatic conditions and fertile land cover allow for planting various types of crops including grains (wheat, barley, corn), legumes (peas, beans, etc.), vegetables (potato, tomato etc.), melons, fruits, and berries, as well as for animal production including sheep, poultry, cattle (dairy cows and cattle for slaughter) etc.

Analysis of data obtained from the target villages shows that Garalar and Shicheybat villages of Tovuz district are mainly specialized in potatoes and legumes. Arabachi, Mormor, Farzali and Zamanli villages of Gadabay district are known mainly for potatoes and cereals. The widely cultivated crops in Kohnegishlag village of Agstafa district are cereals, potatoes, and legumes. The main crops produced in Gazyan and Yukhari Gapanli villages of Tartar district are cereals, fodder crops (Luzerne), cotton and legumes. Regarding animal production, the target villages are mainly specialized to keep the dairy cows, cattle for slaughter and sheep.

The analysis of data obtained from the surveys shows that considerable growth wasn't achieved in grain production in target villages. In Kohnegishlag village of Agstafa district, in Arabachi, Mormor, Farzali and Zamanli villages of Gadabay district and in Gazyan and Yukhari Gapanli villages of Tartar district, the average yield of wheat amounted 1.9 tons/ha, 3.5 tons/ha and 3.1 tons/ha in 2022, respectively. But the current yield of cereals is considerably lower than potential resources. For instance: during harvesting period in 2022, Agro-diary company harvested 7-9 tons of wheat grain per hectare which is about 2-3 times higher than current productivity in the target villages surveyed. Our observations show that this situation is related to droughts and inadequate growing practices used on farms.

As for potato production, which is main product of surveyed villages, in Garalar and Shicheybat villages of Tovuz district and in Arabachi, Mormor, Farzali and Zamanli villages of Gadabay district, the average productivity of potato made up 9.4 tons/ha and 10.5 tons/ha in 2022, respectively. The reason for the low yield of potato in target villages is mainly the drought and unfavorable growing season. Moreover, the average yield of cotton, lucerne (dry hay production) and sugar beet per hectare were 3.8 tons/ha, 21 tons/ha and 20 tons/ha in Gazyan and Yukhari Gapanli villages of Tartar district, respectively. These productivity indicators of cotton, luzerne and sugar beet are more lover than average yield gained from advantage farmers in our country. The results of our research show that the poor yield of cotton, lucerne (dry hay production) and sugar beet in Gazyan and Yukhari Gapanli villages of Tartar district is related with the drought, water deficiency, unfavorable growing season, and lack of the innovative and good practices in plant production.

Therefore, statistical analyzes and results obtained from questionnaires show that the factual production indicators of plant production and livestock in surveyed villages are considerably lower than the potential. The main causes of this problem are mainly related to water deficiency, droughts, unfavorable growing season and insufficient knowledge and skills of farmers in surveyed villages. It should be noted that these surveyed villages did not achieve only the world middle level, even country middle level of productivity of main crops. This fact was also stated in report on Building Azerbaijan`s Farming Middle Class funded by World Bunk [53], as well as in national report prepared under "Strengthening of Agricultural Advisory Services" project funded by the European Union (EU) and implemented by FAO [3].

It allows us to note that most of farmers in surveyed villages have not sufficient skills on innovative technologies and business management know-how and experience due to the weak links to agricultural extension services. Because, if the quality of extension services was satisfactory, we could see these successes in the productivity of crops cultivated by farmers in surveyed villages. It should be noted that, there is a great need to integrate innovations in agricultural practices and provide the trainings for farmers on innovative and good practices in production of main crops such as wheat, potato, legumes, sugar beet, fodder crops and livestock production.

General characteristics of respondents

When it comes to gender proportion, most of the respondents interviewed were male accounted for 85% (44 people) and the minority of the participants were female responsible for 15% (8 people) during the survey period conducted in Tovuz, Agstafa, Gadabay and Tartar districts.

During surveys, most farmers involved to the surveys were male accounted for 87% (41 people), on the contrary the minority was female responsible for 13% (6 people) (Figure 3). Also, 60% (3 people) of extension providers involved to the survey were male, on the other hand 40% (2 people) of them were female (Figure 5).

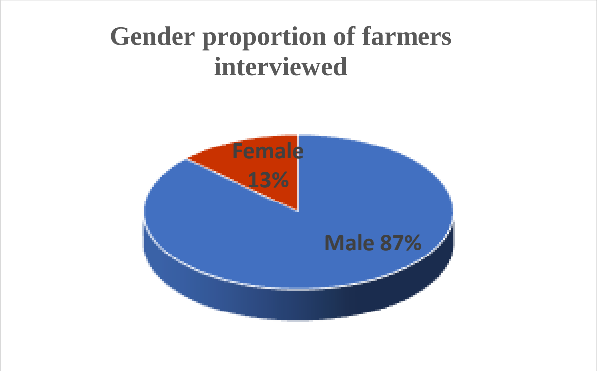

Fig. 3. The gender of respondents
Source: Results of survey

In terms of the age of respondents, the majorities (37%) have an age category between 51 to 60 years (mainly farmers older than 50), 21% of them were aged between 41 to 50 years, 14% of them were aged between 30 to 40 years, 19% of them were aged between 61 to 70 years and 9% of them were aged older than 70 (Figure 4).

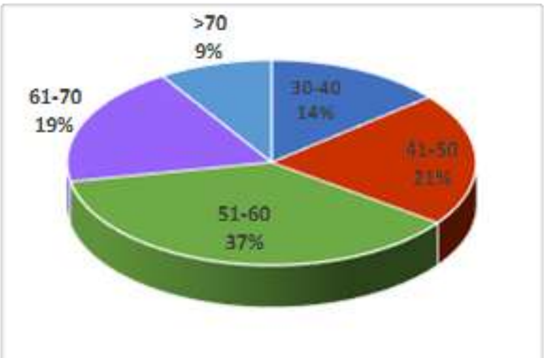

Fig. 4. The age of respondents
Source: Results of survey.

The results regarding the education background of respondents interviewed are illustrated in Figure 6.

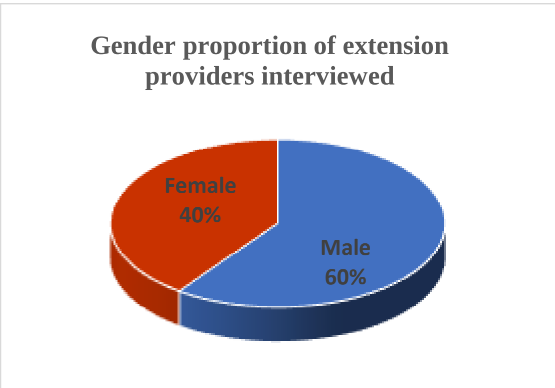

Fig. 5. Gender proportion of the interviewees
Source: Results of survey.

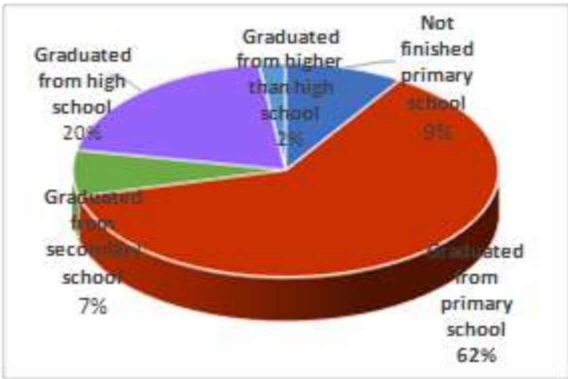

Fig. 6. The education background of respondents
Source: Results of survey.

The land size of farms in target villages

In terms of the land size of respondents, from the sampled farms, as illustrated in Figure 6, all the respondents are small-scale farmers (less than 50 hectares). Figures show that the majority (52%) are small farms occupying less than 1 hectare, 29% of them are farms occupying less than 4 hectares, 13% of them are farms having 10 hectares and 6% of them haven't land. In target villages, we can classify the agricultural producers into three groups: family farms and households.

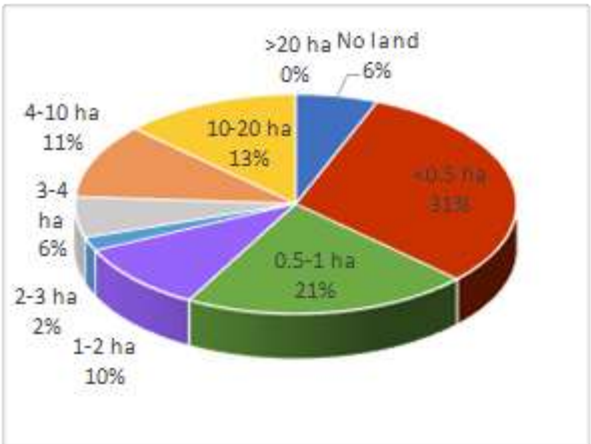

Fig. 7. The land size of respondents
Source: Results of survey.

By far the largest group (52% of total respondents) consists of 'households' with agricultural land producing mainly for home consumption and family farms, which comprise individual farmers that are market oriented. Family farms have only 2-3 ha on average, out of which households have plots of 0.5 ha or less. According to the results of our statistical surveys, average land per capita in the target villages amounts to 0.05-0.20 hectares which results in 0.5-2 hectares of land per family.

The analyses show that 90% of agricultural products are produced by family peasant farms and households in surveyed villages. Also, separate small farms lead to problems such as expensive purchase of seeds, pesticides and fertilizers, improper soil and water use etc. To meet the social-economic demands of small-scale farmers and change their approaches to good agricultural practices, there is a great need to take the advisable measures in surveyed villages. Also, small-scale farmers are obliged to aim for good agricultural practices which are fundamental for high productivity.

The main factors affecting SDGs, especially sustainable agricultural and rural development in surveyed villages

We know that the difficulties faced by farmers in the field of agriculture prevent considerable achievement of SDGs in farms. According to the research and our observations, there are financial and economic problems of farmers including low prices of product, lack of market information and high input cost; natural resources and hazards related problems such as decrease of precipitation, increase of temperature, lack of water resources for irrigation and poor soil and soil fertility; and technical issues in agriculture including lack of tools and equipment, lack of agricultural knowledge in general, lack of pest and diseases management, lack of application of integrated pest management (IPM) and lack of implementation of Good Agriculture Practices (GAP).

Based on the results illustrated in Figure 3, in Figure 8 there are shown the results on how the respondents stated that their finance and economic problems.

As illustrated in Figure 8, The main finance and economic problems of the respondents are mainly related with the lack of capital (29%), high cost of inputs (21%), low prices of product (15%), lack of market information (11%), subsidies programs (11%) and other related issues (13%).

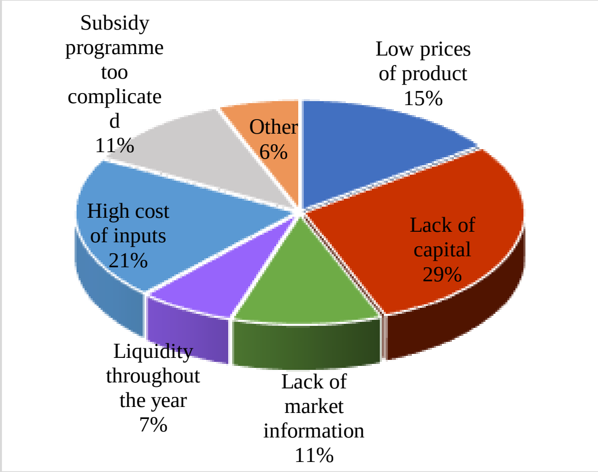

Fig. 8. Finance and economic problems of respondents
Source: Results of survey.

Concerning to the natural resources and hazards related problems, the answers of respondents interviewed showed that lack of water resources for irrigation (28%), decrease of precipitation/ rain fall (24%), soil erosion (13%), poor soil and soil fertility (10%), increase of temperature (9%), loss of biodiversity, floods and other related issues (16%) are main problems faced by farmers in surveyed villages during growing season (Figure 8).

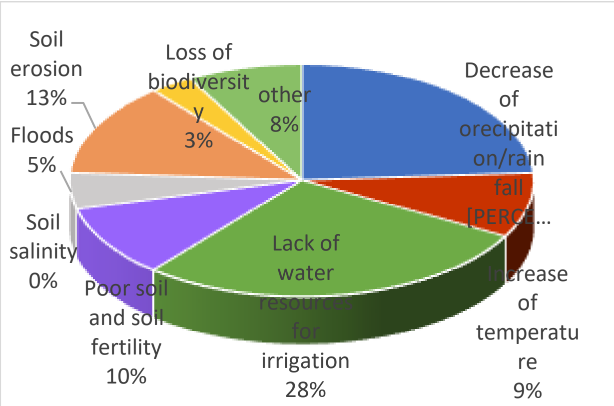

Fig. 9. Natural resources and hazards related problems of respondents.
Source: Results of survey.

Based on both our observations made during the survey process and the results of the questionnaires, many respondents were faced by technical issues including lack of pest and diseases management (31%), the shortage of farm tools and equipment and difficulties in accessing agricultural machinery (30%), lack of agricultural knowledge in general (17%). Also, 22% of respondents state other technical

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problems such as lack of application of IPM, lack of implementation of GAP for growing plants, lack of skilled and knowledgeable workers (Figure 10).

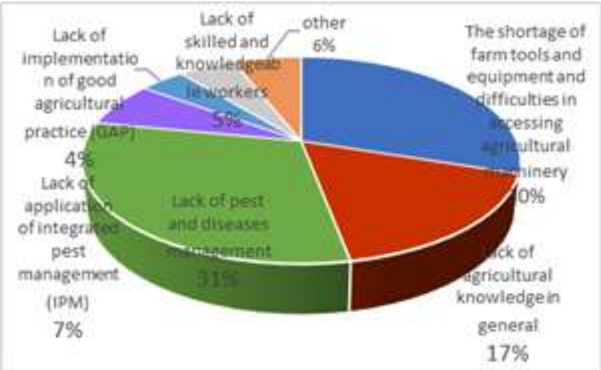

Fig. 10. Technical inadequacies in agriculture
Source: Results of survey.

While the main purpose of countries, especially developing countries, is general development, the multiplier effect of the added value obtained by rural development. It is obvious that it will add potential value to first regional and then general development.

At the core of the sustainable development approach, development is not perceived as just growth. Of course, there will be growth in development, but this may not be enough for development. Sustainable development includes social values such as human and environment rather than physical values such as growth. For this reason, development for the development of human resources in sustainable rural development is defined as human development and constitutes an important structure for both rural development and general development.

In a study conducted in Russia, rural development includes development of the labor market (staff potential), housing construction in rural areas, increasing level of household improvement, formation of a modern appearance, arrangement of engineering infrastructure facilities and improvement of fields located in rural areas. However, it is production that determines the development of all rural areas. Thus, to all the above must be added the restoration and improvement of agricultural production [51].

Another study conducted in Russia, an information model for sustainable rural development was developed. The model enables the formulation and evaluation of settlement scenarios to solve sustainable rural development problems. The research results showed that the information model is an effective tool for monitoring sustainable development at the local planning level. The strategy to be implemented in the country should not only focus on economic development, but also consider social, environmental, political, and other dimensions [19].

The purpose of study was to conduct surveys for assessment of current situation on SDGs and identifying opinions and understandings of farmers and extension providers/input suppliers. Based on the analysis of study, main findings and results are described below:

In target villages, we can classify the agricultural producers into three groups: family farms and households. By far the largest group (52% of total respondents) consists of 'households' with agricultural land producing mainly for home consumption and family farms, which comprise individual farmers that are market oriented. Family farms have only 2-3 ha on average, out of which households have plots of 0.5 ha or less. According to the results of our statistical surveys, average land per capita in the target villages amounts to 0.05-0.20 hectares which results in 0.5-2 hectares of land per family.

Also, separate small farms lead to problems such as expensive purchase of seeds, pesticides and fertilizers, improper soil and water use etc. To meet the social-economic demands of small-scale farmers and change their approaches to good agricultural practices, there is a great need to take the advisable measures in surveyed villages. Also, small-scale farmers are obliged to aim for good agricultural practices which are fundamental for high productivity.

The factual production indicators of plant production and livestock in surveyed villages are considerably lower than the potential. The main causes of this problem are mainly related to water deficiency, droughts, unfavorable growing season and insufficient knowledge and skills of farmers in surveyed villages. It should be noted that these surveyed villages didn't achieve not only the world middle level, but even the country middle level of productivity of main crops.

It allows us to note that most of farmers in surveyed villages have not sufficient skills on innovative technologies and business management know-how and experience due to the weak links to agricultural extension services. Because if the quality of extension services was satisfactory, we could see these successes in the productivity of crops cultivated by farmers in surveyed villages. It should be noted that, there is a great need to integrate innovations in agricultural practices and provide the trainings for farmers on innovative and good practices in production of main crops such as wheat, potato, legumes, sugar beet, fodder crops and livestock production.

In relation to annual production volume in farms surveyed in target villages, answer of respondents shows that the production volume of agro products in farms is low and there were some deficiencies for self-sufficiency by cereals, leguminous, potatoes, fodder crops etc. This fact gives us a good insight into the low-income farm problem of small farmers in target villages.

The responses of respondents showed that most farmers (88% of them) don't conduct farm assessment, margin analyzes of farm and marketing surveys except 12% of them. This fact shows that either the respondents interviewed haven't sufficient knowledge and skills for conducting these assessments or they haven't been aware of the importance of these issues. The farmers managed to trade is sold poorly to wholesale buyers, because of difficulties with moving around the country.

There is a great need for information consulting services intended for the extension providers and farmers about Good Agriculture Practices (GAP): GAP in land preparations, GAP practices for fertilizer application, GAP related to water using, GAP in sowing and seedling production, GAP in managing crop pests and diseases, hygiene and safety hazard during harvesting; new technologies in vegetable growing, field and industrial crop production; IPM for cotton, corn, winter wheat, potato, vegetable growing and etc.; Climate Smart Agriculture and Precession Agriculture; Organic Farming Systems; Conservation agriculture, especially conservation soil tillage in target villages.

Also, farmers are facing some challenges preventing the achievement of SDGs such as finance and economic problems, natural resources and hazards, technical issues in agriculture. To eliminate the negative effects of urbanization in target villages, there is a great need to improve rural income sources and promote employment for people in rural areas.

CONCLUSIONS

When the research results are evaluated in general, it is seen that commercial production is limited in farms with small lands. Farmers encounter problems in the supply of inputs, and they cannot irrigate adequately, especially due to lack of water. It is stated that climate change also has negative effects. Operational lands cannot be evaluated effectively in this way. Farmers must grow certain products. It has been determined that farmers need technical information, but extension services are insufficient. Since farmers cannot develop commercial production, they do not conduct market research. Economic and financial problems of farmers also negatively affect their adoption of new production techniques. They need more information and support on GAP and organic farming practices. In addition, it has been determined that urbanization in the research region has caused the use of agricultural lands for other purposes.

In almost all countries, economic problems are encountered in rural areas. Because this sector is dominated by the agricultural sector. The agricultural sector is also highly affected by the changes in ecological, economic, and political conditions. In this context, both national and international policies and strategies are determined and implemented in the fight against economic conditions. The measures to be taken and the policies to be followed to reduce and prevent the economic problems in developing countries are important both in terms of ensuring the continuity of development and economic growth. Therefore, effective policies for rural areas should be produced in Azerbaijan as well. Objectives should be determined with a sustainable understanding and a holistic approach in the formation of policies for combating poverty and rural development. Policy makers in Azerbaijan should evaluate their effects on ecology, economy, and social areas together while making decisions on these issues. In addition, while determining the policies, a wide participation including the participation and contribution of the local people, non-governmental organizations and representatives of all organizations operating in the region should be ensured.

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REFERENCES

[1]Adenidji, E.M.C., Ozcatalbas, O., 2021, Rural tourism and sustainable development: a bibliometric analysis. International Rural Tourism and Development Journal 5(2):56-69.
[2]Akif, N.K.,Vakif, H.J., Vakif, K.M., 2020, Trends in thedevelopment of agritourism in Azerbaijan. Proceeding of 55th International Scientific Conference on EconomicandSocial Development, 18-19 June, 2020, Baku-Azerbaijan, pp.306-312.
[3]Alakbarov, F., 2020, Assessment of agricultural advisory service systemin Azerbaijan. National Report, Strengthening of Agricultural Advisory Services Project Funded by the EuropeanUnion (EU) and Implemented by FAO, Baku, pp.81-94.
[4]Aliyev, I., 2008, Rural-urban labor migration in Azerbaijan, Master Thesis, Central European University, Department of Public Policy, Austria.
[5]Ammirato, S., Felicetti, A.M., Gala, M.D.,Nicola,F., Volpentesta, A.P., 2017, Sustainable development for rural areas: a survey on the agritourism rural networks. In: Collaboration in a Data-Rich World. PRO-VE 2017. IFIP Advances In Information and Communication Technology, 506. Springer International Publishing, pp. 564-574.
[6]Anonymous, 2023a, Sustainable Development Goals-2018, Baku-Azerbaijan: The State Statistical Committee of The Republic of Azerbaijan, http://sdg.azstat.org:8484/uploads/pages/full-material-636947851694915298.pdf, Accessed on 16 January 2023.
[7]Anonymous, 2023b, TheState Program on Sustainable Development and Reducing Poverty During (2008-2015). https://e-qanun.az/framework/15399, Accessed on 12 January 2023.
[8]Arco, I., Ramos-Pla, A., Zsembinszki, G., Gracia, A., Cabeza, L.F., 2021, Implementing SDGs to a sustainable rural village development from community empowerment: linking energy, education, ınnovation, and research. Sustainability 13:1-13.
[9]Asiry, K.A., Hassan, S.S., Alrashidi, M., 2013, Factors affecting agricultural sustainability: a case study of Hail Region, Kingdom of Saudi Arabia. Asian Journal of Agriculture and Rural Development 3(10):674-687.
[10]Bafoe, G., Zhou, X., Moinuddin, M., Somanje, A.N., Kuriyama. A., Mohan. G., Saito. O.,Takeuch. K., 2021, Urban–rural linkages: effective solutions for achieving sustainable development in Ghana from an SDG interlinkage perspective. Sustainability Science 16:1341-1362.
[11]Bardal, K.G., Reinar, M.B., Lundberg, A.K., Bjørkan, M., 2021, Factors facilitating the ımplementation of the sustainable development goals in regional and local planning experiences from Norway. Sustainability 13(8):1-19.
[12]Buhay, A., Korenev. S.A., 2013, Problems of sustainable development of rural territories. Bulletin of the Altaiagrarian University 1:142-145.
[13]Carter, L.,Cosijn, M., Williams, L.J., Chakraborty, A., Kar, S., 2022, Including marginalised voices in agricultural development processes using an ethical community engagement framework in West Bengal, India.Sustainability Science 17:485-496.
[14]Chekmarev, O., Manilov, A., Ulimbashev, A., Timoshenko, S., 2021, COVID-19 pandemic is a stimulus for sustainable development of rural areas and labormarkets, The 21st International Scientific Conference Globalization and its Socio-Economic Consequences, October 13-14, 2021, Zilina-Slovak Republic. SHS Web of Conferences 129:1-8.
[15]Dumitru, E.A., Petre, L.L., 2021, Family farm: Solution for sustainable development of rural area, The Research Institute for Agricultural Economy and Rural Development (ICEADR), Bucharest, pp. 200-208.
[16]Dumitru, E,A., Ursu, A., Tudor, V.C., Micu, M.M., 2021, Sustainable development of the rural areas from Romania: development of a digital tool to generate adapted solutions at local level. Sustainability 13:1-18.
[17]Ghavidel, G., Jahani, M., Ghanbarzadeh, H., Rahimi, H., 2018, Analysis of social capital impact on rural sustainable development: A case study from villages of central part of Torbat Heydarieh City. Ukrainian Journal of Ecology 8(3):32-41.

[18]Glubokova, L.G., Kokhanenko, D.V., Shevelev, S.Y., Ilyina, M.A., 2020, Analysis of Indicators of Sustainable Development Goals for Rural Areas of Russia, Advances in Economics. Business and Management Research 139:270-275.

[19]Harbiankova, A., Gertsberg, L., 2022, Information model for sustainable rural development. Energies 15:1-15.

[20]Hong, H.N., 2017, Factors affecting sustainable development of agricultural cooperatives in the Mekong River Delta, Vietnam. American Journal of Applied Sciences 14(10):1005-1010.

[21]Huseyn, A., 2020, Assessment of the effects of rural tourism on the socio-economic development of the country. Agricultural Economics 36(2):93-103.

[22]Iannucci, G., Martellozzo, F., Randelli, F., 2022, Sustainable development of rural areas: a dynamic model in between tourism exploitation and landscape decline. Journal of Evolutionary Economics 32:991-1016.

[23]Ismayilov, V., Samadova, A., Mirzayev, S., 2020, The Role of rural tourism in the development of the rural economy, The Journal of Economic Sciences: Theory and Practice, 77(1):51-64.

[24]Ismayilov, V., 2018, Development prospects of agrotourism in Azerbaijan. Journal Kasmera 46(2):2-6.

[25]Kiniorska, I., Wronska-Kiczor, J., 2015, Factors affecting sustainable development of agriculture and rural areas in the Świętokrzyskie Voivodship, Barometr Regionalny, 1(39):41-46.

[26]Koopmans, M.E., Rogge, E., Mettepenningen, E., Knickel, K., Sumane, S., 2018, The role of multi-actorgovernance in aligning farm modernization and sustainable rural development, Journal of Rural Studies, 59:252-262.

[27]Kozakova, J., Savov, R., Lancaric, S., Lancaric, D., 2018, Sustainable development in rural regions of Slovakia: the role of the National Rural Development Program, Rural Areas and Development 15(2018):25-38.

[28]Li, H., He, H., Zhang, J., 2022, Study on rural development evaluation and drivers of sustainable development: evidence from the Beijing-Tianjin-Hebei Region of China. Sustainability 14:1-21.

[29]Lopez-Sanz, J.M., Penelas-Leguia, A., Gutierrez-Rodriguez, P., Cuesta-Valino, P., 2021, Rural tourism and the sustainable development goals: a study of the variables that most influence the behavior of the tourist. Frontiers in Psychology. 12:1-14.

[30]Magda, S., Magda, R., Marselek, S., 2009, Sustainable development of the rural economy, Applied Studies in Agribusiness and Commerce. 5(5-6): 31-36.

[31]Martínez, P.F., Castro-Pardo, M.D., Barroso, V.M., Azevedo, J.C., 2020, Assessing sustainable rural development based on ecosystem services vulnerability. Land 9:1-23.

[32]Okech, R., Haghiri, M., Georghe, B.P., 2012, Rural tourism as a sustainable development alternative: an analysis with special reference to Luanda, Kenya. Cultur 6(3):36-54.

[33]Okunola, A.M., 2016, Nigeria: position in rural economy for ımplementation of sustainable development goals. Turkish Journal of Agriculture - Food Science and Technology 4(9): 752-757.

[34]Ozdemir, L., 2019, A research and the determination of effective elements for the prevention of migration from villages to cities for sustainable rural development in Turkey Suleyman Demirel University Visionary Journal 10(25):450-465.

[35]Ricardo, G.H., Mitchell, A.T., 2007, Are rural–urban migration and sustainable development compatible in mountain systems? Mountain Research and Development 27(2):119-123.

[36]Rogelj, M.J., Micus, O., Hadelan, L., 2020, Selection of economic ındicators forme assuring sustainable rural development. Scientific Papers: Series Management, Economic Engineering in Agriculture and Rural Development 20(3):285-295.

[37]Saglam, U., Erbas, N., Inan, I.H., 2022, Measuring success levels of agricultural producer organizations and organizational problems: The case study in Turkey, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(3):599-608.

[38]Shaporova, Z.T., Tsvettsykh, A.V., 2020. Indicators for assessing the sustainable rural development in the region, IOP Conference Series: Earth and Environmental Science (AGRITECH-III-2020) 548:1-6.

[39]Sharafi, H., 2021, Assessing sustainable rural development using the rough set approach case study: villages of Mahan-Kerman District. Turkish Journal of Computer and Mathematics 12(1):586-601.

[40]Shcherbak, V., Ganushchak-Yefimenko, L., Nifatova, O., Fastovets, N., Plysenko, H., Lutay, L., Tkachuk, V., Ptashchenko, O., 2020, Use of key indicators to monitor sustainable development of rural areas. Global Journal of Environmental Science and Management 6(2): 175-190.

[41]Sheina, S., Fedorovskaya, A., 2018, Conceptual framework for sustainable development of rural areas: environmental issues, 52nd Annual Scientific Meeting of the European Society for Clinical Investigation, 30 May-1 June 2018, Barcelona-Spain, MATEC Web of Conferences, 193:1-9.

[42]Shi, J., Yang, X., 2022, Sustainable development levels and influence factors in rural China based on rural revitalization strategy. Sustainability 14:1-19.

[43]Shishkova, M., 2019, The role of social farming for sustainable rural development in Bulgaria, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 19(2):415-420.

[44]Simkova, E., 2007, Strategic approaches to rural tourism and sustainable development of rural areas. Agricultural Economics (Czech) 53(6): 263–270.

[45]Singh, R., 2018, Sustainable rural development in India: issues and challenges. International Journal of Research in Social Sciences 8(3):330-341.

[46]Sjaf, S., Hidayat, N.K., Kaswanto, K., Barlan, Z.A., Sampean, L.E., Gunadi, H.F., 2021, Measuring achievement of sustainable development goals in rural

area: a case study of Sukamantri Village in Bogor District, West Java, Indonesia. Sodality Jurnal Sosiologi Pedesaan 9(2):1-15.

[47]Sobczyk, W., 2014, Sustainable development of rural areas. Problems of Sustainable Development 9(1):119-126.

[48]Tou, H.J., Noer, M., Helmi, M., 2022, Sustainable pilar of rural tourism development. Rekayasa 12(1):47 - 58.

[49]Vasile Rusu, R.C., Neculita, M., Cristea, D., Mogodan, A., Petrea, S., Simionov, I., 2020, Sustainable development of rural areas of Southeast region of Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 20(2):523-529.

[50]Vasta, A., Figueiredo, E., Valente, S., Vihinen, H., Nieto-Romero, M., 2019, Place-based policies for sustainability and rural development: the case of a Portuguese village “Spun” in traditional linen. Social Sciences 8:2-17.

[51]Volkonskaya, A., Mamai, O., Kudryashov, A., Nikulnikov, N., 2022, Problems of sustainable development of rural areas (on the materials of Samara region), International Scientific-Practical Conference (Agriculture and Food Security: Technology, Innovation, Markets, Human Resources) (FIES 2022), 26-28 May 2022, Kazan-Russia, BIO Web of Conferences 52:1-5.

[52]Wang, Z., Zhao, Y., 2021. Energy strategy for sustainable development of rural areas based on the analysis of sustainable digital economy. Frontiers in Psychology 12:1-11.

[53]World Bank, 2018, Building Azerbaijan`s farming middle class: outcomes of the agriculture sector risk assessment, World Bank Publications, Baku, p.7-30.

[54]Yenigul, S.B., 2017, New approaches in rural development policies and the effects of these approaches on Turkey’s rural development policies. Planning 27(1):16-25.

[55]Zizumbo-Villarreal, R., Roja-Caldelas, R.I., 2011. Assessment of a sustainable rural development model: best practices in Comala, Colima, Mexico. Sustainable Development and Planning, 150:609-621.

[56]https://www.istockphoto.com, Accessed on June 20, 2023

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RISKS IN GRAPES PRODUCING AND ALTERNATIVE RISK MANAGEMENT FOR VITICULTURISTS: A STUDY CASE FROM AZERBAIJAN

Mehseti ALEKBEROVA[1], Farida ASLANOVA[1], Sait ENGINGDENIZ[2]

[1]Azerbaijan State Agricultural University, Faculty of Agronomy, Department of Horticulture, Ganja-Azerbaijan, E-mails: alekberova_1979@mail.ru, farida_aslanova_93@mail.ru
[2]Ege University, Faculty of Agriculture, Department of Agricultural Economics, Izmir-Turkey, E-mail: sait.engindeniz@ege.edu.tr

Corresponding author: alekberova_1979@mail.ru

Abstract

Every activity and fruit production of viticulture farms always brings risks. It is therefore important to develop a risk management system that allows for the identification, assessment and minimization of threats to the production of grape products. The organization of such a system requires a detailed analysis and systematization of the risk factors affecting the viticulture-wine-making activity. Reducing and managing risks is possible by knowing the risk factors and the rules of behavior with the risks. Preventive measures taken to manage the risks that may arise, in addition to the protection of the grape plant, will also create the conditions for increasing the product quality and increasing the yield. The purpose of this study is to examine the different risk sources encountered in grape growing, to reveal different risk management strategies that can be carried out by growers, and to compare and evaluate these aspects of grape growing in Azerbaijan with examples from different countries. The main material of the study consists of the data obtained from FAO, The State Statistical Committee of the Republic of Azerbaijan, The Ministry of Agriculture of the Republic of Azerbaijan and the results obtained from previous researches on the subject. The collected statistical data were arranged in the form of tables and figures and interpreted by making percentage and index calculations. Risk management in grape production depends on the values, knowledge, past experience, financial obligations of the growers, and the magnitude of potential gains or losses associated with any particular risk.

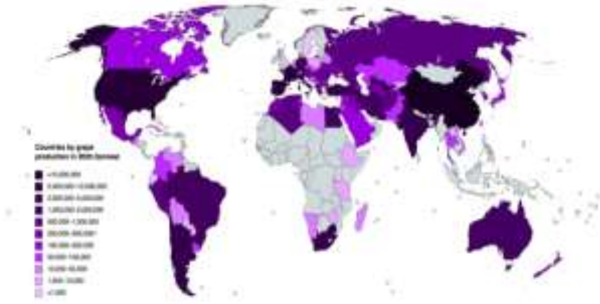
Key words: *grape producing, grape variety, risk analysis, risk strategies, viticulturists'behavior*

INTRODUCTION

Viticulture in the world is generally carried out between 20º-50º latitudes in the Northern Hemisphere and 20º-40º in the Southern Hemisphere. Temperature is the most important factor preventing viticulture from spreading to the north. The reasons such as the various evaluation methods of grapes, not being very selective in terms of climate and soil requirements, being perennial and easy reproduction methods are an important factor in the widespread cultivation [18].

Grapes, like all fruits, are a very important food source for humans. Grapes could be consumed like: fresh food, wine, dried fruit, fruit juice and other processed products [25]. Fresh grapes are an important source of energy and nutrients, as they have high levels of sugar and rich minerals. The vitamins, sugar and minerals that grapes have can also be beneficial to people with grape juice. For these reasons, grapes and their products are used in the treatment of kidney, liver and intestinal diseases and anemia. Wine, which is a low alcohol drink, is also a good source of nutrients because it is made from grapes.

According to FAO data, 73.5 million tons of grapes were produced on 6.7 million hectares of land in the world in 2021.



Map 1. Grape production by countries
Source: FAOSTAT, 2023 [10].

The most important countries in grape production are respectively; China, Italy, USA, Spain, France, Turkey, India, Argentina, Chile and Iran. In 2021 (Map 1), Azerbaijan has a share of 0.22% in the world with a production area of 15,100 hectares, and a share of 0.29% with a grape production of 209,843 tons [10].

Viticulture, which has an important place in Azerbaijan agriculture, is faced with many problems in the process from production to growing, from growing to marketing. Among these problems, the problems related to the amount of product taken from the unit area and low quality have an important place. Productivity in viticulture is closely related to the number and size of clusters and grains on the vine, as well as the number of vines per unit area. However, these characteristics are affected by many internal and external factors such as variety, rootstock, cultural practices and environmental conditions. One of the factors affecting productivity is the characteristics of the fertilization biology of the cultivars. On yield and quality; ecological factors, rootstock and variety, training, pruning, irrigation, fertilization, tillage, diseases and pests, use of growth regulators, etc. is effective.

The Azerbaijani government has published forecasts for production in various sectors of the agro-industrial complex for 2023. The production of grains will continue to grow, but the most noticeable will be the increase in the production of fruits and berries.One of the most important production branches in terms of the sustainability of agricultural production in Azerbaijan and the provision of international competition opportunities is fruit growing. One of the important fruits is grapes. Grape, which was one of the most important fruits in the 1980s, has started to increase its production areas again in recent years. In many studies, the economic importance of fruit growing and grape production for the country and the necessity of its development have been revealed [2, 22, 6, 7, 8, 13, 44, 40].

In Azerbaijan, most fruits are planted in privately owned orchards, mostly by family farms and households, on areas up to 2 hectares, and larger agricultural enterprises cultivate about 7% of the fruit area. In grape production, about 30% of the area is used by agricultural enterprises, and the share of larger companies producing grapes is increasing slightly over time. However, the average farm size in grape production is still quite small [41].

The different natural and economic conditions of the Republic of Azerbaijan, the diversity and complexity of the use of land resources even in small areas, the presence of 8 out of 11 climate types in the world create the need for theoretical and scientific studies. It will also enable growers to make definite decisions about the correct organization of viticulture and to conduct experimental studies to examine grape varieties ripening at different times, as well as to examine the risks encountered and develop strategies, to provide high returns in viticulture.

Many studies have been carried out on the morphological characteristics, genetic variation and breeding of grape varieties in Azerbaijan [9, 31, 32, 27, 14, 1, 20, 33, 22, 24, 15, 47, 34, 23, 45, 35, 30, 5]. Today, however, grape growers face technical, economic and environmental risks and try to find solutions for them. For this reason, there is a need to develop the risks in terms of developing grape production in the country and the researches on the management of these risks.

The purpose of this study is to examine the different risk sources encountered in grape growing, to reveal different risk management strategies that can be carried out by growers, and to compare and evaluate these aspects of grape growing in Azerbaijan with examples from different countries.

MATERIALS AND METHODS

In this study, the risks in grape growing are classified as risks encountered during the production phase, risks during sales, financial risks, human-induced risks and environmental risks [37, 4]. Then, the sources of these risks were evaluated by using the results of the studies conducted in Azerbaijan and other countries. In the study, some alternative measures that farmers can take against risks have also been developed. The most important measure that farmers can take against risks is insurance. In the study, insurance practices for viticulture in Azerbaijan were also examined and concrete evaluations were made on the subject.

The main material of the study consists of the data obtained from FAO, The State Statistical Committee of the Republic of Azerbaijan, The Ministry of Agriculture of the Republic of Azerbaijan and the results obtained from previous researches on the subject. In the study, evaluations were made with the data of 2012-2021 period.

The collected statistical data were arranged in the form of tables and interpreted by making percentage and index calculations.

RESULTS AND DISCUSSIONS

Recent Development in Grape Production and Marketing in Azerbaijan

The "Viticulture and Winemaking Law" leigslated in Azerbaijan on January 20, 2022 is the most important legal basis in the field of viticulture. This law aims to develop viticulture under free market conditions.

Also important is the "2012-2020 State Program on the Development of Viticulture in the Republic of Azerbaijan". This Program, prepared by the Decree No. 1890 of the President of Azerbaijan dated 15 December 2011, later covered the years 2018-2025 with the Decree No. 38 dated 3 May 2018. The State Program for the Development of Winemaking in Azerbaijan has also been prepared. With this program, it is aimed to establish the scientific basis of viticulture, develop production and establish processing industrial enterprises. Within the framework of this program, it is planned to expand production areas [43].

According to the data of the State Statistical Committee of the Republic of Azerbaijan, while the area cultivated for grape in Azerbaijan was 16,327 hectares in 2012, it decreased to 15,962 hectares in 2021. On the other hand, it is seen that cultivated area formed by trees of fruiting age increased by 21% in 2012-2021 period. In 2021, cultivated area formed by trees of fruiting age consisted 95% of the total area cultivated**.** While 150,987 tons of grape was produced in Azerbaijan in 2012, grape production was 209,843 tons in 2021 (Table 1). While the grape yield in Azerbaijan was 12,134 kg/ha in 2012, it was 13,951 kg/ha in 2020 and 13,897 kg/ha in 2021.

In 2021, 19.4% of areas cultivated were located in Mountainous-Shirvan region, 13.7% in Gazakh-Tovuz region, 12.6% in Ganja-Dashkesan region. However, 31.7% of grape production was from Gazakh-Tovuz region, 11.5% from Lankaran-Astara region, 8.7% from Mountainous-Shirvan region (Table 2).

Viticulture is carried out in many regions of the country. However, the areas that are more suitable for viticulture are shown on Map 2. As the green color gets darker on the Map, the suitability for viticulture increases [17].

In Azerbaijan, grape varieties are similar in many characteristics and differ from others. Local grape varieties have a wide variety according to their morphological characteristics.

Therefore, Azerbaijan grape varieties are distinguished by the color, shape and size of the fruits, ripening time, usage direction, processing and storage features [35].

The above statistics show that grape production has increased rapidly in recent years. Grapes can be grown in many regions of the country. Grapes are sold for the fresh market (about 60%) and for wine processing (40%) [41].

The fresh market with grapes to be processed for juices as well as seedless varieties is attractive as a growing market.

The consumption of table grapes is increasing steadily around the world. However, in Russia, consumption has decreased in recent years due to the economic recession of the country, which affects the demand for grapes more negatively than for other fruits. In the global perspective, China, Turkey, Brazil, Italy and Spain are the main producers of table grapes and this can be considered as a benchmark for Azerbaijani growers.

Table 1. Change of area cultivated and grape production in Azerbaijan

Years	Total area cultivated (ha)	Cultivated area formed by trees of fruiting age (ha)	Index (2012=100	Grape production (tons)	Index (2012=100)	Yield (kg/ha)
2012	16,327	12,443	100	150,987	100	12,134
2013	16,115	13,128	105	148,535	98	11,314
2014	15,904	13,491	108	147,701	98	10,948
2015	16,096	13,514	109	157,076	104	11,623
2016	16,004	13,941	112	136,499	90	9,791
2017	16,088	14,140	114	152,843	101	10,809
2017	16,064	14,371	115	167,591	111	11,662
2019	16,061	14,522	117	201,842	134	1,3899
2020	16,068	14,911	120	208,019	138	13,951
2021	15,962	15,100	121	209,843	139	13,897

Source: The State Statistical Committee of the Republic of Azerbaijan, 2023 [42].

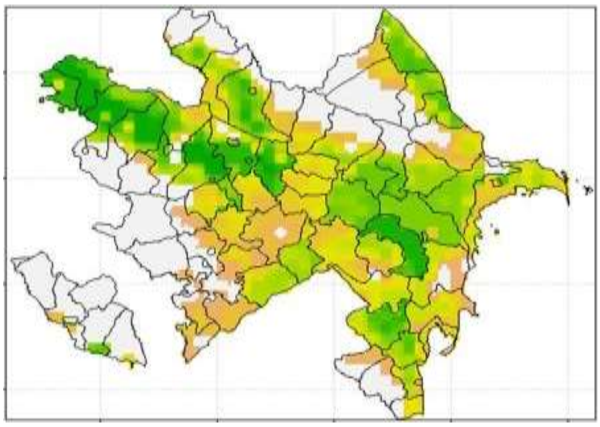
Table 2. Grape production in Azerbaijan according to regions (2021)

Regions	**Area cultivated (ha)**	**Grape production (tons)**	**Yield (kg/ha)**
Baku city	1,308	14,419	11,024
Nakhichevan Autonomous Republic	1,402	17,098	12,195
Absheron-Khyzi	175	919	5,251
Mountainous -Shirvan	2,931	18,274	6,235
Ganja-Dashkesan	1,909	17,534	9,185
Karabakh	150	7,966	5,311
Gazakh-Tovuz	2,062	66,442	32,222
Guba-Khachmaz	778	7,511	9,654
Lankaran-Astara	1,546	24,210	15,660
Central Aran	441	6,250	14,172
Mil-Mugan	212	5,762	27,179
Sheki-Zagatala	950	11,834	12,457
East Zangazur	19	215	11,316
Shirvan-salyan	1,217	11,409	9,375
Total	15,100	209,843	13,897

Source: [42].

China's production is increasing rapidly, as is its export to neighboring countries. Not compatible with health-related fruits such as grapes, strawberries or pomegranates. Many exporting countries struggle to get prices that pay off in international markets [41].

Most of the fresh produce in the country is sold to local markets (open markets, street sale or grocery stores). Grape growers sell their products to shops themselves (family members) or through merchants.



Map 2. Suitable areas for grape producing in Azerbaijan
Source: [41].

Compared to other types of fruit, larger volumes are available from large companies and firms. Therefore, selling to larger supermarkets is possible when growers can comply with quality and stable supply requirements. To obtain more stable and profitable prices for their products, growers need to invest in marketing activities and chain links such as producer sales associations that will allow them to sell in larger volumes and exercise market power. This is extra important to compete in the market. Table 3 shows the development of grape prices received by growers. Compared to some grape producers in the world such as Turkey, Iran and Romania, it is seen that the prices received by the growers in Azerbaijan are lower.

According to the data of the State Statistics Committee, grape prices received by growers have decreased in recent years. It has been determined that prices have decreased significantly especially after 2017 (Table 4).

Azerbaijan also exports fresh grapes and grape juice to different countries. The change in exports in the last ten years is presented in Table 5. The countries that sell the most fresh fruit and juice are Russia, Ukraine, Kazakhstan, Belarus and Germany, respectively.

Table 3. Grower prices for grape in Azerbaijan, Turkey, Iran and Romania

Year	Azerbaijan ($/ton)	Turkey ($/ton)	Iran ($/ton)	Romania ($/ton)
2012	751	700	592	872
2013	1,007	692	559	736
2014	940	555	439	879
2015	715	545	429	723
2016	450	492	327	714
2017	407	436	420	769
2018	382	414	696	652
2019	329	449	798	756
2020	329	427	1,104	814
2021	394	410	1,968	846

Source: [10].

Table 4. Level and dynamic of grower grape price in Azerbaijan

Years	Grower price (*)	Grower price (**)
2017	98.1	91.0
2018	100.9	91.9
2019	99.4	91.3
2020	99.1	90.5
2021	101.0	91.4

(*) Compared to the previous year, in percent
(**) 2015=100, in percent
Source: [42].

In 2017, Azerbaijani winemakers produced more than one million deciliters (or about 25,000 gallons) of wine, of which 375,000 deciliters were exported, generating approximately $6 million in revenue to the country. According to the data of the Azerbaijan Wine Producers and Exporters Association, wine exports are being expanded to Asia and Europe. The main importers of Azerbaijani wine include Russia (338,000 deciliters) and China (27,000 deciliters). With the opening of an Azerbaijan trading house specializing in wine in Shanghai, China, local producers and exporters will have the opportunity to distribute their products as one of the most competitive wines. It is aimed to increase wine exports five times by 2025 [16].

Table 5. Grape and grape juice export of Azerbaijan

Year	Grape (fresh) export		Grape juice export	
	Quantity (ton)	Value ($1,000)	Quantity (ton)	Value ($1,000)
2012	300	247	26	36
2013	1,180	864	51	67
2014	462	345	20	27
2015	2,026	1,531	18	21
2016	4,158	2,485	22	25
2017	2,444	1,742	42	48
2017	3,210	2,349	139	179
2019	4,168	3,028	63	81
2020	6,630	4,906	81	92
2021	10,398	7,144	103	83

Source: [10].

Main Sources of Risk in Grape Growing

Since viticulture is a risky area like other agricultural areas, these risks that may occur during the production process should be taken into account and appropriate preventive measures should be taken. For this reason, growers should think about the risks in advance and be aware of the possible risks and how they will cause harm. Because the risk may arise as a result of the wrong decisions of the grower. For this reason, the lack of knowledge of some farm owners in the field of grape development, cultivation and protection can lead to difficulties and mistakes in product production and may endanger the farms.

Risk refers to factors that may occur and damage the farm. As a grower manager, he is constantly faced with various risks. However, the grower should be aware that ways to deal with risks are a risk reduction strategy.

Although risks are defined as undesirable events and causes of loss, it is a multi-factor process. In the study, it was determined that the risks were concentrated in two groups according to the source and scope of the risk factors;

- External factors unrelated to the activities of the farm. They are difficult to influence and almost impossible to control;

- Internal factors occurring in farm activities. Such factors should be controlled and influenced by management.

The main risks sources in viticulture can be listed as follows [37, 4];

Risks in the production phase

Changes in the production process that are not taken into account due to violation of production technology, poor quality of production tools, non-use of suitable planting material in terms of biological, genetic and phytosanitary, ignorance of growers about agroecology, agrobiology and farm-technological properties of introduced grape varieties, etc. are matters.

It should also be noted that the vineyards planted from poor quality, unknown origin and non-standard vine saplings have a short life span, and the product yield and quality are very low. In addition, due to the lack of domestic production of planting material and the preference of foreign varieties for grape planting, the local grape gene pool in Azerbaijan is shrinking and disappearing [29].

Globally, grapes are the fruit crop with the largest area and highest economic value. Grapes have a variety of pests and pathogens that cause economic damage and require control interventions. As a result, the use of chemicals in grapes is one of the highest among agricultural products [26].

Growers can benefit from meteorological data and disease and pest prediction information in order to combat diseases and pests and develop strategies against risks. While developing strategies against risks, growers should also take into account their local and economic impacts and apply them after obtaining the necessary information on this subject. Availability of information influences growers' strategies. To this end, an empirical analysis of the impact of improved disease prediction information on grape growers' behavior and the environment was conducted. Temporal and spatial data on powdery mildew treatments in California were used to estimate growers' disease management procedural patterns [19].

Risks during the sale: lack of market research, lack of determination of sales channels, poor organization of marketing services, lack of contractual management, etc are matters. Market risks for grape growers include reduced demand for grapes, lower grape prices, and increased competition with foreign or other domestic growers.

Grape growers may face production and market risks. Market risk is evaluated as price fluctuations as a result of changes in market supply and demand. In a study conducted in the USA, a simulation model was carried out to include both types of risks simultaneously, taking into account the combination of bud mortality and weather effects on yields, as well as production costs and prices [11].

Financial risks: the inefficiency of the structure of material resources, debts exceeding the acceptable level, the inability of farms to pay, a decrease in product profitability, etc. are matters.

Financial risks include restricted access to capital, fluctuating interest rates, and slow payment or non-payment from customers. It is also possible to count government risks such as poorly designed, intrusive, destructive and costly policies and regulations.

Human-induced risks: lack of highly qualified scientists and specialists in the field of viticulture and winemaking, insufficient professionalism of staff, incorrect assessment of the time required for training and retraining of personnel, incorrect setting of goals and lack of clear definition of duties, duties and responsibilities for employees, etc. are matters.

Environmental risks: recently, the change of the ecological system has been clearly felt. From this point of view, it is of great scientific and practical importance to determine the changes in the phenological stages of the grape plant, which are mostly related to environmental conditions. Thus, changes in environmental factors during the ontogenesis of grapes have a significant effect on the course of grape phenophases and the resulting environmental stress factors do not affect the life of the grape. It has been determined that the change of environmental conditions in the grape plant is accompanied by the change of phenological phases [3].

Even in some cases, natural disasters cause complete destruction of vineyards or loss of crops. The factor causing natural (ecological) risk is the most dangerous risk for viticulture farms. It affects the yield of grapes, the technology of growing and the quality of agricultural work. The efficiency of the work of each farms depends on the hydrometeorological characteristics of the region [28]. It should be noted that the occurrence of undesirable climatic conditions (hail, drought, storm, diseases, excessive soil moisture, frost, etc.) is poorly controlled and these factors should be taken into account when managing risks. In general, the resistance of grape varieties to adverse environmental conditions is not the same. Therefore, the resistance of grape varieties to spring frosts depends on the late opening of buds and the replacement of shoots.

Viticulture in Peru is an important economic activity for the production and export of early table grapes or the production of wine and pisco. In a study, it was determined that climate change has negative effects on some grape varieties grown in the Ica region of Peru [46].

It is seen that the risks encountered in grape and wine production are also classified as climatic risks, growers' perception of risks, markets and prices risks, relevance of data and information availability in managing risk, risks and transaction costs [37].

In a study examining the behavior of growers under general risky conditions, growers' perceptions of climate risks and strategies to address them were evaluated. According to the research, climate change causes cost increases. The insurance rate of growers is low. The results showed that the behavior of growers is paradoxical because financial instruments are costly and very difficult to understand, although they have to face risks [36].

In a study conducted in Italy, the risk perceptions of producers regarding the risk of production losses caused by climate events were evaluated. The results showed that the long-term perceptions of the growers were significantly higher than the short-term, and that individual beliefs about climate change and personal experiences of past production damage played a role in this difference [21].

Risk Strategies for Growers in Grape Growing

Grape varieties with late budding and fertile replacement shoots should be planted especially in places where there is a danger of spring frost. Therefore, the following measures should be taken to manage the risks arising from winter and spring frosts [4]:

1. Variety selection,
2. Directly affecting the trunk itself by agrotechnical measures,
3. Influencing the environment surrounding the trunk with agrotechnical measures.

Depending on the frosty climatic regions, it should also be noted whether the grape plant is protected from frost with a special method in places with -15-16º C frost. Grape seedlings are buried in the ground where frosts fall below -15-16ºC. In places where frosts are below -35º C, the bushes are protected from frost with a special method [28].

Thanks to the development of the viticulture and processing industry, it is possible to significantly enrich the species composition of quality food products in order to adequately meet the demand for grapes and grape products of the world market and the population of the country. It is one of the most important scientific issues in viticulture in terms of examining the biochemical composition of individual varieties, obtaining a targeted and quality product during processing, evaluating the quality of the grains of grape varieties, determining their suitability for use and examining their biological nutritional value.

Knowing the weaknesses and strengths of the aforementioned internal and external risk-creating environment will enable the evaluation, development and implementation of methods to minimize and neutralize threats. Thus, the following measures should be taken to reduce the risks in viticulture;

1. It is necessary to determine the direction of production: technical or table viticulture;
2. The conditions under which technical varieties should be grown must be determined

in advance, that is, a contracted breeding system must be established.

Therefore, a farmer engaged in technical viticulture should operate on a contractual basis according to the conditions of the processing plant close to the field. Harvest content levels of grapes according to their intended use are shown in Table 6.

Table 6. Approximate harvest status of grapes depending on the direction of use

Uses of grapes	Approximate harvest status of grapes	
	Sugar (%)	Acidity (%)
Fresh use	16-20	6-8
Use in making white table wines	17-20	7-10
Use in making red table wines	17-21	6-9
Use in the production of champagne wine material	16-20	8-12
Use in the production of cognac wine material	16-19	8-12
Use in the production of wine material for dark wines	19-22	5.5-6.5
Use in the production of wine materials for dessert wines	≥22	5-6

Source: [28].

However, a study highlighted that written contracts for the supply of grapes are more reliable than informal agreements because of the risk associated with purchasing grapes of the required quality.

The unpredictable perishability of grapes due to both physiological and climatic events can make it difficult or uncertain to obtain the desired quality grapes. It can even make it costly at times. For this reason, vertical integration strategies should be implemented using detailed written contracts [12].

It is also beneficial for the growers to pay attention to the following points :

1. Where table varieties are produced, it should be determined whether they are used for transportation to regions where grapes are not grown or for storage in winter warehouses.
2. Product variety should be provided on the farm.

Therefore, if the climate (sum of active temperature) of the area where the farm is located allows, the field should be organized from the variety group, from the earliest maturing grape variety to the latest maturing grape variety (Table 7).

In addition to the protection of the grape plant, preventive measures applied to manage the risks that may arise create favorable conditions for the improvement of product quality and reproduction of the product.

Table 7. Active temperature sum and vegetation period of grape varieties ripening in different periods

Grape varieties	Total active temperature from bud opening to full maturation of gills (°C)	Time from bud opening to full ripening of fruit (day)
Ultra fast growing	2,000-2,200	100-110
Very early maturing	2,200-2,400	110-120
Fast growing	2,400-2,600	120-130
Moderately grown	2,600-2,800	130-145
Late grown	2,800-2,900	145-165
Very late maturing	≥ 3,000	165-175

Source: [38].

The main preventive measures to be taken in grape production are as follows;

- The area to be planted should be chosen from well-ventilated areas..
- It should be ensured that the clusters mature at the same time.
- The clusters and fruits should be protected from sunburn.
- Varieties suitable for agricultural climatic conditions should be chosen correctly.
- Planting scheme selection should be made according to the variety and the varieties should be placed correctly.
- Forms should be provided according to the variety.
- The strength of the variety should be taken into account when giving eye load to the trunk.

- Agrotechnical measures should be applied correctly and in a timely manner.

The effects of climatic changes have become more visible in recent years. One of these effects is the negative effects on agricultural productivity. Agricultural productivity decreases due to uncontrollable climatic events, which negatively affects profitability. Growers are trying different strategies and ways to reduce these effects of climate change and try to maintain their production levels and profitability. A study conducted in Italy found that growers suffered productivity and income losses due to climate change. In the study, it was suggested that the most appropriate strategy for climate change risks is insurance. The empirical results revealed that the age and education level of the growers are the variables that support access to insurance for quality grape production [39].

Insurance Applications for Vineyards in Azerbaijan

On June 27, 2019, it was issued a decree on the application of Law № 1617-VQ and the Establishment of the Agrarian Fund, on August 19, 2019, the decree on "Agrarian Insurance" number 809. In accordance with the decree, an Agricultural Insurance Fund was established to ensure the organization, development, and sustainability of the agricultural insurance system.

According to the Law of the Republic of Azerbaijan "On Agricultural insurance", the agricultural insurance system in the country is based on the principles of public-private cooperation. The Agricultural Insurance Fund is a non-profit legal entity established by the state and carries out insurance payments, bearing risks. The management company is a joint insurer established by insurance companies licensed for life insurance and organizes the conclusion of insurance contracts.

The agrarian insurance mechanism provided insurance for 14 types of plants and their products. Among them was the grape plant. Insurance premiums for vineyard insurance vary depending on the region and the productivity of the vineyard. In different regions, the rates for vineyard insurance at the base rate range from 1.95% to 6.38%. According to the rules, 3 insurance packages are offered for grape plant insurance within the framework of agricultural insurance. The first of them is the "basic package", which covers most of the risks, and the other packages cover additional risks. Insurance packages differ from each other both in the amounts of exemption, as well as the risks they cover.

In the first "basic package", the amount of exemption is 10%. This envelope insures the grape plant from hail, fire, earthquake, landslides, hurricanes, storms and actions of third parties.

1st Insurance package: In this package, risks such as hail, earthquake, fire, landslide, storm and hurricane are taken into account and covered.

2nd Insurance package: The deductible rate in this package is 30%. With this package, the grape plant is protected from diseases and pests, especially from the risk of spreading and attacking dangerous pests. The risks associated with this package are the risks of spread and attack by plant diseases and pests, especially dangerous pests.

3rd insurance package: The amount of exemption for the third insurance package is 10%. This package protects the Grape plant from the loss of quality caused by hail. Risks associated with the 3rd insurance package: guarantee of loss of product quality as a result of hail risk.

Simply put, the 3rd insurance package protects farmers from the deterioration of the appearance and quality of goods as a result of hail damage to the crop. The fact is that fruit damaged by hail becomes cheaper, and this circumstance causes financial damage to the farmer. The 3rd insurance package is also designed to replace this damage.

The choice of insurance package, depends on the decision of the farmer or vineyard owner. They can be satisfied with the first insurance package only, or they can choose the 2nd and 3rd packages in addition to it. That is, the 2nd and 3rd insurance packages cannot be selected without choosing the basic package.

Insurance rates and premiums required to insure grapes vary depending on the type of grapes, yield, price and selected insurance package, as well as the region of the country.In regions with a lower risk of natural disasters, insurance premiums are lower. However, in areas with a high risk of natural disasters, insurance rates and fees are relatively high.

CONCLUSIONS

In Azerbaijan, which is taking firm steps towards independent development, reforms are being expanded in the agricultural sector, as in other areas of the economy, new economic forms are being created, and new processing and industrial enterprises suitable for the market are created. However, recently, as a result of global climate change and direct human intervention, the flora has been exposed to serious adverse effects. This situation concerns growers closely and requires them to take more precautions.

One of the recent interests of researchers is to develop measures that can be taken against risks arising from different reasons. Most research, however, looks at the risks from climate change and the strategies that vineyard producers can adopt to address such risks. However, it is useful to evaluate the risks from multiple perspectives. Considering the studies done in the world, it will be useful to examine the same issues for Azerbaijan and to apply the same methodologies. In addition, it is useful to address the issues in terms of the wine industry. At the farming level, it is useful to examine producers' decisions at risk and their choices to handle different types of risk, taking into account costs and revenues, including cost-benefit analysis. Depending on the specificity of the country and region, breeders should take measures to address and manage varying risks. It is possible to manage the expected risks with the timely and correct implementation of the aforementioned measures.

Risk management in grape production depends on the values, knowledge, past experience, financial obligations of the growers, and the magnitude of potential gains or losses associated with any particular risk. Success in risk management in grape production depends on strategies to create adequate and effective personnel, control pests and diseases, optimize vineyard root zones, and regulate vine growth, canopy characteristics, and crop levels and quality. Reliable materials, equipment, labor and specialized machinery operations production necessary to minimize risks. Seeking sound know-how, encouraging grape production research, and further training reduce technical risks.

Growers need to carefully assess and manage risks for the economic management of agricultural enterprises. This is particularly important in agriculture, where climate change has led to lower productivity and profitability. Compared with agriculture, industrial sector, man cannot control the whole production process. Biological and climatic factors play a very important role. To mitigate the risks from climate change, insurance policies should be created and the state should intervene with aid to support some of the spending towards farmers' payments. However, despite the positive benefits of adopting insurance policies, growers may not choose to insure because of the cost. To improve the way growers adapt to increasing climate change, insurance contracts should be promoted and competition among insurance companies should be encouraged to guarantee policy cost reductions.

As market risk management strategies, it is possible to list sales and marketing research, creating a diverse customer base, participating in regional promotion efforts, choosing a diversified variety, and making a difference in the grape market with production techniques and methods. In terms of financial risk management, we can list well-designed contracts with various reliable grape customers, creating a certain amount of equity in business assets, using controlled debt, building cash and credit reserves, and establishing close relationships with the lender.

REFERENCES

[1]Akparov, Z., Musayev, M., Mammadov, A., Salimov, V., 2010, Study of the genetic resources of grapevine in Azerbaijan. Agricultural Science in Azerbaijan 1-2:40-44.

[2]Akparov, Z., Musayev, M., 2012, Diversity of the fruit plant genetic resources in the Azerbaijan. Proceedings of the 1st International Symposium on Wild Relatives of Subtropical and Temperate Fruit and Nut Crops, March 19-23, 2011, California-USA, Acta Horticulturae 948:33-40.

[3]Aleinikova, G.Y., 2018, Phenology of grapes in conditions of local climate change (Yalta: Magarach), Viticulture and Winemaking, 3:4-6.

[4]Alekberova, M.M., 2020, Ways to eliminate the effects of adverse environmental conditions on grape plants, intensive horticulture in Azerbaijan, Proceeding of Conference of Achievements, Perspectives, Problems and Solutions, February 21, 2020, Azerbaijan State Agricultural University, Ganja, p. 21-26.

[5]Alekberova, M.M., Aslanova. F.A., 2022, Localization of grape varieties suitable for the natural and economic regions of our republic and the organization of the "sweet conveyor" in viticulture, Proceeding of Conference of the Application of the Science-Teaching-Production Trend in the Development of Priority Production Areas in Horticulture: The Way from Theory to Practice Conference, Ganja, p. 83-85.

[6]Aliyev, Z.H., 2018a, Agriculture in Azerbaijan and its development prospects. Acta Scientific Agriculture 2(8):79-91.

[7]Aliyev, Z.H., 2018b, Irrigated agriculture problems in Azerbaijan and ıts development prospects. International Journal of Medical and Biomedical Studies 2(5):1-6.

[8]Aliyev, Z.H., 2019, Problems of agriculture in Azerbaijan and the prospects of ıts development. Journal of Plant Sciences and Crop Protection 2(1):104-109.

[9]Aliyev, R., Huseynova, T., Musayev, M.,2007, Biodiversity of grapes on the plant resistance to drought and salinity, Proceedings of VIII International Symposium on New and Non- conventional Plants and the Prospect of their Use, Volume II. Moscow-Russia,, p. 33-35.

[10]FAOSTAT, 2023, Production, Trade and Price Statistics, https://www.fao.org/faostat/en/#data/TCL, Accessed on 26 July 2023.

[11]Folwell, R.J., Gebers, B., Wample, R., Aegerter, A., Bales, T., 1997, Production and marketing risks associated with wine grapes in Washington, Washington State Univ., College of Agriculture and Home Economics Research Center.

[12]Franken, J.R., Bacon, K.J., 2014, Organizational structure and operation of the Illinois wine industry.Agricultural and Resource Economics Review 43(1):104-124.

[13]Gulaliyev, M.G., Abasova, S.T., Samedova, E.R., Hamidova, L.A., Valiyeva, S.I., Serttash, L.R., 2019, Assessment of agricultural sustainability (Azerbaijan case). Bulgarian Journal of Agricultural Science 25 (Suppl. 2): 80–89.

[14]Gurbanov, M.R., Salimov,V.S., 2010, Selection of valuable genotypes from populations of the Kishmish pink and Kishmish white grape varieties by clonal breeding in the conditions of Absheron. National Academy of Sciences of Azerbaijan 5:86-94.

[15]Gurbanov, M.R., Salimov, V.S., 2014, Some clonal selection of raisin grapes of Azerbaijan. National Academy of Sciences of Azerbaijan 70(3):70-74.

[16]Hamidova, L., Valiyeva, S., 2020, Current situation and opportunities for increasing grapes and wine exports in Azerbaijan, Proceeding of 55th International Scientific Conference on Economic and Social Development, 18-19 June, 2020, Baku-Azerbaijan, p.354.

[17]Hennen, W., Daane, A., Duijvendijk, K.V., 2017, Global-Detector; GIS- and knowledge-based tool for a global detection of the potential for production, supply and demand, Proceedings of the 3rd International Conference on Geographical Information Systems Theory, Applications and Management; Porto, Portugal, 27-28 April 2017, pp.161-168.

[18]Kocturk, O.M., Engindeniz, S., 2009, Energy and cost analysis of sultana grape growing: A case study of Manisa, west Turkey. African Journal of Agricultural Research 4(10):938-943.

[19]Lybbert, T.J., Magnan, N., Gubler, W.D., 2010, Powdery mildew risk and forecasting in wine grapes: do growers change risk management strategiesin response to disease forecasts? Proceeding of Annual Meeting, July 25–27, 2010, Denver, Colorado (No. 61745). Agricultural and Applied Economics Association.

[20]Maghradze, D., Akparov, Z., Bobokashvili,Z., Musayev, M.,Mammadov, A., 2012, The importance, usage, and prospective of crop wild relatives of fruits, grapevine, and nuts in Georgia and Azerbaijan. Proceedings of the 1st International Symposium on Wild Relatives of Subtropical and Temperate Fruit and Nut Crops., Davis, Califor- nia, USA, March 19-23, 2011., Acta Horticulturae, 33-40.

[21]Menapace, L., Colson, G., Raffaeli, R., 2014, Farmers' climate change risk perceptions: an application of the exchangeability method, EAAE 2014 Congress (Agri-Food and Rural Innovations for Healthier Societies), August 2014.

[22]Musayev, M., Akparov, Z., 2013,Centuries-old results of cultivation and diversity of genetic resources of grapes in Azerbaijan, Chapter 5, The Mediterranean Genetic Code - Grapevine and Olive (Edit: B Sladonja and D Poljuha), IntechOpen, pp.99-123.

[23]Musayev, M.K., Akparov, Z.I., Mammadov, S.H., Kuliyev, V.M., 2015, Results of the study of genetic resources of grapes in Azerbaıjan. Acta Horticulturae 1074:15-22.

[24]Musayev, M.,2014, Biodiversity and breeding of grapes: a study in Azerbaijan. Journal of Crop and Weed 10(1):25-36.

[25]Örmeci Kart, M. C., Gul, M., Karadag Gursoy, A., 2018, Technical efficiency in grape production: A case study of Denizli, Turkey, Scientific Papers series Management, Economic Engineering in Agriculture and Rural Development, 18(4):211-217.
[26]Ponti, L., Gutierrez, A.P., Boggia, A., Neteler, M., 2018, Analysis of grape production in the face of climate change. Climate 6(2):1-15.
[27]Salayeva, S., Decroocq, S., Mariette, S., Akhundova, E., 2010, Comparison of genetic diversity between cultivated and wild grape varieties originating from the Near-Caspian Zone of Azerbaijan. Journal International des Sciences de la Vigne et du Vin. 44(4):191-200.
[28]Salimov, V.S., Sukurov, A.S., Nasibov, H.N., Huseynov, M.E., 2018, Grape: innovative cultivation technology, conservation and agroecology, Teacher's Publishing House, Baku,p.245-250.
[29]Salimov, V.S., Huseynov, M.E., Sukurov, A.S., Nasibov, H.N., 2019, Innovative different technologies and risks in viticulture, Teacher's Publishing House, Baku, p 298-311.
[30]Salimov, V.S., Huseynov, M.E., Huseynova, A., Shukurova, V., Musayeva, E., Najafova, A., Agayev, U., Guliyev, V., 2022, Examination of variability in morphological and biological characteristics of some grape varieties of Azerbaijan. Viticulture Studies. 2(2): 81-93.
[31]Salimov, V.S., 2009, Prospects of accumulation, protection and long-term use of genetic resources of grapes. Agrarian Science of Azerbaijan 6:39-42.
[32]Salimov, V.S.,2011, Determination and study of variations and biotypes in populations of some table grape varieties. Agrarian Science of Azerbaijan 3:31-35.
[33]Salimov, V.S., Gurbanov, M.R., 2012,. The results of long-term research on the accumulation, study, evaluation and use in the selection of the gene pool of grapes of Azerbaijan. News of National Academy of Sciences of Azerbaijan67(1):68-80.
[34]Salimov, V.S., Musayev, M., Asadullayev, R., 2015, Ampelographic characteristics of Azerbaijani local grape varieties. Vitis 54:121-123.
[35]Salimov, V.S., Shukurov, A., Asadullayev, R., 2017, Study of diversity of Azerbaijan local grape varieties basing on OIV ampelographic descriptors. Annals of Agrarian Science 15(3):386-395.
[36]Salk,S.B., Blondel, S., Daniel,C., Crapsky, C.D., Jutard, C., Sejourne, B., 2007, Management of climate risks in the wine sector, Proceeding 101st EAAE Seminar (Management of Climate Risks in Agriculture), July 5–6, 2007, Berlin- Germany.
[37]Seccia, A., Santeramo, F.G., Nardone, G., 2016, Risk management in wine ındustry: a review of the literature, 39th World Congress of Vine and Wine, Vitiviniculture: Technological Advances to Market Challenges, 24-28 October 2016, Bento Gonçalvez-Brazil, BIO Web of Conferences, 7:1-5.
[38]Serifov, F.H., 2013, Viticulture. East-West Publishing House, p.165-359.
[39]Sgroi, F., Sciancalepore, V.D., 2022, Climate change and risk management policies in viticulture. Journal of Agriculture and Food Research 10:1-6.
[40]Shalbuzov, N., Fikretzade, F., Huseyn, A.R., 2020, The international competitiveness of Azerbaijani fruit and vegetable products. Studies in Agricultural Economics 122: 51-55.
[41]Streef, A., 2017, Master plan Azerbaijan: fruit sector assessment, Wageningen Economic Research and Delphy, The Netherlands, 26 p.
[42]The State Statistical Committee of the Republic of Azerbaijan, 2023, Agricultural Statistics, https://www.stat.gov.az, Accessed on 22 July 2023.
[43]The Ministry of Agriculture of the Republic of Azerbaijan, 2023, Viticulture Production Programs, https://www.agro.gov.az, Accessed on 20 July 2023.
[44]Valiyeva, S., 2020, Current situation and development opportunities of the grape and wine export in Azerbaijan. Agricultural Economics 31:85-92.
[45]Vugar, S., Musayev, M., Asadullayev, R., 2015, Ampelographic characteristics of Azerbaijani local grape varieties. Vitis 54:121-123.
[46]Yzarra, W., Sanabria, J., Cáceres, H., Solis, O., Lhomme, J.P., 2015, Impact of climate change on some grapevine varieties grown in Peru for Pisco production. OENO One 49(2):103–112.
[47]Zarneh, S.N., Aminzadeh, B., Dinpanah, G.R., Barzegar, S., 2014, Study of compatibility of grape with East-Azerbaijan climate. International journal of Advanced Biological and Biomedical Research 4(2):192-198.

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HONEY AND THE IMPORTANCE OF HONEY SUPPLY IN SIBIEL VILLAGE, SIBIU COUNTY, ROMANIA

Iuliana ANTONIE[1], Ghizela VONICA[2], Elena Cosmina CAIBAR[1]

[1]"Lucian Blaga" University, The Faculty of Agricultural Sciences, Food Industry and the Protection of the Environment, Sibiu, 7-9 Dr. Ion Raţiu, 550012, Sibiu, Romania, Phone: +40 269 211338, Fax: + 40 269 213381, E-mails: iuliana_antonie@yahoo.com, elena.caibar@ulbsibiu.ro
[2]Natural History Museum, 1st Cetăţii Street, 550160, Sibiu, Romania, Phone: +40269 436 545, Fax: +40 269 211 545, E-mail: aghizela@gmail.com

Corresponding author: iuliana_antonie@yahoo.com

Abstract

For beekeepers, understanding the honey base in their area is crucial to producing quality honey. Placing hives in locations with adequate nectar and pollen sources can lead to honey production with area-specific properties. In addition, knowledge of the honey flora in a certain region can help identifying optimal times for nectar collection. It is also important to monitor and manage the honey flora in order to maintain bee health and ensure the availability of food sources. This research has two objectives: identification of the honey flora in Sibiel village, Sibiu county, Romania and the quality analysis of honey collected from the area. The honey bee flora was analysed according to several classification criteria: botanical, by the type of food provided to the bees, by biological and economic criteria. In the laboratory, the following quality analyses of honey samples from the four hives studied were carried out: acidity index, electrical conductivity, pH and water content determination. The results obtained show that Sibiel has a honey production base that ensures maintenance, development and even production for upcoming years, and that the honey is a natural, high quality product with high chances of certification.

Key words: *honey base, honey quality, Sibiel village, Romania*

INTRODUCTION

Bees fed the gods as well as mortals. They have been admired by everyone, especially scientists, for whom the organisation of the bee family was a model for the organisation of human society. The Greek Herodotus said from the darkness of the Hyperborean lands: "The lands beyond Istru are difficult to penetrate because of the multitude of bees". The "king of kings", Darius, entered in his desire to expand his kingdom. Alexander Macedon also entered in order to impose peace on the rebellious tribes, and then left for his campaign in Asia, from where he returned ten years later in a coffin of honey. Historical accounts state that the diet of the Geto-Dacians consisted mainly of milk, vegetables, fruit and honey [11]. The metopes on the Rome column also confirm these claims.

The honeybee - honey flower relationship is a truly indestructible relationship, essential for natural ecosystems and agricultural production. This binomial, which has a major impact on pollination and plant reproduction, adds, in our era, a third factor: the beekeeper who completes the relationship and enhances the finished product, thus adding the economic and social aspect of beekeeping [1, 2, 3, 4, 5]. In this symbiotic honeybee-flower relationship, the honey plants produce nectar and pollen, essential resources for the bees, and the bees in turn collect the nectar to turn it into honey. The honey base is the primary source of honey and plays a crucial role in determining the quality, taste and nutritional attributes of this important hive product.

The diversity of plants in the hive environment has a major impact on the characteristics of the honey produced.

According to information in the literature, at present, more than 1,000 plant species are identified that provide nectar for bees [7], of which 398 species have been identified in our country, with relevant significance in the field of beekeeping, representing pollen, nectar and manna resources, essential for bee welfare [17]. From a practical point of view, honey plants are distributed in the following categories: plants cultivated for agricultural purposes, fruit trees and shrubs, forest species, as well as plants that provide nectar in meadow and pasture ecosystems [12]. These categories are considered either reliable, accessible sources of nectar and pollen that provide high honey yields, or sources with a role in early harvest or maintenance, all of which result in a wide range of honey assortments. In this context, the purpose of this research is identification of the honey flora in Sibiel village, Sibiu county, Romania and the quality analysis of honey collected from the area. The flora is studied from a botanical, biological and economic point of view. Honey quality was analyzed in the laboratory, assessing acidity index, electrical conductivity, pH and water content.

MATERIALS AND METHODS

Sibiel is a picturesque "touristic village" located in Sibiu county, in the centre of Romania, in the Cindrel Mountains. Known for its traditional charm, rich diversity of flora, including traditional orchards with local varieties of fruit trees, deciduous and coniferous forests and a variety of wild plants, it presents itself as a favourable environment for the development and expansion of beekeeping activity and higher honey production.

Fig. 1. Location of the apiaries in Sibiel village
Source: Google Maps.

The study was carried out in four stationary apiaries (study areas) in the area of Sibiel. The apiaries belong to the families: Săroiu Daniel (Apiary 1), Someșan Maria (Apiary 2) Ciorgodă Sorin (Apiary 3), Moga Ilie (Apiary 4) (Fig. 1). The apiaries are located at an altitude of 575 m.

The investigation period was the entire growing season of 2022. The sample areas in the four apiaries were 10 m x 10 m. The floristic species in each sample were observed, photographed in order to identify and inventory them. Direct, qualitative collections of botanical material were made. It was prepared for transport to the laboratory where it was identified using various bibliographic resources [6, 8, 10, 13, 14, 15, 16, 18]. Honey samples were also taken from the four apiaries in the study. Sampling was carried out with sterilised instruments in clean glass containers that provided adequate protection against contamination, damage and leakage. The containers were labelled and transported to the laboratory of the Faculty of Agricultural Sciences, Food Industry and Environmental Protection, "Lucian Blaga" University of Sibiu for qualitative analyses such as: determination of honey acidity index; determination of honey electrical conductivity; determination of honey pH; determination of water content. The standard norms STAS SR 784-3: 2009 in Romania and 1151/2012 in Europe were respected.

RESULTS AND DISCUSSIONS

Honey is considered the most valuable food available to man. The product, extracted from honeycombs, is made from nectar, which is not only a source of sugar for bees, but also the main factor contributing to the variety and quality of honey. The origin and quality of nectar is essential for the production of high quality honey, and the diversity of nectar sources plays a significant role in the rich and complex range of honey available. Thus, knowledge of the honey resource by beekeepers is important and is considered the key to success in achieving high quality and high production.

Objective 1. In order to support the beekeepers in the area of Sibiel in the efficient management of honey resources, we present a list of the most common species of honey plants in the study area. The identified honeybee species have been organized in alphabetical order, grouped by families and species**:**

Apiaceae: *Daucus carota* L. ssp. sativum (Hoffm.) Arc;
Asteraceae: *Taraxacum officinale* Weber s.l;
Betulaceae: *Corylus avellana* Al.;
Boraginaceae: *Myosotis scorpioides* L.;
Brassicaceae: *Barbarea vulgaris* W.T.Aiton, *Brassica nigra* (L.) Koch;
Convolvulaceae: *Convolvulus arvensis* L.;
Cucurbitaceae: *Bryonia alba* L.;
Fagaceae: *Castanea sativa* Mill.;
Juglandaceae: *Juglans regia* L.;
Lamiaceae: *Clinopodium vulgare* Bentham, *Glechoma hederacea* L., *Lamium album* L., *L. maculatum* L., *Melissa officinalis* L., *Salvia glutinosa* L., *Stachys sylvatica* L.;
Leguminosae: *Lotus corniculatus* L., *L. Pedunculatus* Cav., *Medicago lupulina* L., *M. sativa* L., *Robinia pseudoacacia* L., *Trifolium repens* L., *T. pratense* L., *T. rubens* L., *Vicia hirsute* (L.) Gray, *V. sativa* L., *V. sepium* L., *V. villosa* Roth.;
Malvaceae: *Malva neglecta* Wallr.;
Oleaceae: *Syringa vulgaris* L.;
Papaveraceae: *Chelidonium majus* L.;
Rosaceae: *Cerasus vulgaris* Mill., *Cydonia oblonga* Mill., *Filipendula ulmaria* (L.) Maxim., *Fragaria vesca* L., *F. viridis* Duch., *Malus domestica* Borkh., *Prunus cerasifera* Ehrh., *P. domestica* L., *Pyrus communis* L., *Rosa canina* L., *Rubus caesius* L., *R. idaeus* L.;
Rubiaceae: *Galium verum* L.;
Violaceae: *Viola canina* L.;
Vitaceae: *Vitis vinifera* L.

In order to improve the organization and understanding of honey plants in the area, various classification criteria have been adopted including: botanical, by type of food provided to bees, by biological and economic criteria [8].

1. *Botanical classification*. In the analysed apiaries, located in uncultivated or semi-cultivated gardens in Sibiel, 109 plant species were identified [19], of which 47 species have honeybee potential. Botanically, these plants belong to 18 plant families (Table 1).

Table 1. Numerical and relative abundance of honey species in the 4 apiaries surveyed in Sibiel village in 2022

Nr. crt	Plant family	Numerical size	Relative size (%)
1.	Leguminosae	12	25.59
2.	Rosaceae	12	25.59
3.	Lamiaceae	7	14.89
4.	Brassicaceae	2	4.25
5.	Cucurbitaceae	1	2.12
6.	Fagaceae	1	2.12
7.	Papaveraceae	1	2.12
8.	Convolvulaceae	1	2.12
9.	Betulaceae	1	2.12
10.	Rubiaceae	1	2.12
11.	Juglandaceae	1	2.12
12.	Apiaceae	1	2.12
13.	Malvaceae	1	2.12
14.	Boraginaceae	1	2.12
15.	Oleaceae	1	2.12
16.	Asteraceae	1	2.12
17.	Violaceae	1	2.12
18.	Vitaceae	1	2.12
	Total	47	100

Source: Own calculation.

Based on the information in Table 1, the families Leguminosae and Rosaceae have the largest number of honey species, 12 each, representing 51.18% of the total honey species in the area surveyed. The second place is occupied by the family Lamiaceae, with 7 species (14.89%). The third place belongs to the family Brassicaceae, with 2 species (4.25%). The rest of the families Cucurbitaceae, Fagaceae, Papaveraceae, Convolvulaceae, Betulaceae, Rubiaceae, Juglandaceae, Apiaceae, Malvaceae, Boraginaceae, Oleaceae, Asteraceae, Violaceae, Vitaceae are represented by 1 species each (2.12%).

2. *According to the nature of the food* they provide to bees, several beekeeping groups have been identified:

- nectar-pollinating plants that provide bees with both nectar and pollen. The products are offered to bees from March to the end of October, ensuring the maintenance and development of bee families. Of the 47 honey species identified, the majority, 45 species, fall into this group. The flowers of this category are intensively explored by bees at different hours: *Pyrus communis* L., *Mellissa officinalis* L. are visited at midday, *Taraxacum officinale* Weber s.l. is visited in the hours before midday, and *Trifolium repens* L. provides collections throughout the day. *Trifolium pratense* L., on the other hand, provides abundant secretion to bees only after the second brood, when the flowers are less developed and the bee's proboscis is at that time about the same length as the corolla tube.

- Less common nectar plants provide bees exclusively with nectar. Our research has identified only one taxon in the surveyed area: *Salvia glutinosa* L. Local children are accustomed to plucking the flowers and sucking nectar from the base of the corolla.
- Pollen plants only provide bees with pollen. From this category we cite the representative of the Betulaceae family: *Corylus avellana* Al. The abundance of pollen in spring is an important food resource for bees in the area.

3. In terms of biological and economic classification, the Sibiel honey base comprises the following groups:

Trees and shrubs, also known as forest species, constitute an essential and diversified source of honey resources. The species flower gradually from the beginning of March, when the snow melts, until late autumn. In this category we find specie: Castanea *sativa* Mill., *Corylus avellana* Al., *Juglans regia* L., *Robinia pseudoacacia* L., *Rosa canina* L., *Rubus caesius* L., *R. idaeus* L., *Syringa* vulgaris L. In addition to their economic and forestry relevance and their contribution to the beekeeping industry (by providing nectar and pollen to bees), deciduous species such as *Castanea sativa* Mill., *Corylus avellana* Al. and *Robinia pseudoacacia* L. serve as hosts for some manna-producing insects of the Aphydidae and Lecaniidae families. We note that manna-producing insects on leafy tree species are of limited honey production importance [12], which is reflected in variable manna honey production in the locality.

Wild herbaceous honey plants, including woodland, meadow, roadside and garden plants, which in turn provide significant amounts of nectar and pollen. Of the 32 species identified, the most important are listed below: *Lamium album* L., *Lotus corniculatus* L., *Salvia glutinosa* L., *Taraxacum officinale* Weber s.l, *Trifolium repens* L.

Mellissa officinalis L. has a dual role: it provides nectar collection and is used by beekeepers at the time of flowering to catch the swarm of bees.

Cultivated plants, this category includes fruit trees and shrubs. Tree species, due to their biodiversity and gradual flowering, provide important honey resources for bees in spring when the honey base is poorly represented. Maximum nectar secretion is reached between 7-11 am [12]. We list the fruit species of interest for beekeeping in Sibiel: Cerasus vulgaris Mill., Cydonia oblonga Mill., Malus domestica Borkh., Prunus cerasifera Ehrh., *P. domestica* L., *Pyrus communis* L. They are joined by the shrub *Vitis vinifera* L. whose flowers are searched by bees during the mornings.

According to the economic weight (EAP), the Sibiel honey resources fall into 4 of the 5 categories identified for our country [9].

Table 2. Economic weight of honey plants in the Sibiel area

Crt. No.	EAP	Species
1	M4	*Robinia pseudoacacia* L., *Rubus idaeus* L.
2	M3	*Brassica nigra* (L.) Koch, *Castanea sativa* Mill., *Trifolium repens* L.
3	M2	*Barbarea* vulgaris W.T.Aiton, *Bryonia alba* L., *Clinopodium vulgare* Bentham, *Convolvulus* arvensis L., *Corylus avellana* Al., *Cydonia oblonga* Mill., *Daucus carota* L. ssp. sativum (Hoffm.) Arc, *Filipendula ulmaria* (L.) Maxim., *Fragaria viridis* Duch., *Glechoma hederacea* L., *Lamium album* L., *L. maculatum* L., *Lotus corniculatus* L., Malus domestica Borkh., *Medicago lupulina* L., *M. sativa* L., *Melissa officinalis* L., *Myosotis scorpioides* L., *Prunus cerasifera* Ehrh., *Cerasus vulgaris* Mill., *Prunus domestica* L., *Pyrus communis* L., *Rosa canina* L., *Rubus caesius* L., *Salvia glutinosa* L., *Stachys sylvatica* L., *Taraxacum officinale* Weber s.l, *Trifolium pratense* L., *T. rubens* L., *Vicia villosa* Roth., *V. vativa* L., *V. sepium* L., *Viola canina* L., *Vitis vinifera* L.
4	M1	*Chelidonium majus* L., *Fragaria vesca* L., *Galium verum* L., *Juglans regia* L., *Lotus pedunculatus* Cav., *Malva neglecta* Wallr., *Syringa vulgaris* L., *Vicia hirsute* (L.) Gray,

Surce: [17].

Analysis of the data in Table 2 shows that in the ecosites surveyed, the honeybee species fall into the following groups:

1. Species with a very high apiculture weight (M4) represent 4.26% of the total honey plants identified. They provide important annual production crops.

2. Species with a high beekeeping weight (M3) representing 6.38% of the honey resource and providing regular or annual production harvest.

3. Species with medium beekeeping weight (M2) with the highest representation, 72.34%. The species provide maintenance, development and sometimes production crops.

4. The low beekeeping species (M1), at 17.02%, provide bees with nectar and pollen, but no production crops.

Of economic importance for beekeepers in the area are nectar-pollinated plants in the first three categories, which account for 82.98%, and support significant honey production.

The symbiotic relationship between bees and the plant world is carried out through entomophilous flowers in the hive environment. The amount of honey obtained from flower nectar is directly related to the total amount of nectar produced and the concentration of sugar in the nectar. These complex interactions between bees and plants are essential to obtain quality honey production and underline, once again, the close dependence between bees and the plant world.

Objective 2. Qualitatively speaking, honey is a complex mixture, the components of which vary primarily according to floral origin, weather conditions, storage and extraction methods. Its composition includes sugars, enzymes, organic acids, vitamins, minerals, antioxidant compounds, antibacterial substances, aromatic substances, water [12].

The following data on the quality of Sibiel honey were obtained from analyses carried out in the faculty laboratory:

a. Acidity index of honey. It is influenced by the honey flora of the studied area and provides information about the quality, freshness and preservation of the honey. Determining the honey acidity index involves measuring the amount of 0.1 N sodium hydroxide (NaOH) needed to neutralise the acids present in a given quantity of honey. This process was carried out by titration and using the formula:

$$\text{Acidity index} = v_{NaOH} * c_{NaOH} * 10 \quad (1)$$

where:
v_{NaOH} – volume of NaOH solution used for titration
c_{NaOH} – concentration of NaOH solution

Table 3. Acidity index values for acacia and polyfloral honey from Sibiel

Apiary	**Honey type**	**Acidity Index (mEq)**	**Maximum value, Standard SR 784:3/ 2009**
A1	Acacia	2.78	4
A1	Polyflora	2.82	4
A2	Polyflora	2.93	4
A2	Acacia	2.31	4
A3	Polyflora	2.41	4
A4	Polyflora	1.93	4

Source: Own calculation.

The results obtained are given in Table 3 and show that in Sibiel area, acacia or polyfloral honey has a low acidity index, below the maximum permitted value of 4, which indicates a fresh and good quality honey.**b. The electrical conductivity of honey** refers to its ability to allow electric current to pass through it and is an indirect indicator of honey quality. This is influenced by the content of mineral salts, organic acids and other ionic compounds dissolved in honey.

Table 4. Electrical conductivity values for Sibiel honey

Apiary	Honey type	Electrical conductivity $\mu S \cdot cm^{-1}$
A1	Acacia	1.430
A1	Polyflora	1.150
A2	Polyflora	1.410
A2	Acacia	1.430
A3	Polyflora	1.160
A4	Polyflora	1.120

Source: Own calculation.

As a rule, honey with a higher content of dissolved substances has a higher electrical conductivity. In our research, a conductivity sensor attached to the SPARK LXi2

Datalogger with wireless sensor PS-3210A was used to evaluate the electrical conductivity of honey. The results obtained are shown in Table 4.According to SR 784/3-2009, the electrical conductivity of quality honey ranges from 0.970- 1.430 µS· cm-1. The values obtained from laboratory determinations are within the values of the standard. It results that Sibiel honey is genuine and of high quality, influenced by the type of flowers, the environment and other factors.c.

c. Honey pH refers to the measure of the level of acidity or alkalinity present in honey. pH ranges from 0 to 14, where 7 is considered neutral pH. Values below 7 indicate acidity, while values above 7 indicate alkalinity. Honey pH can fluctuate depending on the type of flowers from which the honey was collected and other variables such as processing and storage.

Honey is slightly acidic, with a pH around 3.9 to 4.5 according to PSR 784-3:2009. Acidity plays an important role in preserving honey and preventing the growth of micro-organisms that could deteriorate its qualities.

In general, honey with a lower pH has better stability over time and attests to its authenticity.

For pH determination in the laboratory, a 5:1 dilution (50 ml distilled water with 10 g honey) was prepared and the pH sensor attached to the SPARK LXi2 Datalogger with wireless sensor PS-3204 was inserted. The values are given in Table 5.

Table 5. pH values of Sibiel honey

Apiary	Honey type	The pH level
A1	Acacia	4,8
A1	Polyflora	4,7
A2	Polyflora	4,8
A2	Acacia	4,7
A3	Polyflora	4,8
A4	Polyflora	4,8

Source: Own calculation

It is found that the pH values of the honey samples from Sibiel are between 4.7- 4.8, which indicates that the honey from the analysed hives is natural.

d. Determination of water content. Honey must have a low water content in order to be considered of good quality and to keep for a long time without problems.

The Abbe-Zeiss refractometer was used to determine the water content of honey. It measures the refractive index which is influenced by the concentration of sugars in honey (Table 6).

Table 6. Water content values of Sibiel honey

Apiary	Honey type	Refractive Index (°Brix)	Water (%)	Dry substance (%)	Density (g/cm^3)
A1	Acacia	1.4896	19.1	80.9	1.4885
A1	Polyflora	1.4910	17.6	82.4	1.4296
A2	Polyflora	1.4785	20.4	76.6	1.3946
A2	Acacia	1.4873	20.1	74.6	1.4580
A3	Polyflora	1.4915	16.8	83.2	1.4310
A4	Polyflora	1.4920	18.9	81.1	1.4930

Source: Own calculation.

According to the standard (STAS SR 784-3: 2009 in Romania and 1151/2012 in Europe), the maximum water content of a quality honey is 20%.

According to Table 6, all honey varieties tested fall within this limit, but honey from hive 2 has a slight risk of fermentation and the taste may be slightly attenuated.

CONCLUSIONS

In the four stationary apiaries in the area of Sibiel, 47 honey species belonging to 18 plant families, both herbaceous and woody, have been identified, constituting an important reservoir of nectar and pollen for bee families, providing important production crops.

The Leguminosae and Rosaceae plant families are the richest in the number of taxa, each with 12, representing half of the identified honeybee base (51.18%).

Of the 47 honeybee species, 45 of them (95.74%) are classified in the nectar-pollinating plant group, which provides the necessary food for the development of bees at different stages, increasing the number of bee families, thus contributing to the expansion of beekeeping activities in the region.

The floristic potential of the area is 82.98% in the first three economically important categories: species with a very high beekeeping weight (4.26%), species with a high beekeeping weight (6.38%) and species with a medium beekeeping weight (72.34%). Following qualitative laboratory analyses, all the honey varieties taken from the hives of Sibiel are natural.

None of the varieties are interfered with by additives or other stimulants, their value being determined by the nectar collected by the bees from the honey plants in the hives.

The results of the analyses carried out compared with the standard quality norms for honey in Romania and Europe confirm that Sibiel honey is a superior quality product.

The preliminary analyses conducted are intended to pave the way for the future certification of Sibiel honey.

In pursuit of this objective, we suggest conducting more comprehensive examinations encompassing pollen, micro and macro elements, heavy metals, as well as pesticides.

Understanding the honey potential of Sibiel beekeepers results in protecting the biodiversity of honey species, encouraging the development of bee farms and producing more varieties of honey.

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REFERENCES

[1]Antonie, I., 2016, Honey resources of Avrig city (Sibiu County) and economic relevance, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 16 (4): 37-41.

[2]Antonie, I., 2017, A mellifer base from Marginimea Sibiului Case study Saliste. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 17 (4): 51-57

[3]Antonie, I., 2018, About the melliferous resources of the Sibiu County. Apoldul de Jos- A case study. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 18 (4): 41-45.

[4]Antonie, I., 2020, The importance of the melliferous flora for the beekeeping in Gura Râului countryside area (Sibiu county), Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 20 (4): 57-63.

[5]Antonie, I., 2021, The melliferous base in the Cisnadioara area, Sibiu County, Romania and its importance in honey production, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 21 (4): 13-17.

[6]Ciocârlan, V., 2000, Illustrated flora of Romania (Flora ilustrată a României), In Romanian.Ceres Publishing House, Bucharest, 116-882.

[7]Cîrlig, N., Lupan, A., Țîțel, V., Guțu, A., Iurcu-Străistaru, E., 2020, Initiation of the foundation of the collection of melliferous plants within the national botanical garden (institute) "Alexandru Ciubotaru" (Inițierea fondării colecției de plante melifere în cadrul grădinii botanice naționale (institut) „Alexandru Ciubotaru"), Journal of Botany, Vol. XII, 2(21): 169-170.

[8]Cîrnu, I., 1989, Honey flora (Flora meliferă), Ceres Publishing House, In Romanian. Bucharest, 31-120.

[9]Eftimescu, M., Berbecel, O., Cîrnu, I., Roman, A. M., 1982, Weather influence on honey production (Influența vremii asupra producției de miere), Ceres Publishing House, In Romanian. București, 56-68.

[10]Grau, M., 2009, Flowering plants during the seasons. Guide to plants in Transylvania (Plante cu flori în decursul anotimpurilor. Ghid al plantelor din Transilvania), Hora Publishing House, Sibiu, 34-152.

[11]Guariti D., 2013, The Honey, (Mierea), the Publishing House, Oradea, p.8.

[12]Mărghitaș, L. Al., 2008, Bees and their products (Albinele și produsele lor), Ceres Publishing House, Bucharest, 238-292.

[13]Pârvu, C., 2002, Encyclopedia of plants. Plants from the Romanian flora (Enciclopedia plantelor. Plante din flora României), Vol. I, Tehnica Publishing House, București, 54-869.

[14]Pârvu, C., 2003, Encyclopedia of plants. Plants from the Romanian flora (Enciclopedia plantelor. Plante din flora României), Vol. II, Tehnica Publishing House, București, 221-660.

[15]Pârvu, C., 2004, Encyclopedia of plants. Plants from the Romanian flora (Enciclopedia plantelor. Plante din flora României), Vol.III, TehnicA Publishing House, București, 47- 773.

[16]Pârvu, C., 2005, Encyclopedia of plants. Plants from the Romanian flora (Enciclopedia plantelor. Plante din flora României), Vol. IV, Tehnica Publishing House, București, 151- 1008.

[17]Pop, I., 1982, Spontaneous and subspontaneous plants with economic value from the flora of R.S. Romania, Botanical Contributions, Botanical Garden (Plante spontane și subspontane cu valoare economică

din flora R.S. România, Contribuții Botanice, Grădina Botanică), Cluj-Napoca, 131-141.

[18]Speta, E., Rákosy L., 2010, Wildpflanzen Siebenbürgens, Plöchl Druck GmbH, Freistad.

[19]Vonica, G., Antonie, I., Stancă-Moise, C., Rusu, R., 2023, Analysis of melliferous flora from Sibiel locality (Sibiu county), Brukenthal. Acta Musei, XVIII, 3: 607-611.

THE ECONOMETRIC ANALYSIS OF THE EXPORTS AND FOREIGN EXCHANGE RATES IMPACT ON WINE PRODUCTION: THE CASE OF ARMENIAN WINE INDUSTRY

Felix H. ARION[1], Karlen KHACHATRYAN[2], Vardan ALEKSANYAN[2], Hovhannes ASATRYAN[3]

[1]University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Department of Economic Sciences, 3-5 Manastur Street, Cluj-Napoca, 400372, Cluj, Romania, Phone/Fax: +40 (264) 596 384 ext. 380; E-mail: felixarion@usamvcluj.ro
[2]Yerevan State University, Faculty of Economics and Management, 1 Alex Manoogian Street, 0009, Yerevan, Armenia, Phones/Fax: +37 460 710 640, +37 491 712 388, E-mails: karlen.khachatryan@ysu.am, vardan.aleqsanyan@gmail.com
[4]Institute of Economics Named after M. Kotanyan, National Academy of Sciences of the Republic of Armenia, 15 Grigor Lusavorich Street, 0015, Yerevan, Armenia, Phone/Fax: +37 477 011 297; Email: hov97hov@gmail.com

Corresponding author: hov97hov@gmail.com

Abstract

This article uncovers relationships between the wine export and production in Armenia. Wine industry is a strategically important economic sector in Armenian. The importance of its development is strongly supported by the fact that alcoholic beverages from grape processing are products with high customs value exported from Armenia (in 2020 the share of alcoholic beverages in the entire export structure was about 8.4%). Within the framework of this study, a detailed analysis of the wine production was performed. By applying econometric analysis, we assessed the impact that the increase of wine export has on wine production. Also, the empirical analysis of the impact of USD and RUB exchange rates on wine industry was performed. Overall, the econometric analysis indicated that export volumes and USD exchange rate significantly affect Armenian wine industry. This study provides enough evidence for us to conclude that the export of Armenian wine must be heavily promoted by Government policies and the same time the export directions must be diversified. The results of this study can be basis for scientific substantiation of sectorial strategies developed by the Government of Armenia.

Key words*: *winemaking, viticulture, commodity exports, quantitative analysis, statistics

INTRODUCTION

Scannell [28] observed that, in Armenia, the winemaking is one of the iconic economic sectors. Wine is one of the most popular alcoholic drinks in Armenia. Besides large-scale, traditional wineries there are many small wine producers, which produce wine not only from grapes but also from various fruits. Also, it is emphasized the fact that winemaking is a closed related with the history of Armenia, where struggle for survival was a constant.

It can be stated that winemaking in Armenia has a very long history. It was practiced there more than 6,000 years ago. According to National Geographic [23], the oldest winery in the world dates back to 6100 years ago and is located in the village of Areni, Republic of Armenia (RA). Viticulture and winemaking gained industrial importance in RA starting from the 20th century. Around 1920, the private farms of the Soviet Republic of Armenia were dissolved and integrated into the wine trust called "Ararat wine trust". Then in the scope of this trust a net of wine processing farms was created within Russia and Ukraine [17]. The further development of viticulture and connected economic branches was damaged due to the anti-hard-drinks "Prohibition Laws" introduced in 1985. The fight against hard drinking caused a destruction of a large area of vineyards including old and young vineyards. During the final decade of the Soviet period, viticulture development and the planning of winemaking regulation were carried out by the Ministry of Agriculture and the Ministry of Food Industry [28]. According to experts' estimations, due to the anti-hard-drinks policy, the wine and vodka production volumes were reduced 12-13 times, the champagne wines production volumes decreased 3-5 times, while the brandy production suffered a 4-5 times reduction in volume [16].

According to Hanf [17], the winemaking sector registered a moderate expansion at the beginning of the new millennium However, brandy manufacturing was primarily the sector's main driver. The majority of the grapes grown in Armenia are converted into brandy. According to USAID [16], Armenian brandy accounts for a significant portion of the country's exports, which account for 80% of its "processed exports".

During early 2000-s the sector started to grow slowly. However the main driver of the sector was mainly brandy production. Around 90% of the grapes produced in Armenia are processed to brandy. The Armenian brandy is of worldwide high reputation and has great shares of the exports that make 80% of the 'processed exports' [35].

On the same trend as brandy and wine sectors' development, grape producing too recorded some growth in gross grape output, which is due to higher yield per hectare [6]. The higher yields were mainly provided thanks to improvement of cultivation processes, usage of new agriculture machinery, the increased use of technology, but not only. It is noteworthy, though, that grape production in Armenia cannot be definitely described as steadily developing. The dynamics of the indicator of vineyard areas has an oscillating nature over past 30 years. This means that grape growers stop producing grape, demolish their vineyards, and then start to producing wine again. So, there is a gap between the development of grape production and wine production [5]. As the head of the Union of Winemakers of the RA Avag Harutyunyan awareness, in the country is to be expected a shortage of grapes due the fact that the development of the winemaking sector is faster that the development of viticulture [19].

Marquardt and Hanf [18] studied the development of the Armenian wine and brandy business and the influence that foreign investors have taken in this development concluding that wine production and consumption have increased since the start of the economic and financial crisis. Also, they affirm that the level of industry competitiveness has increased, which has improved product quality, but, in the same time, as the rivalry increased, so did innovation and the use of new technology in the industry. They estimate that the wine and brandy industry receive a higher amount of foreign direct investment (FDI) than other agricultural and agro-processing industries, and Armenian diaspora investors account for the majority of these investments. Finally, they observed that wine producers employ both trust-based contracts and contracts that are revised annually for the purchase of grapes.

So basically, several researchers agree in that record that the grape sales to the wineries are regulated either by oral agreements or contracts based on trust [17, 10].

The main finding from studies [10] on the Armenian wine market is that there are some peculiarities, including low levels of competition on the domestic market, the absence of substitute products as a threat to the domestic wine industry, and low bargaining power of grape growers relative to other suppliers (technology, machinery, etc.) and high bargaining power of other suppliers relative to wine producers.

Despite the steady growth of the wine making in Armenia there are also some obstacles that hinder the capacity of wine producers in achieving higher sales volumes and quality excellence. According to surveys carried out among Armenian wine producers [36] such obstacles are: need for financial means, lack of technical solutions availability, unpredictability of legislative and tax on field, lack of skilled labor, and, finally, barriers to entry into the market.

There are problems in macro level too. For example, the lack of appropriate branding of Armenian wines is major issue that must be addressed. Armenia has a large potential of having its own unique wine brand, with its long and rich history. That is why state regulation and marketing strategy in wine industry must have crucial role in coming years [3].

Literature review

The increase of export volumes of Armenian wine provides favorable environment for further development and expansion of wine industry. The relationships between export and GDP growth, productivity, efficiency is constant topic for studies. Many scholars have addressed the impact that export can have on production development of any kind of product. In economic literature this is described as export-led growth hypothesis. Many studies support the relevance of this hypothesis for different countries. For example, the trajectories of economic growth of Bangladesh, Jordan, Chilly, Brazil, India, Republic of South Africa, sub-Saharan Africa countries are examples of export-led growth [14, 4, 1, 29, 26].

It was revealed that both outward-oriented and inward-oriented economies benefit from export-led growth [38]. The economies of East Asian countries are well known examples that represent the economic miracles that export-oriented economy can achieve [20].

It is important to note that export-led growth hypothesis has its limits, because some studies show that developed countries are less impacted from export-led growth, and this hypothesis is more descriptive for fast developing countries [39]. The researches of Thangavelu and Rajaguru [32] further solidify the notion that export has bigger impact on productivity growth in developing countries that in developed ones. For example, among the East Asian countries, only Singapore has experienced export-led productivity growth over the long-run. The rest of studied countries (Hong Kong, Indonesia, Japan, Thailand and Taiwan) shifted to import-led productivity growth over long-run.

Exporting and productivity levels have positive correlation in US manufacturing sector. But in this case, it is export that is conditioned by productivity and only then the other way around. So basically, high productive companies are more likely to enter foreign markets and export, and then exporting level increase will result the growth of productivity [8]. Studies show that companies which are export-oriented display a higher level of productivity that those which are domestic-market oriented. Both Pack [24] and Aw [7] support the idea that between the companies that sell similar products the ones that are exporters have higher level of productivity than those sell primarily in domestic markets. Similar patterns are found in sub-Saharan Africa [37]. Exporters of sub-Saharan Africa show higher productivity levels than domestically oriented firms. African exporters improve their economics performance after entering foreign markets.

Export plays as a driving force for adopting innovations and further insertion of newest technologies. In France particularly, the studies show that export has a more positive effect on innovation in high productivity firms, whereas it may negatively affect innovation in low productivity firms [2]. Bustos [12] states the research' results suggests that increased export opportunities may enhance company performance.

So, in one hand export-conditioned revenue growth provides ground for investing in new technologies and in the other hand expanding of export leads to an increase of farms economics performance. This situation can play in other way round as in case of Germany manufacturing firms. Firms with good economic performance in Germany most certainly become exporters [9]. German exporters are larger, more capital-intensive, and more productive than non-exporters. Studies carried out amongst Romanian wine firms revealed that profitability of wine makers is positively impacted by exports and a high level of exports is associated with better financial performance [21]. Similarly in Chinese firms the growth of export brings the increase of productivity, sales and return on assets [25].

So, the situation with exports and economic performance can be described as double-aged sword, where better performance is a major precondition for export and export leads further enhancing of economic performance.

These two economic phenomena are interconnected and condition each other.

Thus, literature findings provide evidence that export is one of the main economic conditions that can positively affect on further development of Armenian wine industry. Armenia is a developing country with lots of potential in wine industry that can be translated into steady growth and expansion in foreign markets. So, we state the importance of increase of exporting of Armenian wines. Studies carried out by native researchers also justify this approach. According to the product mapping method, alcoholic beverages (wine, brandy etc.) are classified in group A, which means these products have a competitive advantage in international trade and provide a flow of foreign currency to the Republic of Armenia [22].

In this context, the purpose of the paper to assess the impact of the increase in wine export on wine production using an econometric analysis and also to evaluate the impact of USD and RUB exchange rates on wine industry.

MATERIALS AND METHODS

Data collection

Data for our study is provided by Statistical committee of the RA, from the publications “Main Indicators of Industrial Organizations by Economic Activities (five-digit code), for January-December (Armenian)” (2001-2021) [30]. These publications provide data about wine production volumes, number of employees in winemaking companies.

Monthly values of exports of wine and countries of exports were retrieved from the UN Comrade Database [34].

The data of monthly average exchange rates were retrieved from Exchange rates archive of Central Bank of Armenia [13].

Methodological aspects

The impact of changes in real exports (net weight) and foreign exchange rates (USD, EUR, RUB) on the wine production was estimated using monthly data spanning from June 2016 to December 2021 and by utilizing the ordinary least squares (OLS) estimation method. The original dataset included 67 observations.

The data seasonality was adjusted using the Moving average method, and then took the natural log of all variables of interest.

The Augmented Dickey-Fuller test was performed on the variables and the evidence on non-stationarity was found. So, to solve the problem we took the first difference.

After testing the existence of multicollinearity and it was found that there is multicollinearity problem between USD and EUR.

The correlation among USD and EUR was rather high; therefore, EUR was excluded as a variable and left only USD.

Then, it was estimated the following equation (1) by incorporating lagged variables using the OLS method.

$$DLPORDWSAt = \alpha 0 + \alpha 1 * DLEXPWSAt + \alpha 2 * DLEXRDt\text{-}3 + \alpha 3 * DLEXRRt + \varepsilon t \quad ....(1)$$

where:

DLPORDWSAt is the value of the wine production in period t (first difference of logged value).

DLEXPWSAt is the value of the wine exports (first difference of logged value).

DLEXRDt-3 is the value of the USD exchange rate in period t-3 (first difference of logged value).

DLEXRRt is the value of the RUB exchange rate in period t (first difference of logged value).

α0, α1, α2, α3 are model unknown parameters.

εt is the error term in period t.

The test to check the evidence of autocorrelation was performed, and included respective orders (AR – that involves regressing the variable on its own lagged and MA – that involves modeling the error term as a linear combination of error terms occurring contemporaneously and at various times in the pas) processes to deal with the problem.

It was not found the evidence of heteroscedasticity.

The residuals are distributed normally, and no specification error was identified.

RESULTS AND DISCUSSIONS

Current State of Armenian Wine Industry

The development of winemaking in the Republic of Armenia is supported by such strategic documents as "Republic of Armenia 2014-2025 Strategic Program of Prospective Development" [27] and "The Strategy of Export-Led Industrial Policy of Republic of Armenia" [33].

Winemaking in the Republic of Armenia is a type of activity subject to notification; that notification procedure is regulated by relevant legislative documents. No license is required to produce wine, just state registration is done and state annual fee of 25,000 AMD is paid, which is equivalent of 60.15 USD.

The wine in Armenia is mainly produced by large companies, which do the grape processing and further manufacturing processes. Of course, there are many households that produce wine at home, but they do not play a significant role in the market, as they have very small production volumes and are on an amateur level. But at a same time, especially in Tavush and Vayoc Dzor regions, small households produce more wine than in the rest of regions, and this strongly decreases the commodity levels of wine grape [31].

Armenian wine industry is described as oligopolistic, as only a few wine producers dominate the market and industry rivalry is low due to expanding market capacity. At the same time the entry barriers for new competitors are low. The Armenian wine market is increasing in size; this leads to an increase in attractiveness of market and creates a high threat of new entrants [11].

There is no common, unified approach to the purchase of raw materials in the field of winemaking. Some manufacturers carry out the process on the basis of pre-signed contracts. Many people have a verbal agreement when the grape growers just know that they will sell the grapes in a specific factory after the harvest. There is also no common approach to pricing raw materials. Payments are usually made within three business days of purchase, usually non-cash. Contracts often do not have a purchase price, sometimes just a minimum price. There are many cases when the prices are reduced by the wine producers during the actual procurement, even below the minimum price specified in the contract. Grape growers have no choice but to agree to such procurement conditions. In some years, when an unprecedented grape harvest was registered, the purchasers took advantage of the situation and drastically worsened the procurement conditions: price reduction, quality deductions from the payment amount, concessions in the weight of purchased grapes to the detriment of grape growers, delays in payments for purchased grapes, unreasonable delays, etc. All the listed activities have a very negative impact on the development of viticulture. Such actions by procurement companies create a state of uncertainty, in which case farmers interested in viticulture do not decide whether to engage in such activities or not. So basically, the bargaining power of grape suppliers is low and as wine producers purchase grapes from many suppliers, they are not dependent on a specific farmer and it makes bargaining power of wine producers greater [11].

Despite the similar problems, it should be noted that the practice of concluding contracts is developing year by year. This is mutually beneficial for both suppliers and growers.

Over the past decade, the number of wine companies has increased significantly from 21 to 31 (Table 1).

Table 1. The number of winemaking organizations and its employees in 2010-2021

Indicator / Year	Number of organizations	Number of employees
2010	21	453
2011	22	549
2012	21	956
2013	21	824
2014	24	888
2015	25	706
2016	25	713
2017	29	847
2018	36	1,029
2019	40	1,090
2020	40	1,002
2021	31	1,023

Source: Statistical committee of the RA, from the publications "Main Indicators of Industrial Organizations by Economic Activities (five-digit code), for January-December (Armenian)" (2001-2021) [30].

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As shown in Table 1, the average list of industrial staff has become more than doubled (if in 2010 this figure was only 453 people, in 2020 it reached 1,002). Such a situation reflects an increase in the level of economic activity in the wine industry

The development trend of the wine industry is positive. Wine production volumes increased by 87.6% in 2021 compared to 2001. The same picture was observed in terms of exports. The growth of exports has higher temps: compared to 2001, wine exports in 2021 increased by 95.4%. It should be noted that until 2015, including the volume of wine production, exports also had a downward trend, and in some years recorded a negative growth.

However, since 2016, wine production and exports have grown steadily. At the same time, it should be noted that even in 2020, in the conditions of the coronavirus pandemic the development of the industry was not disrupted. The current situation is logically supplemented by the increase in the number of wineries and the number of employees.

Armenian wines are sold both in domestic and in foreign markets. More than 50% of produced wines are purchased in domestic market and the export volumes are still behind domestic sales (Table 2).

Table 2. The structure of wine exports from Armenia

Rank	2017	2018	2019	2020	2021
1st	Russia 79.7 %	Russia 69.9 %	Russia 68.3 %	Russia 54.6 %	Russia 46.0 %
2nd	US, 5.1 %	US, 8.9 %	US, 8.9 %	US, 13.3 %	US, 17.2 %
3rd	China 1.1 %	Switzerland 2.3 %	China 2.1 %	Ukraine 4.4 %	Ukraine 6.0 %
4th	Lithuania 1.0 %	France, 2.0 %	France, 2.0 %	Belgium 3.7 %	Switzerland 4.6 %
5th	Switzerland 1.0 %	Italy 1.6 %	Switzerland 1.6 %	Switzerland, 2.8 %	France 3.2 %

Note: this table does not include the share of exports of countries identified as non-recognized territories.
Source: Author's own calculations based on the data from [34].

Russia has the largest share in the structure of wine exports. In other words, Armenian wines are mainly sold in Russia. However, compared to 2017, the share of Russia in the structure of exports in 2021 has significantly decreased from 79.9% to 46%. This situation is not due to the reduction of total wine exports, but to the increase of specific weights in the structure of exports. Anyway, such changes in export structure indicate the intensification of export diversification. Such dependence from exports to Russia bears very dangerous economic consequences. Because of such undiversified wine export approach, economic shocks happening in the Russia can directly affect Armenian wine exports. For example, the devaluation of the RUB back in 2014 resulted in a large decrease of Armenian wine exports (up to − 40% in one year) [15]. The United States is the second largest exporter in terms of exports, with the share of exports in this area increased from 5.1% to 17.2%. Other countries that have a significant share in the structure of exports are China, Switzerland, France, Ukraine and Belgium. It is very likely that the diversification of export directions will deepen along with the increase of export volumes.

Increasing exports to different countries diversifies potential risks, reduces the dependence of wine exports on the economic situation of different countries, fluctuations in exchange rates. The latter has a positive effect on the sustainable development of wine industry.

Thus, summarizing the dynamics of the indicators characterizing the RA wine industry, we prove that the industry has a tendency of sustainable development. Production volumes and export volumes have increased. The structure of exports has improved and the number of companies involved in the industry has increased. In other words, the branch contributes to the increase of the general economic activity of the Republic of Armenia, as it will also have a positive impact on the development of viticulture.

Taking into account the fact that the increase of export volumes can have a significant impact on the further development of winemaking in Armenia and the domestic market of the Republic of Armenia is limited; the increase of the production volumes of the sphere can be imagined only in the context of the continuous increase of the export. Also, it is very important to take into account the impact that exchange rates of USD, EUR and RUB can have on Armenian wine industry.

That is why we consider it relevant to develop an econometric assessment of the situation.

The impact of exports on wine production based on the econometric analysis

Regarding the wine exports it is observed that an increase in the exports of wine by 10% could cause a 2% statistically significant increase in the wine production. This further solidifies the notion that exports have positive impact on production growth (Table 3).

Table 3. Estimated Model

Dependent variable: DLPORDWSAt	**Estimation 1: Sample: 2016M06 2021M12**
$DLEXPWSA_t$	**0.205124** (2.367980)**
DLEXRDt-3	**4.239482** (2.649571)**
DLEXRRt	0.381426 (0.639690)
Constant	0.005986 (0.954094)
AR(1)	-0.805680 (-8.210657)***
MA(2)	-0.581020 (-4.026717)***
R-squared	0.399162
Adjusted R-squared Included Observations	0.349913 67

Note: value of t statistics in parentheses. ** significant at 5%; *** significant at 1%.
Source: Authors' own calculations.

Impact of USD and RUB exchange rates on wine industry

On the exchange rate of USD, it is shown that depreciation of the AMD against the USD lagged 3 periods by 1% could cause a 4.2% statistically significant increase in wine production. This situation is not only conditioned by the fact that second largest share in wine exports is the US market, but also by the fact that large sum of foreign monetary transactions of Armenian wine producers are performed by USD. During last couple of months USD depreciated against AMD created difficulties for Armenian exporters. The dram appreciation and the dollar depreciation in Armenia are affecting exporters as the contracts for export are mostly signed in USD.

The incomes of Armenian exporters, including winemakers that export, suffer from the drop of USD's exchange rate. Armenian experts insist that Central bank of Armenia must pay special attention to USD depreciation and adjust its monetary policy in a way that will lower the negative effects of AMD appreciation on exporters. This situation not only includes wine industry but Armenian economy as a whole.

Analyzing of the exchange rate of RUB, we found that the changes in RUB exchange rate do not have statistically significant impact on Armenian wine production. The value of t-Statistics indicates that the impact of DLEXRRt on dependent variable is not statistically significant. These results contradict the situation of the 2014, when the devaluation of the RUB resulted in a large decrease of Armenian wine exports. This is partially due the fact that in comparison to 2014 when Russia had lion's share in export structure RUB devaluation had a very strong negative impact on Armenian wine industry.

Adjusted R-squared has a value of 0.349913, which means that independent variables included in our model describe the variation of dependent variable by nearly 35%.

The change of wine production volumes in Armenia are conditioned by export volumes, USD and RUB rate fluctuations by nearly 35%, the other 65% is described by other variables which are not included in our study, namely the domestic demand (as the major market). One of those main variables is domestic consumption volumes, because as we mentioned above, more than half of Armenian wines is purchased within domestic market, hence the export volumes have relatively little impact in overall performance.

As a result of the studies carried out within the framework of the research, it became clear that winemaking is one of the most important and rapidly developing branches of the RA economy. Over the past ten years, the volume of wine production in RA has registered an increasing trend, the number of winemaking organizations and the annual average number of employees in them has increased.

In addition, the work productivity of winemaking organizations has also increased, that is wine producing companies' economic performance has been improved. The lion's share of the produced wine is sold in the domestic markets. However, over the past ten years, a significant increase in the volume of wine exports has been recorded. The main export destinations of wine from Armenia are Russia, USA, China etc.

As mentioned before, researchers who studied Armenian wine industry, conclude that wine industry is rapidly and steadily developing, while the Armenian wine has a potential of expansion in foreign markets.

At a same time, wine industry has some obstacles on its path of development that must be addressed. The lack of wine grape varieties, weak legal regulation, and scarcity of financial means for producers are crucial points that must be studied and solved. In our estimation the further development of wine industry must be ensured by increasing exports.

Many foreign researchers support the export-led growth hypothesis, which ensures the economic growth by the further increase of exports and expansions in foreign markets. Armenian wines are the kind of domestic products that have competitive advantage in international markets and provide a flow of foreign currency to the RA.

So, all these findings provide enough ground for us to conclude that the main driving force behind wine industry development must be the export growth. Taking into account the importance of the effect of export on the volume of wine production, an econometric analysis was carried out, as a result of which it became clear that an increase in the volume of wine export by 10 % leads to an increase in the volume of production by 2 %. But the highlight of the research was the fact that USD rate changes have greater impact on wine production. 1% appreciation of USD leads to an increase in wine production with 4.2% after three months.

This is very important conjuncture that Armenian Government and industry representatives must take into account. We suggest that wine industry further development must not only be ensured by export promoting policies but also special attention must be paid to the monetary policy regarding USD exchange rate. Specifically, the Central Bank of Armenia must lead the kind of monetary policy that will soften possible negative effects of USD depreciation, because export promotion is pointless if the exchange rates fluctuations jeopardize exporters' incomes.

CONCLUSIONS

In general, it can be stated that winemaking in RA has a great potential for further development. The increase of the production volumes is already an objective reality, but the further growth must be provided by increasing export.

So, we recommend the state regulation policies that are export-oriented and the introduction of foreign wine production experiences in terms of solving marketing and sales issues in RA wine industry. The countries neighboring Georgia, France, USA and many other countries have their own approaches to winemaking. Therefore, we suggest that as a result of combining these different approaches and experiences in RA, a single Armenian wine-making culture must be formed, which will become the business card of Armenian wines in international markets.

Wine tourism is another topic of discussion in the context of wine industry development. In par with winemaking sector development wine tourism also has developed quite a bit in RA, but official statistics are still missing in this regard, so we could not give precise assessment in that regard. Therefore, we cannot make any concrete analyses.

Various wine festivals and similar events are held in RA, but it is desirable that they be supported at the governmental level and an attempt is made to ensure the participation of well-known foreign winemaking brands. This is very important for increasing the visibility of Armenian wine in foreign markets and further enhancing exports.

REFERENCES

[1] Abual-Foul, B., 2004, Testing the export-led growth hypothesis: evidence from Jordan. Applied Economics Letters, 11(6), 393-396. Doi: 10.1080/1350485042000228268.
[2]Aghion, Ph., Bergeaud, A., Lequien, M., Melitz, M. J., 2018, The Impact of Exports on Innovation: Theory and Evidence. Banque de France Working Paper No. 678, http://dx.doi.org/10.2139/ssrn.3171084.
[3]Aleksanyan, V., Aleksanyan, I., 2019, The analysis of alcoholic beverages exporting mechanisms in the republic of Armenia, The Bulletin of Eurasia international university, (1), 93-102. (In Armenian).
[4]Al Mamun, K. A., Nath, H. K., 2005, Export-led growth in Bangladesh: a time series analysis. Applied Economics Letters, 12(6), 361-364. Doi: 10.1080/13504850500068194.
[5]Asatryan, H. S., 2022, The nature of correlation between production factors and viticulture development of Armenia, Journal of The contemporary issues of socioeconomic development in the Republic of Armenia, (1), 235-251.
[6]Avetisyan, S., 2010, Agriculture and food processing in Armenia, Yerevan, Armenia, Limush Publishing House. (In Armenian).
[7]Aw, B.-Y., Hwang, A. R., 1995, Productivity and the export market: A firm-level analysis. Journal of Development Economics, 47(2), 313–332. Doi: 10.1016/0304-3878(94)00062-h
[8]Bernard, A. B., Jensen, J. B., 1999, Exporting and Productivity, NBER Working Paper No: 7135, Cambridge, MA. http://dx.doi.org/10.2139/ssrn.167569
[9]Bernard, A. B., Wagner, J., 1997, Exports and success in German manufacturing. Weltwirtschaftliches Archiv, 133(1), 134–157. Doi:10.1007/bf02707680.
[10]Bitsch, L., 2017, A structural analysis of the Armenian wine industry: elaboration of strategies for the domestic market. Master Thesis, Justus-Liebig-Universität/Hochschule Geisenheim University, Gießen/ Geisenheim, http://icare.am/Publications/Master-Thesis_Linda-Bitsch_Publication-ICARE%20(1).pdf, Accessed on 25/07/2023.
[11]Bitsch, L., Richter, B. Hanf, J. H., 2022, The competitive landscape in transitioning countries: the example of the Armenian wine industry. Wine Economics and Policy, 11(1), 31-45. https://doi.org/10.36253/wep-10657
[12]Bustos, P., 2011, Trade Liberalization, Exports, and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms. American Economic Review, 101(1), 304–340. doi:10.1257/aer.101.1.304.
[13]Central Bank of Armenia, 2023, https://www.cba.am/en/sitepages/pmessagesannouncements.aspx, Accessed on 25/06/2023.
[14]Ee, C.Y., 2016, Export-led Growth Hypothesis: Empirical Evidence from Selected Sub-saharan African Countries. Procedia Economics and Finance, (35), 232-240, Doi: 10.1016/s2212-5671(16)00029-0
[15]Ghvanidze S., Bitsch L., Hanf J., Svanidze M., 2020, The Cradle of Wine Civilization—Current Developments in the Wine Industry of the Caucasus. Caucasus Analytical Digest. (117). 9 - 15. DOI: 10.3929/ethz-b-000442947
[16]Grigoryan, K. A., 2000, Issues of grape production, processing economics and marketing in the transitional phase of reforms. Yerevan, Armenia. Sponsoring body. (In Armenian).
[17]Hanf, J., Marquardt, V., Urutyan, V., Babayan, A., 2016, The impact of foreign direct investment on the agribusiness of transition countries: The example of the Armenian wine business. International Journal of Business and Globalization 16 (4), 423–447. 10.1504/IJBG.2016.076813.
[18]Hanf, J. H., Marquardt, V., 2012, Armenian wine business and its interplay with foreign influence, Journal of Applied Management and Investments, 1(4), 406-417.
[19]Hovhannisyan, A., 2019, Expert: Viticulture in Armenia is inferior to winemaking in terms of development. In Financial Portal, November 11 2019 21:23, available on line https://finport.am/full_news.php?id=39993&lang=3, Accessed on 26/07/2023.
[20] Krueger, A. O., 1997, Trade Policy and Economic Development: How We Learn, American Economic Review, 87(1), 1-22. https://EconPapers.repec.org/RePEc:aea:aecrev:v:87:y:1997:i:1:p:1-22, Accessed on 25/07/2023.
[21]Lessoua, A., Mutascu, M., Turcu, C., 2020, Firm Performance and Exports: Evidence from the Romanian Wine Industry. Journal of Wine Economics, 15(2), 207–228. https://doi.org/10.1017/jwe.2020.
[22]Makaryan, A.R., 2018, The choice of industries for export promotion and priorities of the labor policy in the republic of Armenia. Proceedings of the conference. 66-79. (In Armenian)
[23]Owen, J., 2002, Earliest Known Winery Found in Armenian Cave. In National Geographic News 2011, 1/12/2011. https://www.nationalgeographic.com/culture/article/110111-oldest-wine-press-making-winery-armenia-science-ucla, Accessed on 25/07/2023.
[24]Pack, H., 1988, Industrialization and trade, in: H. Chenery, Srinivasan, T.N., eds., Handbook of development economics, Vol. 1. Amsterdam, Elsevier Science Publishers.

[25] Park, A., Yang, D., Shi, X., Jiang, Y., 2010, Exporting and firm performance: Chinese exporters and the Asian financial crisis. Review of Economics and Statistics, 92, 822–842. Doi: 10.2307/40985797

[26]Rani, R., Kumar, N., 2018, Is There an Export- or Import-led Growth in BRICS Countries? An Empirical Investigation. Jindal Journal of Business Research, 7(1), 13-23. Doi: 10.1177/2278682118761748.

[27]Republic of Armenia 2014-2025 Strategic Program of Prospective Development. Republic of Armenia Government, Tbilisi, 2014.

[28]Scannell, N. J., Newton, J. G., Ohanian, R., 2002, Viticulture, Wine Production, and Agriculture in Armenia: Economic Sectors in Transition, Journal of Applied Business Research (JABR), 18(4). Doi: 10.19030/jabr.v18i4.2125.

[29]Siliverstoys, B., Herzer, D., 2006, Export-led growth hypothesis: evidence for Chile. Applied Economics Letters, 13(5), 319-324. Doi: 10.1080/13504850500407293.

[30]Statistical Committee of the Republic of Armenia, 2023, Main Indicators of Industrial Organizations by Economic Activities (five-digit code), for January-December (Armenian) (2001-2021). https://www.armstat.am/en/?nid=81&id=2356, Accessed on 20.07.2023.

[31]Tamoyan, H., 2019, Vayots Dzor marz natural-economics state and convenience for viticulture Development. Alternative Quarterly Journal. (2). 165-173. (In Armenian).

[32]Thangavelu, S. M., Rajaguru, G., 2004, Is there an export or import-led productivity growth in rapidly developing Asian countries? a multivariate VAR analysis. Applied Economics, 36(10), 1083–1093. Doi: 10.1080/0003684042000246795

[33]The Strategy of Export-Led Industrial Policy of Republic of Armenia. Ministry of Economy. Republic of Armenia Government, Tbilisi, 2011.

[34]UN Comtrade Database, 2023, https://comtrade.un.org/data, Accessed on 25/06/2023.

[35]United States Agency for International Development (USAID), 2010. Rapid Assessment of Value Chain Opportunities in Armenia.

[36]Urutyan, V., Yeritsyan, A., 2015, Assessment of training needs of winemakers and management systems of the wineries in Armenia. BIO Web of Conferences. 5. 03005. 10.1051/bioconf/20150503005.

[37]Van Biesebroeck, J., 2005, Exporting raises productivity in sub-Saharan African manufacturing firms. Journal of International Economics. 67(2), 373–391. Doi:10.1016/j.jinteco.2004.12.002

[38]Xu, Z., 1996, On the Causality between Export Growth and GDP Growth: An Empirical Reinvestigation," Review of International Economics, Wiley Blackwell, Vol. 4(2), 172-184, June.

[39]Yamada, H., 1998, A note on the causality between export and productivity. Economics Letters, 61(1), 111–114. Doi: 10.1016/s0165-1765(98)00154-2

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IMPACT OF SURFACE IRRIGATION MANAGEMENT ON WHEAT YIELD AND QUALITY PARAMETERS IN EGYPT

Tarek Mahmoud ATTAFY, Mohamed Sobhy KHATAB, Nermeen Mohammed TOLBA

Institute of Agricultural Engineering, Agricultural Research Center, Dokki District, Giza Governorate, Egypt, Phones: 00201027367157, 00201063098195, 01015749022; E-mails: tarek.attafy@yahoo.com, eng_khatab10@yahoo.com, nermenafk@gmail.com

Corresponding author: tarek.attafy@yahoo.com

Abstract

This research was conducted at El-Gemmeiza Agricultural Research Station, Gharbia Governorate, middle of the Nile Delta, Egypt, during the winter seasons of 2021/2022 and 2022/2023 to determine the effect of different bed-furrow irrigation management strategies on irrigation efficiency, wheat grain yield and its components and quality parameters. The field experiment was designed in RCBD and included: basin-flooding (control, Tf) and bed-furrow with three irrigation times as a percentage of advance time (Ta); T1=Ta,T2=1.20Ta, and T3=1.30Ta. The results revealed that; increasing irrigation time had a simple effect on the Ta while had an obvious effect on the depletion and recession time. The T1 saved 23.3% of irrigation water compared to the Tf, increasing irrigation time increased water applied. The soil moisture content in the Tf was higher than in the bed-furrow treatments. Increasing irrigation time increased the moisture content in the furrows and within the beds. Bed-furrow enhanced irrigation efficiency compared to Tf. The highest application efficiency and distribution uniformity values were 76.6, 74.7 and 80.7, 82.3%, which were achieved by T3 treatment. Bed-furrow increased wheat grain yield compared to Tf. The T3 treatment is superior in grain yield with values of 3107 and 3185 kg fed^{-1}.Bed-furrow enhanced the 1000 grain weight and spike length, while Tf surpassed in the number of spikes and straw yield. The highest water productivity was 1.87 and 1.67 kg m^{-3} achieved by T1. There is no significant difference in quality parameters except for dry gluten, the highest values achieved by T2 treatment.

Key words: *bed-furrow, storage phase, irrigation efficiency, wheat*

INTRODUCTION

Choosing an appropriate irrigation method has a vital role in crops production and the sustainability of water resources. Since water has become one of the most significant elements in crop production, it should be utilized efficiently to provide the optimum yield [1]. Furrow irrigation is a common method of irrigating crops in developing countries; it is particularly recommended for cultivating row crops in soils of medium to heavy texture, and it is favored over the flooding method because of its ease of use and low capital cost [8]. In this regard, the basin-flooding irrigation method (F) for wheat in the Nile Delta in Egypt causes excessive application losses and encourages water logging, while the bed-furrow irrigation method commonly defined as raised beds (B) improves irrigation efficiencies and wheat productivity [11, 20, 24]. Replacing the (F) method with the (B) method is considered one of the innovative solutions to address water scarcity in Egypt. Furrow irrigation is recommended in clay soil and is preferred over flooding irrigation method because it saves irrigation water and raises wheat grain yield [18] The optimum management of the furrows under bed sowing should ensure good lateral movement of the irrigation water to the bed center for getting a proper grain yield and water productivity, the lateral movement of irrigation water to the bed center is one of the main determinants of bed width [4]. Suboptimal bed width causes insufficient lateral movement of irrigation water to its center, resulting in poor crop germination and water productivity [3]. Wide beds have advantages in that they reduce drainage losses, crop productive area losses, and irrigation water saving, however, the wide beds are defective with poor lateral infiltration and, thus, poor yield for rows in the middle.

Therefore, optimal irrigation practices such as over irrigation of the beds in the initial growing stages are essential to encourage lateral infiltration. However, due to a lack of knowledge and the absence of appropriate guidelines, such management has been uncommon in field conditions to date [2, 5]. A comprehensive understanding of how wheat responds to irrigation timing encourages better management of the irrigation system, enhancing positive effects and minimizing unfavorable effects on grain yield and quality [25]**.** As indicated by [6], many researchers divided the surface irrigation process into four phases: Tad, advance; Ts, storage or wetting; Td, depletion; and Tr, recession. Advance phase refers to the movement of the water stream from the upstream end of the field towards the downstream end; this phase is complete once the water stream reaches the field's downstream end. The storage phase begins after the water has reached the downstream end, as the flow continues to collect in the field. The storage phase ends when the inflow is cut off, after which the depletion phase occurs and remains until the surface waters disappear at the upstream end. The recession phase occurs when surface water disappears from the upstream end and finishes when no irrigation water remains on the soil surface. The [10] referred to the behavior of some quality traits under deficit irrigation: gluten, kernel hardness, and falling number decreased while protein content increased. The proper combination of irrigation practices and genotypes is necessary to produce winter wheat with adequate grain yield and quality indices. According to many researchers, such as [13] increased protein and wet gluten content are obtained under full irrigation, while others, such as [21] found the opposite. Irrigation water regime had a significant effect on grain yield, protein content, and grain hardness, reducing the irrigation regime from 100 to 30% of ETc decreased grain yield and increased protein content; the raise in protein content was most likely a function of grain yield shortage resulting from water stress [23]**.** The applied irrigation strategy is a determinant factor in identifying wheat grain quality [15]. The impact of four irrigation regimes (I1=25%, I2= 50%, and I3= 75%) on the maximum allowable depletion of available soil moisture and I4 = 4 events in the four growth stages on wheat grain quality was investigated in sandy loam soil under semi-arid conditions. The hectoliter weight, protein content, and wet and dry gluten content were significantly affected by irrigation regimes, while grain hardness non significantly affected. The highest hectoliter weight was 81.5 kg/hL for treatment I1, the highest protein and wet and dry gluten content were 13.4 and 34.0, and 11.79 %,respectively, which were obtained by I3 treatment. The highest grain hardness was 83.26%, found by I3 treatment [19]**.** The differences in grain quality among sixteen wheat genotypes under stress and full irrigation were evaluated. A significant reduction in 1,000-grain weight (g) and hectoliter (kg/hL) caused by water stress, while protein and gluten contents (%) increased at the same conditions [21]. Therefore, the purpose of this study was to improve the irrigation performance, wheat grain yield, and quality traits of the bed-furrow irrigation method and to identify the optimal strategies for this.

MATERIALS AND METHODS

Field description

A field experiment was carried out in El-Gemmeiza Agricultural Research Station, Gharbia Governorate, middle of the Nile Delta, Egypt, during the winter growing seasons 2021/2022 and 2022/2023. The site was located at 31° 07´ longitude, 30° 43´ latitude, and 20 m mean altitude above sea level. Some climatic data, such as maximum and minimum air temperatures; T, wind speed; WS, relative humidity; RH, and monthly total rainfall, mm for growing seasons recorded by the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research center, Table 1.

Soil samples from three layers (0-20, 20-40 and 40-60 cm) were collected from three sites of the experimental field. The soil was characterized as clay, the mechanical analysis and some physical properties were analyzed by the Soils, Water and Environmental Research Institute Laboratory, El-Gemmeiza Agricultural Research Station, Table 2.

Table 1. Meteorological data for the experimental site during the two growing seasons

Month	T_{mini},°C	$T_{max,}$ °C	RH, %	WS m/sec	Rainfall mm
First season 2021/2022					
Nov.	16.5	28.7	66.1	2.2	6.3
Dec.	10.9	20.3	71.6	2.6	12.0
Jan.	7.0	17.6	71.2	2.5	26.2
Feb.	8.0	19.9	70.1	2.3	20.8
Mar.	8.2	20.8	65.3	2.8	22.8
Apr.	13.2	30.8	56.2	2.9	0.7
Second season 2022/2023					
Nov.	15.4	26.8	60.5	2.2	3.2
Dec.	13.1	24.2	67.2	2.1	23.5
Jan.	10.2	21.7	69.2	2.1	6.4
Feb.	8.8	20.7	61.5	2.5	7.2
Mar.	12.4	27.0	52.1	2.9	15.7
Apr.	13.9	30.1	50.0	2.9	2.3

Source: Central Laboratory for Agricultural Climate (CLAC), Agricultural Research center, Egypt.

Table 2. Mechanical analysis of the experiment site

Soil depth, cm	Particle size distribution			Bd, g/cm^3	FC, %	PWP, %
	Clay, %	Sand, %	Silt, %			
0-20	50.67	14.52	34.81	1.10	45.60	24.30
20-40	53.09	11.00	35.9	1.15	40.90	21.55
40-60	52.76	10.63	36.61	1.34	38.20	19.80

Bd: Bulk density, FC: Field capacity, PWP: Permanent wilting point
Source: Own calculation.

The field was prepared using the traditional seed bed preparation method (Chiseling twice + traditional leveling). Wheat (variety Giza 171) was drilled at a distance of 15 cm between rows in November and harvested in May; the field length is 50 m without dikes and with a closed end. For bed treatments; the beds were raised at a distance of 130 cm between beds with a 100 cm net bed width. Furrow dimensions were top width 30 cm, bottom width 10 cm and depth 15 cm. All agricultural practices have been applied. Wheat was irrigated 4 irrigations in the season (planting + 3 irrigations; an event at every growing stage) as recommended by [12].

Irrigation system

Perforated pipes network were used for irrigation, it consists of aluminum pipes with 75 mm diameter and 6 m length joined together by quick coupler. The orifices were distributed at a distance equal to the distance between furrows (130 cm).The discharge rate was controlled by 32 mm valve and male adaptor (32 X 3/4") installed at every orifice by a saddle (75 X 32 mm). A centrifugal pump with 3" inlet and outlet diameters was used to transfer the water to the pipes. The discharge rate was calibrated at 1.0 L s^{-1}. Discharge rate was measured by the volumetric method as explained by [17].

Experimental design

Four treatments with three replicates were arranged in a randomized complete block design in the two growing seasons: a control treatment viz basin-flooding irrigation method (Tf) and bed-furrow irrigation method with three irrigation patterns: irrigation to the end of the furrow (irrigation time = advance phase; T1), irrigation to the end of the furrow + storage phase equal 20% of advance time (irrigation time = 1.20 advance phase; T2) and irrigation to the end of the furrow + storage phase equal 30% of advance time (irrigation time = 1.30 advance phase; T3). Each replication included five furrows and four beds. The Co-Stat program for windows was utilized to analysis of variance (ANOVA), the mean of results for different treatments were compared at the 5% significance level.

Measurements

Inlet flow rate, irrigation phases and water applied: The orifices flow rate was calibrated at 1.0 L s^{-1} per furrow for bed-furrow treatments and per 1.3 m width in Tf treatment (2.77 m^2 h^{-1} discharge rate per unit width). The advance time (Tad) along the field was recorded at 10 stations (each 5 m). The storage time (Ts) as a percentage of the Tad according to every treatment was recorded. After irrigation cut-off the depletion time (Td) and the recession time (Tr) along the field at the same 10 stations were recorded. Applied irrigation water per event was measured as well as the seasonal water applied. The Tad and Tras the function of the furrow length (L) were formatted in an empirical power equations [22] as follows:

$T_{ad} = a\, L^m$ .... (1)

$T_r = c\, L^x$ .... (2)

where:
a and m are empirical advance coefficients, and c and x are empirical recession coefficients.

Soil moisture content: It was measured gravimetrically at three depths (0-20, 20-40 and 40-60) cm at the furrow center, and bed center. The soil samples were collected every 10 m along the field prior to irrigation and at field capacity. The soil moisture content was calculated using Eq. 1 according to [27]:

$$\theta_m = (M_w/M_d) * 100 \quad (3)$$

In which: θ_m is soil moisture content on a dry mass basis (%), M_w is mass of water within the soil sample (g) and M_d is dry mass of dry soil (g).

Application efficiency (Ea, %): it indicates the beneficial utilization percentage of the water applied. It is calculated by Eq. 4 according to [17].

$$E_a = (RZ/\forall) * 100 \quad (4)$$

where:
RZ is amount of water stored in the root zone and ∀ is total water applied.

Distribution uniformity (DU, %): It describes how precisely the system distributes water evenly along the field. DU is defined as low quarter distribution uniformity and calculated by Eq. 5 according to [17].

$$DU = \left(x^{\backslash}_{LQ}/x^{\backslash}\right) * 100 \quad (5)$$

where:
$x^{\backslash}_{LQ}$is low-quarter average depth infiltrated and $x^{\backslash}$ is average depth infiltrated.

Wheat grain yield, its components, and straw yield: At harvesting, wheat grain yield; kg fed^{-1}, some yield components include 1,000 grain weight; g, spike length; cm, and number of spikes m^{-2} and the straw yield; kg fed^{-1} were calculated.

Water productivity (WP, kg m^{-3}): It shows the change in crop yield related to irrigation management strategies. It calculated according to [17] as follows:

$$WP = \frac{Total\ grain\ yield, kg/ha.}{Total\ applied\ irrigation\ water, m^3/ha.} \quad (4)$$

Quality parameters

After harvesting the second season (2022/2023), random grain samples were collected from each treatment to assess quality parameters performed in the Food Technology department, faculty of agricultural Kafr El-Sheikh University and Rice Mechanization Center (RMC) Laboratory, Meet El-Deyba, Kafr El-Sheikh Governorate, Egypt. Test weight or hectoliter mass (HLM, kg 100L^{-1}) defines the grain's bulk density and indicates the potential percentage of milling extraction. It is an important wheat grading factor [9] and some cultivars might have the ability to always have higher HLM than others grown under similar conditions. A higher HLM indicates a well-filled wheat grain.HLM was obtained by filling a 100 ml measuring cylinder with wheat grain, weighing it, and expressing it in kg 100L^{-1} [7]. Kernel hardness refers to the ability of a kernel to resist breaking under pressure and directly affects the yield of flour. It was measured using a digital grain hardness tester (Model: AGW).The protein is the most important component of wheat grain ranged from 8 to 15% on weight basis. it is a reference index for evaluating the high quality of strong gluten wheat. It depends on genetic and environmental factors [14]. The protein percentage (%) had been determined using the Kjeldahl method, as defined by [7], Method 46-13, and the factor 5.7 to convert the nitrogen value in to total protein. The protein concentration in wheat grain depends on genetic and environmental factors [14]. Wet gluten percentage (%) was evaluated using the hand-washing method (AACC 38-10.01), and dry gluten percentage (%) was produced after oven-drying the dough at 105 °C for 6 hours [7]. The falling number (FN) value expresses the speed required to move a hot aqueous starch gel subjected to liquefaction at a constant temperature of 100°C in a viscometer and then let the viscometer initiator fall a certain distance via the gel [7].

RESULTS AND DISCUSSIONS

Irrigation phases

The data showed that Tf treatment had a longer advance compared to bed-furrow treatments, where the average Tad was 164 min for Tf treatment, this finding is in agreement with many researchers as [2]. The average irrigation phases for the two growing seasons and the three events per season for the bed-furrow treatments are shown in Fig. 1.The (Tad) for the three treatments T1, T2, and T3 were 100, 98 and 95 min, respectively. This means the existence of the storage phase had a simple effect on the advance time, possibly because the effect of the storage phase began with the third event and was more pronounced with the last event; on the contrary, it had an obvious effect on the depletion and recession time. The T1 treatment recorded a 13 min depletion time Td and a 90 min recession time Tr, the presence of 20% storage time Ts in the T2 treatment, increased Td and Tr by about 53.8 and 50.0%, respectively. In the T3 treatment, where Ts = 30% Tad, The depletion time Td and recession time Tr recorded 25 and 170 min respectively which increased by about 92.3 and 88.9 %, respectively compared to the T1 treatment. The empirical power equations for advance and recession phases for the three bed-furrow treatments described as follow:

T1:-

$$Tad = 0.25\, L^{2.57} \qquad R2 = 0.95$$

$$Tr = 102.3\, L^{0.26} \qquad R2 = 0.92$$

T2:-

$$Tad = 0.37\, L^{2.54} \qquad R2 = 0.90$$

$$Tr = 121.7\, L^{0.30} \qquad R2 = 0.91$$

T3:-

$$Tad = 0.09\, L^{3.16} \qquad R2 = 0.84$$

$$Tr = 133.6\, L^{0.32} \qquad R2 = 0.91$$

Water applied

Water applied per event for different treatments for the two growing seasons (m3/fed.) is shown in Fig 2. In planting irrigation; bed-furrow irrigation treatments consumed irrigation water more than basin-flooding irrigation treatment (Tf) by about 36.7 and 23.3% for the two growing seasons, respectively.

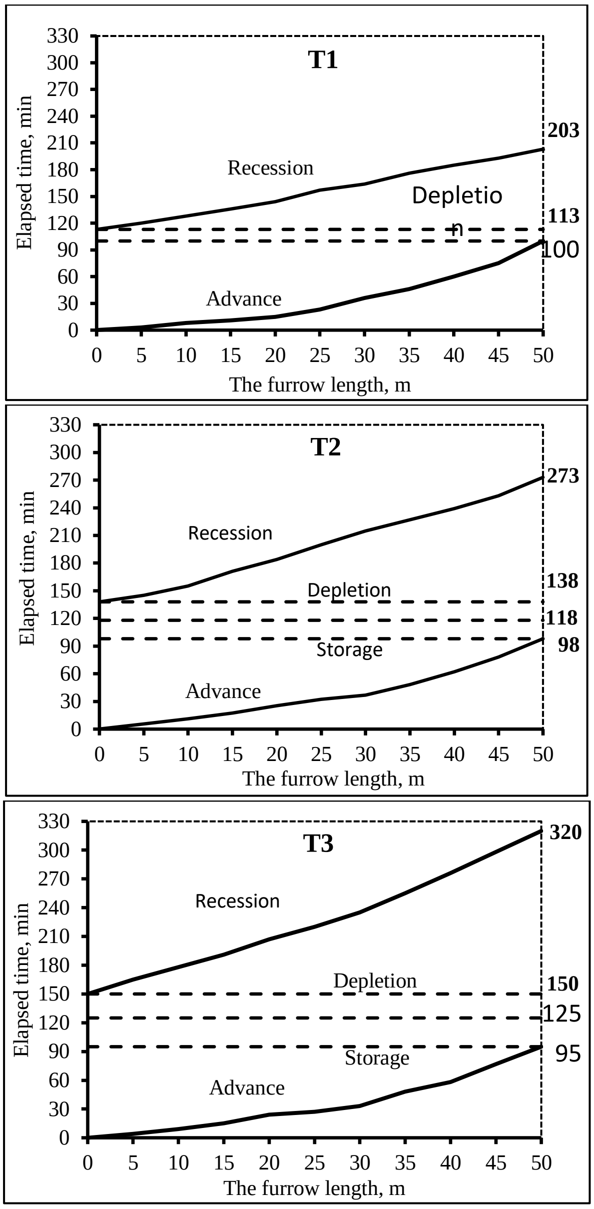

Fig. 1. Surface irrigation phases for bed-furrow treatments
Source: Own calculation based on experimental data.

This finding could be attributed to that in the Tf treatment, the irrigation water advanced directly above the soil surface from the upper to the lower end of the field, and irrigation was stopped (advance phase only), while in bed-furrow irrigation water was transported along the furrows (advance phase), then continued (storage/filling phase) until the beds were completely submerged with irrigation water to promote optimal seed germination. Inbed-furrow, the advance phase accounted for 20% of total irrigation time, while the storage/filling phase accounted for 80%. For the subsequent irrigations, (Tf) utilized more irrigation water than bed-furrow treatments, where the whole field is irrigated; also, increasing the plant growth and density creates an obstacle to the advancement of water in the field, while in bed-furrow the soil is partially irrigated through paths prepared for this. Increasing the storage phase in the bed-furrow treatments increased the amount of the water applied. Water applied for each event increased compared to the previous event; increasing air temperature and weed growth in the furrows had an impact on bed-furrow treatments. The amount of water applied was influenced by the variation in rainfall throughout the two growing seasons.

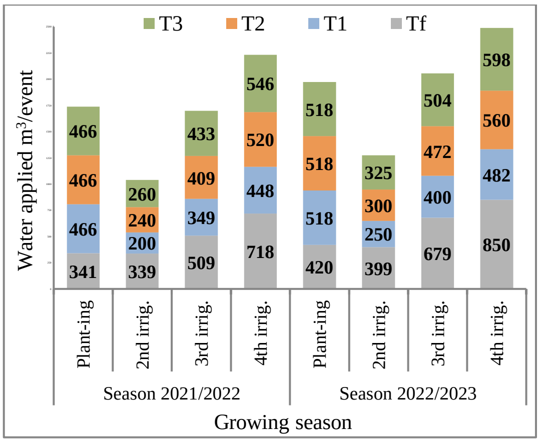

Fig. 2. Water applied per event during the two growing seasons.
Source: Own calculation based on experimental data.

The average seasonal water applied (m^3/fed.) for the different treatments are listed in Table 3. The results showed that there was a highly significant difference in the total water applied between the different irrigation treatments. Bed-furrow treatments T1, T2, and T3 saved irrigation water compared to Tf treatment by about 23.3, 14.3 and 10.5 % and 29.7, 21.2 and 17.1 %, for the two growing seasons, respectively.

This result is consistent with that obtained by several researchers [5, 18]. The application of 20 and 30 % storage phase in the T2 and T3 treatments increased the water applied by about 12.1 and 17.9 % compared to the T1 treatment.

Table 3. Average seasonal water applied for the different treatments.

Treatment	Water applied, m^3 fed^{-1}	
	2021/2022	2022/2023
Tf	1907 a	2347 a
T1	1463 c	1650 c
T2	1634 b	1850 b
T3	1706 b	1945 b
LSD 0.05	92.0	146.0

Means followed by the same letter in the same column are not significantly different at the $p \leq 0.05$ level.
fed. = 4,200 m^2
Source: Own calculation based on experimental data.

Soil moisture content

The averages of soil moisture content in the bed center and furrow bottom at field capacity are showed in Fig. 3. The results revealed that the soil moisture content in the Tf treatment was higher than in the bed-furrow treatments, where the soil was completely submerged with water, as well as fewer evaporation losses from the soil surface due to the high density of plants. The moisture content of the Tf treatment exceeded the field capacity, which means an increase in irrigation water loss and a decrease in irrigation efficiency. For the bed-furrow treatments, the existence of storage time had a positive effect on the moisture content in the furrows and within the beds. The storage phase promotes the lateral movement of the irrigation water and thus raises the moisture content within the beds. The moisture content in the surface layer (0-20) cm in the furrow increased from 38.6% for T1 to 39.8% for T2 and 42.2% for T3 and increased in the center of the bed from 35.5% for T1 to 37.7% for T2 and 39.3% for T3. The same trend is observed for the subsequent two layers.

Application efficiency (Ea, %) and distribution uniformity (DU, %)

The average application efficiency (Ea, %) and distribution uniformity (DU, %) for the different treatments are listed in Table 4. The statistical analysis showed a significant effect of irrigation treatments on application efficiency and distribution uniformity at a 95% probability level.

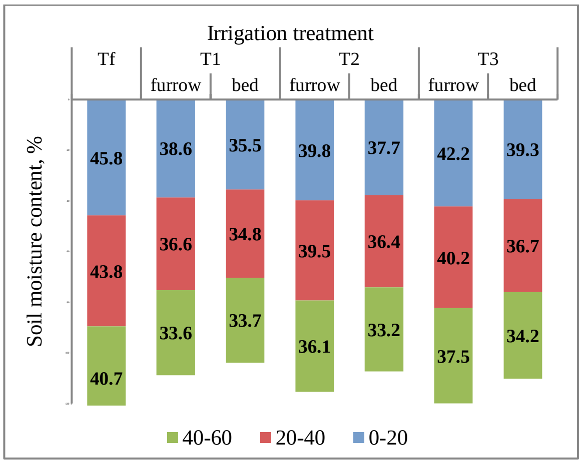

Fig. 3. Soil moisture content in the bed center and furrow bottom at field capacity
Source: Own calculation based on experimental data.

Table 4. Average application efficiency and distribution uniformity for different treatments

Treat.	Ea, %		DU, %	
	2021/022	2022/023	2021/022	2022/023
Tf	64.7 b	60.0 c	69.2 c	70.5 c
T1	71.7 a	66.6 b	73.3bc	75.2bc
T2	72.8 a	69.5 b	77.9 ab	77.5 ab
T3	76.6 a	74.7 a	80.7 a	82.3 a
LSD 0.05	5.3	4.9	5.5	5.6

Source: Own calculation based on experimental data.

Bed-furrow treatments enhanced the Ea and DU compared to flat sowing in the two growing seasons; the same results were obtained by [2]. The existence of the storage phase had a positive effect on the Ea and DU where stored water increased. The highest Ea values for the two growing seasons were 76.6 and 74.7% for treatment T3 followed by 72.8 and 69.5% for treatment T2; while Tf gave the lowest values of 64.7 and 60.6%. It was observed that there is no significant difference in the Ea values between bed-furrow treatments in the first season. The T3 treatment achieved the highest DU with values of 80.7 and 82.3% followed by the T2 treatment with values of 77.9 and 77.5% while the Tf treatment gave the lowest values of 69.2 and 70.5%. There is no significant difference in the value of DU between treatments T3 and T2 and between treatments T2 and T1.

Wheat grain yield

The averages wheat grain yield for different treatments are listed in Table 5.The analysis of variance indicated that irrigation treatment had a significant effect on wheat grain yield at the 95% probability level. Raised bed increased wheat grain yield compared to flat sowing in the two growing seasons; the same findings were obtained by [3, 5]. Bed-furrow treatments T1, T2 and T3 increased wheat grain yield compared to Tf treatment by about 22.6, 27.1 and 39.3 % and 13.8, 15.5 and 31.6 % for the two growing seasons, respectively. Increasing the storage phase leads to an increase in wheat grain yield where the lateral infiltration in the middle zone of the bed is enhanced. The T3 treatment is superior in grain yield compared to the other treatments. It achieved 3,107 and 3,185 kg fed^{-1} for the two growing seasons, respectively.

Table 5. Average wheat grain yield for different treatments

Treat.	Grain yield, kg fed^{-1}		Water productivity, kg m^{-3}	
	2021/022	2022/023	2021/022	2022/023
Tf	2,230 b	2,421 b	1.17 b	1.03 b
T1	2,734 a	2,755 a	1.87 a	1.67 a
T2	2,835 a	2,796 a	1.74 a	1.51 a
T3	3,107 a	3,185 a	1.82 a	1.64 a
LSD 0.05	501.0	627.0	0.44	0.39

Means followed by the same letter in the same column are not significantly different at the $p \leq 0.05$ level.
fed. = 4,200 m^2
Source: Own calculation based on experimental data.

Yield components and straw yield

The averages for some yield components, including the 1,000 grain weight; g, spike length; cm, and the number of spikes m^{-2} and straw yield; kg fed^{-1} for different treatments, are listed in Table 6. The statistical analysis showed a significant effect of irrigation treatments on the 1,000 grain weight, spike length, and straw yield in the first season, while there was no significant effect on the number of spikes m^{-2} and straw yield in the second season. The results showed that bed-furrow irrigation enhanced the 1,000 grain weight and spike length while, basin-flooding irrigation surpassed in the number of spikes and straw yield. The superiority of basin-flooding in the number of spikes m^{-2} and straw yield is due to the fact that, in basin-flooding irrigation, the field is cultivated completely since there are no area losses due to furrows, as in bed-furrow irrigation. The existence of the storage phase enhanced the yield components and straw yield. There is no significant difference in the 1,000 grain weight between bed-furrow treatments, and the highest value was 72.5 and 80.0 g for the two growing seasons, which was achieved by the T3 treatment. The difference in spike length between bed-furrow treatments was significant in the first growing season only; the highest values were 13.0 and 13.2 cm for the two growing seasons achieved by T3 treatment. The highest number of spikes in the first growing season was 237 spikes m^{-2} achieved by the T3 treatment, followed by T2 and Tf with a value of 225 spikes m^{-2}, while the highest number of spikes in the second growing season was 271 and 270 spikes m^{-2} achieved by the Tf and T3 treatments, followed by T2 with a value of 263 spikes m^{-2}.The highest straw yield was achieved by the Tf treatment with values of 3,641 and 3,130 kg fed-1 for the two growing seasons respectively, followed by 3,062 kg fed-1 for the T3 treatment in the first season and 3,130 kg fed-1 for the T2 treatment in the second season.

Table 6. Average yield components and straw yield for different treatments.

Treatment	1,000 grain weight; g		Spike length; cm		Number of spikes m^{-2}		Straw yield; kg fed^{-1}	
	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023	2021/2022	2022/2023
Tf	52.3 b	60.0 b	11.0 c	11.2 b	225	271	3,641 a	3,130
T1	59.5 a	67.5 a	11.7 b	12.3 a	217	233	2,847 b	2,878
T2	72.5 a	68.8 a	12.0 b	12.8 a	225	263	2,796 b	3,130
T3	72.5 a	80.0 a	13.0 a	13.2 a	237	270	3,062 b	3,124
LSD 0.05	19.60 *	14.30 *	0.47 *	1.08 *	37.6 ns	68.9 ns	328.5 *	446 ns

Means followed by the same letter in the same column are not significantly different at the $p \leq 0.05$ level.
*, ns significant and not significantly different at the $p \leq 0.05$ level.
fed. = 4200 m^2
Source: Own calculation based on experimental data.

Water productivity

The averages of water productivity for different treatments are listed in Table 7. The analysis of variance indicated that irrigation treatment had a significant effect on water productivity at a 95% probability level. Raised beds enhanced water productivity compared to flat sowing; many findings fixed that [3, 18]. The T1 treatment achieved the highest water productivity with values of 1.87 and 1.67 kg m^{-3} for the two seasons, respectively, followed by the T3 treatment with values of 1.82 and 1.64 kg m^{-3}. The lowest water productivity was obtained by the Tf treatment with values of 1.17 and 1.03 kg m^{-3} for the two seasons, respectively. The existence of a 20% storage phase decreased water productivity because the water applied increased but was not matched by a corresponding increase in grain yield.

Quality parameters

Wheat grain quality parameters, including hectoliter mass (HLM, kg $100L^{-1}$), Kernel hardness (kg), protein percentage (%), wet and dry gluten percentage (%), and falling number (FN, sec.) for the second season are shown in Table (7). The statistical analysis showed that the irrigation treatments had no significant effect on the quality parameters except for dry gluten. The obtained HLM values ranged from 68.30 to 72.50 kg $100L^{-1}$ without significant differences between treatments. The HLM of normally wheat is between 70 to 85 kg hL^{-1}, but can be altered due to environmental conditions, damage due to insects, water and temperature stress, and nutrient deficiency [26]. The protein concentration was influenced by the availability of water during the growing season. Wheat having high protein content tends to be hard, has strong gluten, and produces good quality bread. The positive correlations between protein content and hardness were reported by [16]. Grains with higher protein content tended to be harder, which results in higher water absorption [14]. The Tf treatment gave the lowest values of HLM and FN, while T1 gave the lowest values of Hardness and wet gluten. The T2 treatment achieved the highest quality parameters.

Table 7. Average quality parameters for different treatments.

Treat	HLM	Hard--ness	Protein	Gluten %		FN
				wet	dry	
Tf	68.3	6.0	13.6	27.4	9.4 b	431
T1	72.5	5.9	13.6	27.3	9.3 b	435
T2	72.5	6.51	13.8	27.8	11.1a	453
T3	71.2	6.3	13.7	27.7	10.7a	446
LSD 0.05	8.1 ns	0.7 ns	1.2 ns	3.2 ns	1.2 *	50.9 ns

Means followed by the same letter in the same column are not significantly different at the $p \leq 0.05$ level.
*, ns significant and not significant at the $p \leq 0.05$.
fed. = 4200 m^2
Source: Own calculation based on experimental data.

CONCLUSIONS

Depending on the results obtained, the bed-furrow irrigation system saved irrigation water and improved the wheat grain yield at the same time. The presence of a storage phase leads to an improvement in water application efficiency and distribution uniformity. The application of the storage phase by 30% increased the wheat grain yield, while the application of the storage phase by 20% increased the water productivity and grain quality parameters. The application of the storage phase is considered a successful irrigation management strategy to enhance bed-furrow irrigation efficiency and raise wheat grain yield and quality parameters.

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REFERENCES

[1]Ahmad, R.N., Mahmood, N., 2005, Impact of Raised Bed Technology on Water Productivity and Lodging of Wheat, Pakistan Journal Water Research, 9: 7-15.
[2]Akbar, G., Ahmad, M.M., Khan, M., Asif, M., 2017, Furrow lateral wetting potential for optimizing bed width in silty clay, Irrigation and Drainage, 66: 218–226.
[3]Akbar, G., Hamilton, G., Raine, S., 2010, Permanent raised bed configurations and renovation methods affect crop performance, Paper presented at the 19th World Congress on Soil Science, Brisbane, Australia (1-6 August 2010).
[4]Akbar, G., Hamilton, G., Hussain, Z., Yasin, M., 2007, Problems and potentials of permanent raised bed cropping systems in Pakistan, Pakistan Journal of Water Resources, 11: 11–21.
[5]Akbar, G., Raine, S., McHugh, A., Hamilton, G., 2015, Managing lateral infiltration on wide beds in clay and sandy clay loam using Hydrus 2D', Irrigation Science, Vol. 33(3): 177-90. https://doi.org/10.1007/s00271-014-0458-9.
[6]Amer, A.M., Amer, K.H., 2010, Surface irrigation management in relation to water infiltration and distribution in soils, Soil and Water Research, Vol. 5(3): 75-87.
[7]American Association of Cereal Chemists (AACC), 2005, Approved methods of the AACC, 11th ed. Method 38-12A., St Paul, Minnesota, USA.
[8]Bedane, H., Tadese, A., Genemo, G., Mekonnen, E., 2021, Effect of furrow dimensions on yield and water productivity of maize in Sibu Sire district, Eastern Wollega, Ethiopia, Irrigation and Drainage Systems Engineering, Vol. 10(2): 254-258.
[9]Donelson, J.R., Gaines, C.S., Andrews, L.C., Finney, P.L., 2002, Prediction of test weight from a small volume specific gravity measurement, Cereal Chemistry 79: 227-229.
[10]Eivazi, A., Abdollahi, S., Salekdeh, H., Majidi, I., Mohamadi, A., Pirayeshfar, B., 2006, Effect of drought and salinity stress on quality related traits in wheat (*Triticumaestivum* L.) cultivar. Iran Journal Crop Science, 7: 252- 267.
[11]El-Hag, W.A.A., 2015, Morphological studies on bread wheat under different regimes and planting methods, Ph. D Thesis, Agronomy Department, Faculty of Agriculture, Kafr Elsheikh University, Egypt.
[12]El-Sayed, M.O., 2015, Performance of some new wheat cultivars under different irrigation regimes and sowing methods, Ph. D. Thesis, Faculty of Agriculture, Tanta University, Egypt.
[13]Garrido-Lestache, E., López-Bellido, R., López-Bellido, L., 2004, Effect of N rate, timing and splitting and N type on bread-making quality in hard red spring wheat under rainfed Mediterranean conditions, Field Crop Research, 85: 213−236.
[14]Guttieri, M., Mclean, R., Stark, J.C., Souza, E., 2005, Managing irrigation and nitrogen fertility of hard

spring wheat for optimum bread and noodle quality, Crop Science, Madison, 45: 2049-2059.
[15]Hellemans,T., Landschoot, S., Dewitte, K., Bockstaele, F.V., Vermeir, P., Eeckhout, M., Haesaert, G., 2018, Impact of crop husbandry practices and environmental conditions on wheat composition and quality: A Review, Journal of Agricultural and Food Chemistry, DOI: 10.1021/acs.jafc.7b05450.
[16]Huebner, F.R., Gaines, C.S., 1992, Relationship between wheat kernel hardness, environment and gliadin composition, Cereal Chemistry 69: 148-151.
[17]James, L.G., 1988, Principles of farm irrigation system design, John Willey/Sons (ed.), New York, pp. 543.
[18]Jin, H., Hongwen, L., Kuhn, N., Xuemin, Z., Wenying, L., 2007, Soil loosening on permanent raised-beds in arid northwest China. Soil and Tillage Research, 97: 172–183.
[19]Meena, R.K., Parihar, S.S., Singh, M., Khanna, M., 2016, Effects of sowing dates and irrigation regimes on grain quality of wheat grown under semi-arid condition of India, Journal of Applied and Natural Science, Vol. 8(2): 960- 966.
[20]Razaq, A., Khan, M.J., Sarwar, T., Jamal, K.M, 2019, Influence of deficit irrigation, sowing methods and mulching on yield components and yield of wheat in semiarid environment. Pakistan Journal of Botany, Vol. 51(2): 553–560.
[21]Rehman, M., Akhtar, L.H., Bakhsh, A., Anum, W., Tariq, K., Zubair, M., Khan, M.M., Manzoor, N., Kanwal, N., Hassan, W., Arshad, M., 2020, Estimation of varietal differences for grain quality traits in wheat under two different irrigation regimes, International Journal of Biology and Biotechnology, Vol. 17(4): 707-711.
[22]Rodriguez, J.A., 2003, Estimation of advance and infiltration equations in furrow irrigation for untested discharges, Agricultural Water Management, 60: 227–239.
[23]Saint Pierre, C., Peterson, C.J., Ross, A.S., Ohm, J., Verhoeven, M.C., Larson, M., Hoefer, B., 2008, White wheat grain quality changes with genotype, nitrogen fertilization, and water stress, Agronomy Journal, Vol. 100(2): 414-420.
[24]Sorour, S.GH.R., Ragab, A.Y., Abdel-Raheem, H.A., Meleha, A.M.I., 2016, Effect of irrigation water management on wheat yield. Journal of Soil Science and Agricultural Engineering, Mansoura University, Vol. 7(5): 375 – 382.
[25]Torrion, J.A., Stougaard, R.N., 2017, Impacts and limits of irrigation water management on wheat yield and quality, Crop Science, 57: 3239-3251.
[26]Wardlaw, I.F., 2002, Interaction between drought and chronic high temperature during kernel filling in wheat in a controlled environment, Annals of Botany, London, 90: 69-76.
[27]William, T.L., Whitman, R.V., 1969, Description of an Assemblage of Particles, Soil Mechanics 1st ed. John Wiley & Sons, Inc: New York, Chichester, Brisbane, Toronto, Singapore.

MYCOTOXINS - INCIDENCE, IMPACT ON FEED, FOOD SAFETY, FOOD CHAIN AND ECONOMIC LOSSES

Ionuţ Silviu BEIA[1], Roxana CICEOI[2], Violeta Elena BEIA[3], Liliana BĂDULESCU[2], Dragos Ion SMEDESCU[1], Alexandru FÎNTÎNERU[1]

[1]University of Agronomic Sciences and Veterinary Medicine Bucharest of Bucharest, Faculty of Management and Rural Development, 59 Mărăști Boulevard, District 1, 011464, Bucharest, Romania, E-mail: beiaionut@yahoo.com, smedescudragos@yahoo.com, alexandru.fintineru@gmail.com
[2]Research Center for Studies of Food Quality and Agricultural Products, University of Agronomic Sciences and Veterinary Medicine Bucharest of Bucharest, 59 Mărăști Boulevard, District 1, 011464, Bucharest, Romania, E-mail: roxana.ciceoi@qlab.usamv.ro,
[3]The National Sanitary Veterinary and Food Safety Authority, Bucharest, Romania, E-mail: beia.violeta@ansvsa.ro

Corresponding author: roxana.ciceoi@qlab.usamv.ro

Abstract

Mycotoxin contamination in animal feed is a significant point of concern within the European food supply network. These toxic secondary metabolites produced by fungi have the potential to contaminate feed and pose a risk of making their way into the human diet via animal products like meat, milk, and eggs. The consequences of mycotoxin contamination extend beyond animal health, affecting economies and public health, presenting complex issues for agricultural producers, regulatory bodies, and consumers. Even with stringent controls and surveillance in place, mycotoxins remain a persistent issue. This study provides updated findings on the prevalence of mycotoxins globally and specifically in Europe, with a focus on analyzing the incidence of ochratoxin A both worldwide and within European contexts. The dispersion of mycotoxina within a given region can have considerable economic consequences for the trade of animal feed, directing stakeholders toward making informed decisions about the types of analyses in which they should allocate more resources.

Key words: *mycotoxin prevalence, food safety, ochratoxin A, cereals, economic impact*

INTRODUCTION

The presence of mycotoxins in animal feed represents a critical vulnerability in the European food chain. In a worldwide study examining the prevalence of mycotoxins, 77% of feed ingredient samples from North America were found to contain at least one mycotoxin at levels exceeding the established threshold [24]. Another estimation imply that 25-50% of the world's food crops are affected by mycotoxins [5]. Worldwide investigations have revealed that between 30% and 100% of food and feed samples exhibit co-contamination with mycotoxins, even when the levels of individual mycotoxins remain under the designated safe thresholds. This phenomenon heightens the significance of mycotoxin management because of the potential cumulative and possibly synergistic harmful impacts these toxins can have when present together [25]. Mycotoxins, toxic secondary metabolites produced by fungi, have the potential to contaminate feed and subsequently enter the human food supply through meat, milk, or eggs [30]; [36]. The financial and health-related consequences of mycotoxins have a broad and significant impact, posing challenges to farmers, policymakers, and consumers alike [20].

Aflatoxins (AFB1, AFB2, AFG1, AFG2, AFM1, and AFM2) [21], zearalenone (ZEN), fumonisin B1 (FB1), patulin, ochratoxin A (OTA), and deoxynivalenol (DON) are the mycotoxins of significant importance in terms of agroeconomics, specifically food safety and food security, as well as public health [8]; [37]. The range of adverse health effects encompasses acute poisoning, disorders of the central nervous, cardiovascular, and pulmonary systems, as well as hepatotoxicity, nephrotoxicity, immunosuppression, genotoxicity, carcinogenicity, disorders at the level of intestinal tract, leading to potential fatality [11]; [19]; [23]. For animals, these substances have the effect of decreasing the rate of growth in juvenile animals, and in certain cases, they disrupt the natural mechanisms of resistance and compromise the animals' ability to mount an immune response, thereby increasing their vulnerability to infections [14]. It has been established that they possess immunosuppressive properties and could impede the process of DNA synthesis [4].

The molds predominantly responsible for mycotoxins productions are *Aspergillus, Penicillium, and Fusarium* fungi [12]; [3]; [1], and these can grow on a diverse array of crops and food and feedstuffs that includes, but is not limited to, maize, sorghum, millet, wheat, rice, various spices, dried fruits, apples, coffee beans, and cocoa [35]. The production of mycotoxins is contingent upon specific environmental conditions, particularly warm and humid settings, which are prevalent during the stages of harvesting, handling, storage, and processing. Certain mycotoxins, including deoxynivalenol (DON), zearalenone (ZEN), and fumonisin (FB), have the potential to contaminate grains either during the preharvest stage or in the field. Conversely, aflatoxin (AF) and ochratoxin (OT) can arise during storage because of inadequate postharvest practices. The primary route of mycotoxin exposure is through ingestion, which presents a significant health risk to both humans and livestock [35]; [4].

Mycotoxin regulations have been established in more than 100 countries, and the maximum acceptable limits vary greatly from country to country [37]. The European Union harmonized regulations for the maximum levels of mycotoxins in food and feed among its member nations [25]. Despite rigorous regulations and monitoring systems in place, the enduring presence of mycotoxins continues to be a matter of concern.

The present review provides a comprehensive analysis of the presence of mycotoxins in feed commodities within the European region and focuses on the presence of ochratoxin A in feed commodities. This analysis is based on a systematic review that places particular emphasis on the health hazards associated with the agrifood value chain. We aim to explore the multiple dimensions of mycotoxins issue, especially ochratoxin A, focusing also on its economic impact and implications for food security and public health in Europe.

MATERIALS AND METHODS

To quantify the incidence of mycotoxins in European feed market, we analyzed data on mycotoxins in all feed commodities, for all kind of animal consumers (ruminants, poultry, fish etc.) to identify mycotoxin prevalence and how these varied across Europe in the last 3 years. Data on feed mycotoxin analysis were supplied by the DSM World Mycotoxin Surveys published on the downloads of DSM-Firmenich Animal Nutrition & Health, for 2021 - 2023 period [8], [9], [10]. Data were filtered to retain samples that had as origin countries from Europe for analyzing total risk posed by mycotoxins and the prevalence of the main six mycotoxins in feed commodities, and from the world and Europe, for analyzing the prevalence of the ochratoxin A in feed commodities.

Data were analyzed using Microsoft Excel of Microsoft 365 Personal All edition (v. 2023).

RESULTS AND DISCUSSIONS

The prevalence of mycotoxins in feed commodities within the European region

The prevalence of mycotoxins can vary due to a multitude of factors including climate, agricultural practices, and the efficacy of regulatory frameworks. Furthermore, the presence of mycotoxins in feed commodities is subject to seasonal and yearly fluctuations, making it difficult to give a straightforward ranking. Therefore, analyzing the mean data for several years, for all feed categories can allow some general observations and conclusions, as follows:

Southern European Countries: Due to warmer climates, countries like Spain, Italy, and

Greece may be more susceptible to certain types of mycotoxins like aflatoxins.

Eastern European Countries: Nations like Romania, Poland, and Ukraine have been noted in some studies to have elevated levels of mycotoxins like deoxynivalenol (DON) and zearalenone. This could be due to various factors, including less stringent regulatory oversight in some cases.

Northern European Countries: While less conducive to some types of mycotoxins, countries like the UK, Germany, and Scandinavia can still suffer from others like ochratoxins that prefer cooler, temperate climates.

Western European Countries: France, Belgium, and the Netherlands generally have rigorous testing and regulatory frameworks but are not immune to the problem.

It is important to consider that these observations may not be consistent, and they are also influenced by the international trade of feed commodities. Different countries have different standards and frequencies for testing for mycotoxins, making direct comparisons challenging [6].

One of the ways to compare data are the analysis performed by multinational companies, that are using the same working protocols all over the world. According to DSM World Mycotoxin Survey, the total risk of mycotoxins contaminations in Europe in feed, in the period 2021 – 2023 has an obvious rising trend in 2023, compared with the previous 2 years, with a pick for Southern Europe (Fig. 1). Generally, northern Europe has a lower risk of mycotoxin contamination when compared with the Central and Southern Europe.

Aflatoxins, zearalenone, deoxynivalenol, T2, fumonisin, and ochratoxin A are the main mycotoxins affecting feed. Their prevalence is of maximum importance for the animal production industry and millions of Euro are spent for the mycotoxin analysis yearly.

Aflatoxins are produced by *Aspergillus flavus* and *Aspergillus parasiticus* and are abundant in warm and humid regions of the world [34].

Zearalenone (ZEN), is a potent estrogenic metabolite produced by some *Fusarium* and *Gibberella* species [18].

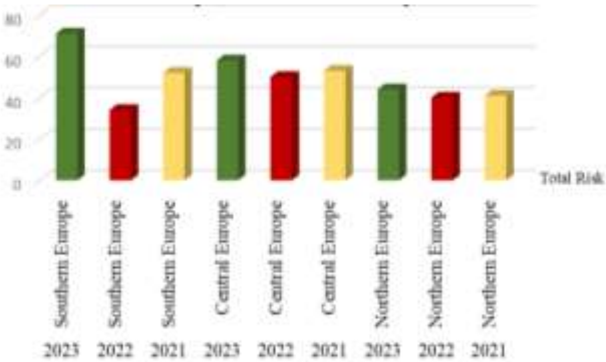

Fig. 1. The total risk of mycotoxins contaminations in Europe, in the period 2021 – 2023
Source: data according to DSM World Mycotoxin Survey [8, 9, 10].

Deoxynivalenol (DON) is one of several mycotoxins produced by certain *Fusarium* species that frequently infect corn, wheat, oats, barley, rice, and other grains in the field or during storage [29].

T-2 toxin is the most toxic fungal secondary metabolite produced by different *Fusarium* species, being also the most common cause of poisoning that results from the consumption of contaminated cereal-based food and feed reported among humans and animals [16].

Fumonisin is a mycotoxin produced by the fungus *Fusarium verticillioides*, a common contaminant of corn and corn products [28].

Ochratoxin A are produced by *Aspergillus ochraceus* and *Penicilium verrucosum* and are at least ten times more toxic than ochratoxin B, ochratoxin C or citrinin [15].

The evolution of the prevalence of these main six mycotoxins in Europe in the period 2021-2023 (Fig. 2) depicts quite alarming situation for Southern Europe in 2023, especially for zearalenone, and fumonisin. As a general remark, deoxynivalenol is the mycotoxins usually present in all the areas, every year, while for fumonisin the prevalence is very variable, depending on the region and testing period, indicating a correlation with the climatic conditions.

Huge amount of data is available on DSM World Mycotoxin Surveys, based on yearly reports from around 25,000 samples, 120,000 analyses, from samples from around 80 countries.

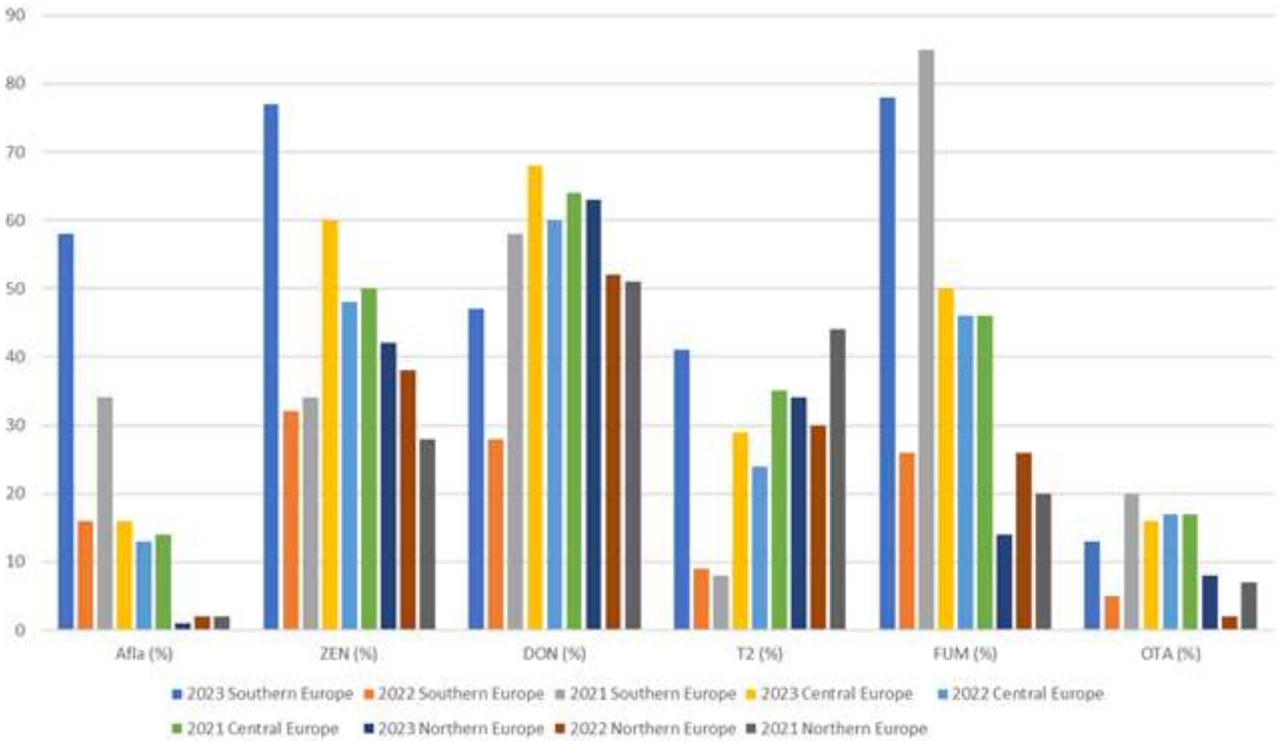

Fig. 2. The prevalence of the main six mycotoxins in feed commodities within the European region
Source: data according to DSM World Mycotoxin Survey [8, 9, 10].

The presence of ochratoxin A in feed commodities in the world

The presence of ochratoxin A (OTA) in the food chain has raised serious health concerns due to its toxicological properties, which include nephrotoxicity, immunotoxicity, and potential carcinogenic effects. The fungi responsible for OTA production, of *Aspergillus* and *Penicillium* genous [33], can proliferate on crops pre-harvest, during storage, or along the food supply chain. *Aspergillus ochraceus* grows better in oilseeds *Penicillium. verrucosum* may grow better in wheat and corn. Generally, the formation of OTA takes place predominantly post-harvest, particularly in cereal and cereal-based products that have not been adequately dried. Various factors contribute to the production of OTA, including environmental variables like temperature and moisture levels, as well as the quality and type of the seeds involved [7].

Given its stability, OTA can endure food processing techniques, thereby posing a significant risk for end consumers, either animal or human. European Food Safety Authority (EFSA) and the Food and Agriculture Organization (FAO) have established maximum permissible limits for OTA in different matrices, however, regulations are often challenging to enforce due to the widespread nature of this contaminant and gaps in surveillance.

The Commission of the European Communities Recommendation 2006/576 established the values for OTA in feedstuffs at a level of 250 µg/kg for cereals and cereal products, at 50 µg/kg for completary and complete feedstuffs for pigs and at 100 µg/kg for completary and complete feedstuffs for poultry [7].

Swine exhibit a higher vulnerability to ochratoxin A (OTA) exposure relative to other livestock species [33]. In Italy, research by Pozzo et al., 2010, detected contamination of ochratoxin A (OTA) in swine feed, with concentrations ranging from 0.22 to 38.4 µg/kg, while [27], in the Czech Republic, Zachariasova et al., 2014, reported an average OTA concentration of 3 µg/kg, noting that just a single sample surpassed the European Union's advised OTA limit of 50 µg/kg [38].

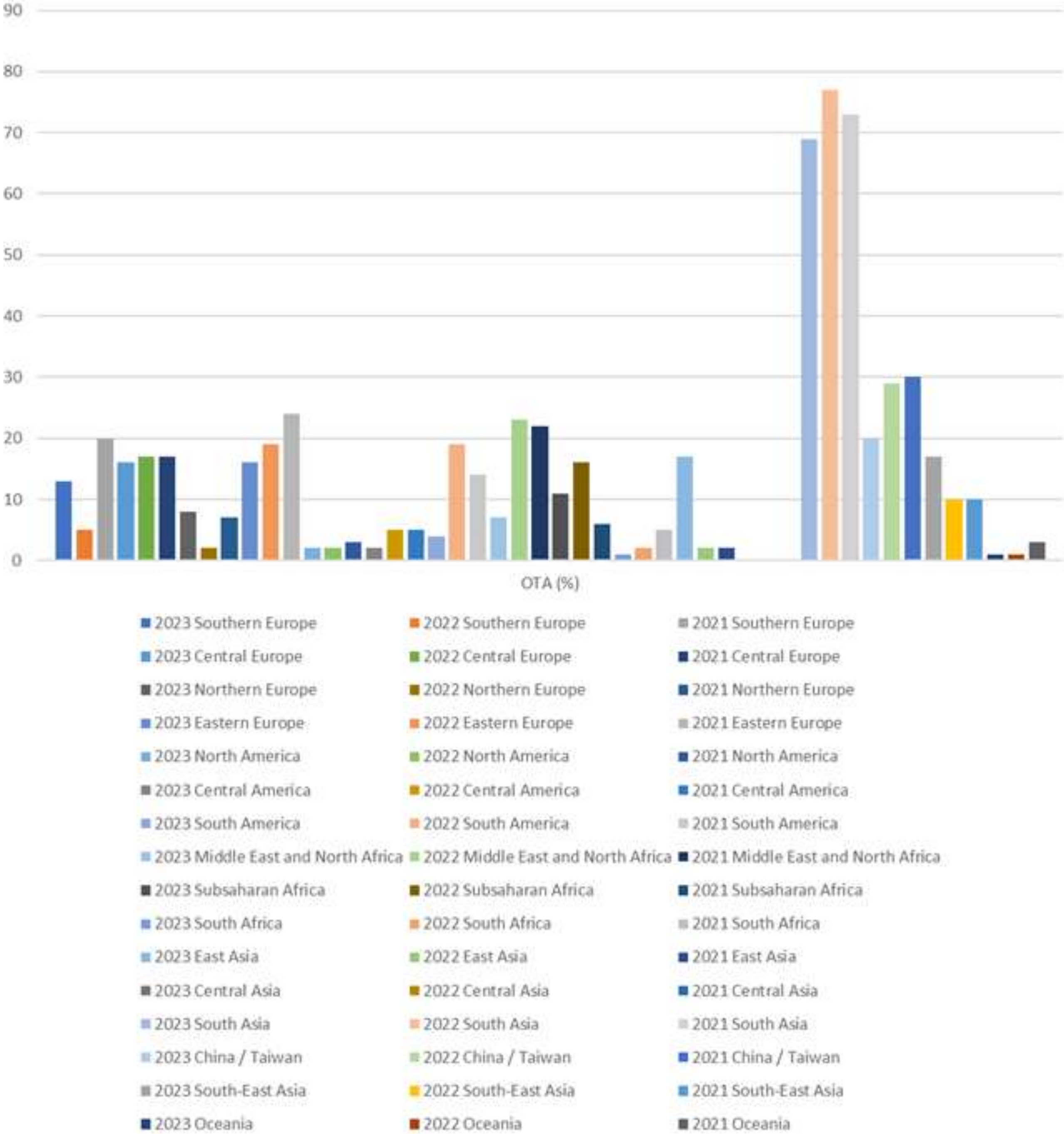

Fig. 3. The prevalence of the ochratoxin A in feed commodities in the world
Source: data according to DSM World Mycotoxin Survey [8, 9, 10].

At the world level, the prevalence of OTA in feed is below 10% Northern Europe, North and Central America, South Africa, and Oceania (Fig 3). Southern, Eastern and Central Europe, South America, Subsaharan Africa, and South- East Asia generally have a prevalence of OTA between 10-20%. The situation is alarming in China/Taiwan, with a prevalence of more than 20-30%, and even more in South Asia, where OTA can be found in more than 70% of the analyzed samples.

The presence of ochratoxin A in feed commodities in Europe

The prevalence of ochratoxin A in feed commodities in Europe was below 10% in Northern Europe, with a minimum in 2022, when it only been 2% (Fig.4.) The same pattern happened for Southern Europe, where in 2022 the prevalence was only 5%, although in 2021 this was 20% and in 2023 raised to 13%. As the summer of 2022 was Europe's worst drought in the last 500 years [31], one possible explanation could rely on the lack of humidity, that did not favor the fungi development. Still, for Eastern and Central Europe, the decreasing trend continued in 2023, indicating that the lack of water in the first part of the season can contribute to a dramatical drop down of the presence of mycotoxines in feed commodities.

Still, Eastern Europe has an average prevalence of almost 20%, indicating also that other measures should be put in place to reduce the mycotoxins risk for human and animal health.

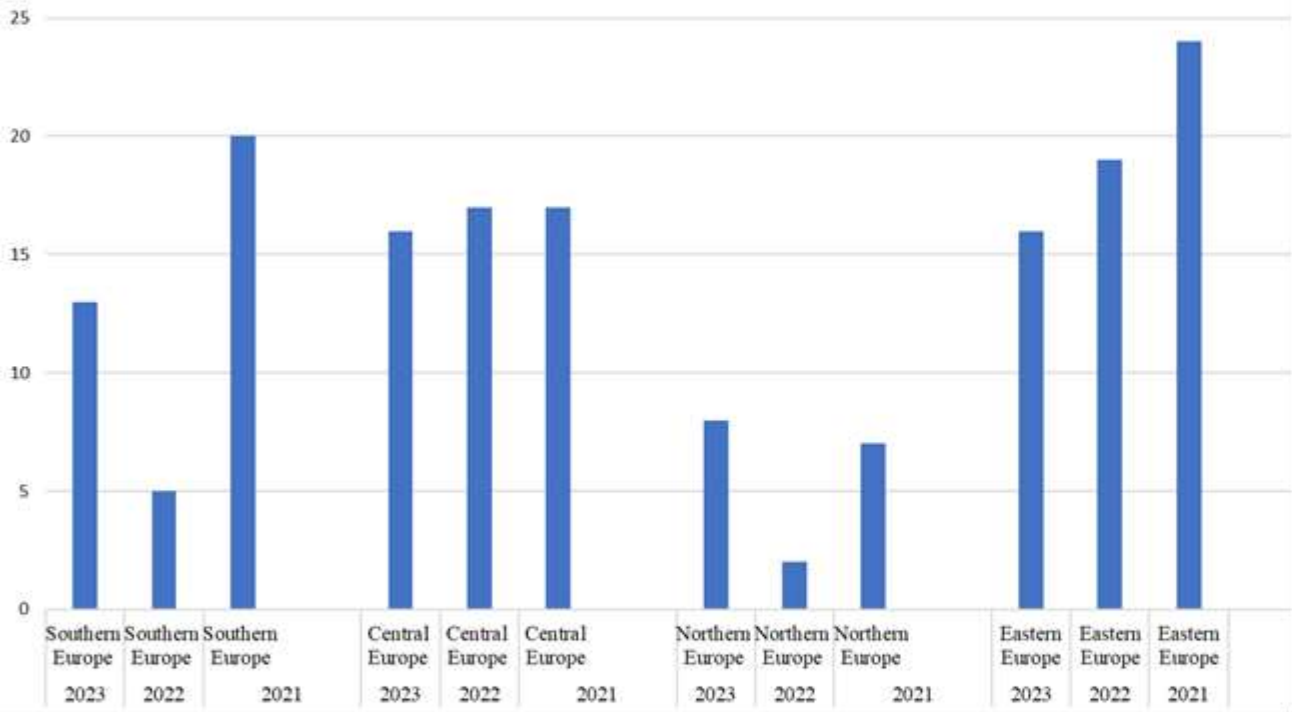

Fig. 4. The prevalence of the ochratoxin A in feed commodities within the European region
Source: data according to DSM World Mycotoxin Survey [8, 9, 10].

Impact on feed, food safety and food chain

The economic repercussions of mycotoxins in animal feed are extensive and multi-faceted. The presence of mycotoxins in animal feed has a ripple effect on food security and public health. Residues can accumulate in animal-derived products, such as meat and milk, which may then be consumed by humans. Long-term exposure to low levels of these toxins can lead to chronic health issues, including immune suppression and carcinogenic effects. The mycotoxin issue thus extends beyond the agricultural community to affect the general population, posing challenges for public health officials and medical researchers.

The expansion of international trade and the increasing complexity of supply chains are introducing novel challenges in ensuring food and feed safety across the globe. A precautionary strategy for consumer protection should encompass a Risk Assessment that accounts for every phase of the worldwide food supply chains. There exist significant knowledge deficits within the trade structures of these chains, particularly in logistical components like transportation and storage [2].

European countries have established stringent regulations concerning mycotoxin levels in animal feed, aligned with guidelines from the European Food Safety Authority (EFSA). However, the ever-changing climatic conditions and global feed supply chains add layers of complexity to regulatory enforcement. Additionally, the variety of mycotoxins and their different impacts on various animal species complicate the regulatory landscape.

Non-compliance not only leads to economic losses but also hampers market access, as some countries outside the EU have even stricter regulations concerning mycotoxins in imported animal products.

Regardless of regulations, many possible strategies may be adopted by farmers, to reduce mycotoxins contaminations. Focker et al., 2020, mentions the use of a fungicide to control Fusarium head blight, use of resistant maize cultivars and/or biocontrol, improved storage management, innovative milling strategies and use of mycotoxin degrading enzymes for bioethanol production [13].

Economic impact

In US, Mitchel et al., 2016 estimate that only aflatoxin contamination in corn could cause losses ranging from US$52.1 million to US$1.68 billion annually [22]. Some studies suggest that the European Union could face annual losses ranging from €3 to €5 billion due to the adverse effects of mycotoxins on livestock health and productivity [17].

Table 1. Different categories of costs related to the presence of mycotoxins in feed commodities within the European region

Direct costs	Indirect costs	Research and development Costs
Feed Contamination and Waste: Mycotoxin-contaminated feed often has to be discarded to prevent further risks, leading to waste and requiring replacement with uncontaminated feed.	Testing and Monitoring: To comply with regulations and ensure the safety of animal feed, producers often need to invest in mycotoxin testing, which can be expensive.	Innovation and Technology: Firms may invest in research to develop mycotoxin-resistant feed varieties or more effective detoxifying agents, which is a long-term but essential cost.
Reduced Feed Efficiency: Animals consuming low levels of mycotoxins may exhibit reduced feed conversion rates, affecting productivity and thus increasing costs per unit of animal product.	Regulatory Penalties: Non-compliance with mycotoxin regulations can result in fines and other penalties.	Detection and Analysis: Developing, refining, and implementing new detection methods for various mycotoxins in feed. This includes the cost of purchasing and maintaining sophisticated analytical equipment, reagents, and materials.
Veterinary Expenses: Animals exposed to mycotoxins may require medical treatment for symptoms ranging from digestive issues to severe illnesses. This adds to the veterinary costs, including both medicines and professional services.	Market Access and Trade Restrictions: Exceeding mycotoxin limits can result in restricted market access, both domestically and internationally, as some markets may ban products from sources with known mycotoxin issues.	Surveillance Programs: Conducting regular monitoring and surveillance of feedstocks to assess mycotoxin levels, which requires ongoing funding for sample collection, testing, and data analysis.
Decreased Animal Productivity: Mycotoxins can impact the growth rates, reproductive capacity, and milk production of livestock. Reduced productivity means fewer marketable goods and thus, lower revenues.	Consumer Confidence: News of mycotoxin contamination can erode consumer trust, leading to reduced demand and prices for animal products.	Prevention and Control Strategies: Investing in the development of new feed additives or treatments that can inhibit mycotoxin production or mitigate their effects. This involves funding laboratory research, field trials, and regulatory approval processes.
Mortality: In severe cases, exposure to mycotoxins can lead to animal deaths, resulting in immediate economic loss for the producers.	Loss of Man-hours: Managing a mycotoxin outbreak involves significant time and labor, including diagnosing the problem, treating affected animals, and implementing preventive measures.	Data Management and Software Development: Developing software for the prediction, management, and documentation of mycotoxin risks, which includes costs for programmers, data scientists, and IT infrastructure.
Loss of Market Access: For feed producers and exporters, the presence of mycotoxins can lead to restrictions in certain markets, which can have significant financial implications.	Litigation Costs: In extreme cases, failure to manage mycotoxins effectively could lead to legal consequences, adding litigation costs to the economic burden	Collaborative Research: Funding joint research initiatives with academic institutions, government agencies, and industry partners to advance the understanding and management of mycotoxin contamination.

Source: Pitt et al., 2012 [26].

Regarding contamination with deoxynivalenol (DON) in Europe from 2010 to 2019, Johns et al., 2022 reported that 75 million tons of wheat, accounting for 5% of the wheat intended for human consumption, was relegated to animal feed as it surpassed the threshold of 750 µg/kg due to Fusarium head blight contamination. his downgrading led to an economic loss of around €3 billion, a figure that was estimated without considering additional losses from diminished crop yields, the presence of other mycotoxins associated with Fusarium head blight, or the expenses related to fungicide treatments and mycotoxin assays. Consequently, this estimate represents only a portion of the overall economic burden imposed by head blight [17].

Another modeling calculation in wheat in EU indicated annual losses due to mycotoxins at a level of 5-10%, which equates to €1.2-2.4 billion in lost income just [32].

The economic impact could be evaluated considering the direct costs and the indirect costs [26], but also the research costs, as a separate category (Table 1). Direct costs include immediate losses from rejection or destruction of contaminated feed, increased veterinary expenses, and decreased animal productivity. Indirect costs extend to market restrictions, especially in terms of exports, as well as additional costs for testing and monitoring to ensure feed quality. The financial burden disproportionately affects smaller farms that may lack the resources for extensive monitoring and compliance, exacerbating economic disparities within the agricultural sector.

Moreover, indirect costs such as loss of market access for exports due to stricter import regulations in other countries, as well as the financial burden of constant feed monitoring, add to this considerable economic impact.

This enduring issue challenges the stability and profitability of the European livestock industry, affecting small-scale farmers and large enterprises alike.

CONCLUSIONS

The persistent occurrence of mycotoxins in animal feed continues to pose a substantial risk within Europe's feed supply chain. Despite extensive regulatory measures and surveillance efforts, the intricate nature of mycotoxin contamination makes it an ongoing challenge. The repercussions are economically significant, with implications for the agricultural industry and the wider economy. Understanding the distribution of particular mycotoxin within a given region can have considerable economic consequences for the trade of animal feed, directing stakeholders toward making informed decisions about the types of analyses in which they should allocate more resources.

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REFERENCES

[1]Abdel-Wahhab, M.A., Kholif, A.M., 2008, Mycotoxins in Animal Feeds and Prevention Strategies: A Review. Asian Journal of Animal Sciences, 2: 7-25. doi: 10.3923/ajas.2008.7.25

[2]Achten, E., Zupaniec, M., Mader, A., Mädge, I., Bodi, D., Spolders, M., Kowalczyk, J., Horn, B., Schafft, H.A., 2019, Global feed supply chains − Plant resources for animal feed. In Feed and food safety in times of global production and trade. Bundesinstitut für Risikobewertung, Berlin. doi 10.17590/20190930-102623

[3]Armendáriz, C. R., Fernández, Á. J. G., Gironés, M. C. L. R., de la Torre, A. H., 2014, Mycotoxins. Encyclopedia of Toxicology, 424–427. doi:10.1016/b978-0-12-386454-3.00519-4

[4]Awuchi, C.G., Ondari, E.N., Nwozo, S., Odongo, G.A., Eseoghene, I.J., Twinomuhwezi, H., Ogbonna, C.U., Upadhyay, A.K., Adeleye, A.O., Okpala, C.O.R., 2022, Mycotoxins' Toxicological Mechanisms Involving Humans, Livestock and Their Associated Health Concerns: A Review. Toxins:14(167). doi:10.3390/toxins14030167

[5]Borutova, R., 2019, The economic impact of mycotoxins, Poultry World, https://www.poultryworld.net/health-nutrition/the-

economic-impact-of-mycotoxins/, Accessed on November 1, 2023.

[6]Chhaya, R. S., O'Brien, J., Cummins, E., 2021, Feed to fork risk assessment of mycotoxins under climate change influences - recent developments. Trends in Food Science & Technology. doi:10.1016/j.tifs.2021.07.040

[7]Denli, M., Perez, J. F., 2010, Ochratoxins in feed, a risk for animal and human health: control strategies. Toxins, 2(5), 1065–1077. doi.org/10.3390/toxins2051065.

[8]DSM-Firmenich, 2023, DSM World Mycotoxin Survey, The Global Threat. January – June 2023. https://www.dsm.com/anh/news/downloads/whitepapers-and-reports/download-the-dsm-firmenich-world-mycotoxin-survey-january-to-june-2023.html, Accessed on October 26, 2023

[9]DSM-Firmenich, 2022, 2022 dsm-firmenich World Mycotoxin Survey Report. https://www.dsm.com/anh/news/downloads/whitepapers-and-reports/dsm-world-mycotoxin-survey-2022-report.html , Accessed on October 26, 2023

[10]DSM-Firmenich, 2021, 2021 dsm-firmenich World Mycotoxin Survey Report. https://www.dsm.com/anh/news/downloads/whitepapers-and-reports/2021-dsm-world-mycotoxin-survey-report.html, Accessed on October 26, 2023

[11]EFSA, 2023, Mycotoxins. https://www.efsa.europa.eu/en/topics/topic/mycotoxins#, Accessed on October 26, 2023

[12]Eskola, M., Kos, G., Elliott, C. T., Hajšlová, J., Mayar, S., Krska, R., 2019, Worldwide contamination of food-crops with mycotoxins: Validity of the widely cited "FAO estimate" of 25%. Critical Reviews in Food Science and Nutrition, 1–17. doi:10.1080/10408398.2019.1658570

[13]Focker, M., van der Fels-Klerx, H.J., Magan, N., Edwards, S.G., Grahovac, M., Bagi, F., Budakov, D., Suman, M., Schatzmayr, G., Krska, R., de Nijs, M., 2020, The impact of management practices to prevent and control mycotoxins in the European food supply chain: MyToolBox project results. doi: 10.3920/WMJ2020.2588

[14]Grenier, B., Applegate, T., 2013, Modulation of Intestinal Functions Following Mycotoxin Ingestion: Meta-Analysis of Published Experiments in Animals. Toxins, 5(2), 396–430. doi:10.3390/toxins5020396

[15]Gupta, R. C., 2018, Veterinary Toxicology, Academic Press, Elsevier Inc., doi.org/10.1016/C2016-0-01687-X

[16]Janik, E., Niemcewicz, M., Podogrocki, M., Ceremuga, M., Stela, M., Bijak, M., 2021, T-2 Toxin-The Most Toxic Trichothecene Mycotoxin: Metabolism, Toxicity, and Decontamination Strategies. Molecules (Basel, Switzerland), 26(22), 6868. https://doi.org/10.3390/molecules26226868

[17]Johns, L.E., Bebber, D.P., Gurr, S.J., 2022, Emerging health threat and cost of Fusarium mycotoxins in European wheat. Nat Food 3, 1014–1019. https://doi.org/10.1038/s43016-022-00655-z

[18]Kaur, Y., Verma, R.K., 2023, Plant-Microbe Interaction - Recent Advances in Molecular and Biochemical Approaches. Volume 1: Overview of Biochemical and Physiological Alteration During Plant-Microbe Interaction, 1st Edition. doi:10.1016/B978-0-323-91875-6.00006-2,

[19]Latham, R.L., Boyle, J.T., Barbano, A., Loveman, W.G., Brown, N.A., 2023, Diverse mycotoxin threats to safe food and feed cereals. Essays Biochem. 67(5):797-809. doi: 10.1042/EBC20220221

[20]Marc, R.A., 2022. Implications of Mycotoxins in Food Safety. Chapter 1. Form Mycotoxins and Food Safety - Recent Advances. IntechOpen. doi:10.5772/intechopen.102495

[21]Mehmood, N., Sohail, F., Sohail, S., Aslam, M., Ali, M., Ijaz, N., Rana, H., 2012, Carcinogenic Properties of Aflatoxins in Maize Production and Recent Technologies Involved. Austin Journal of Nutrition and Food Sciences. 9(2): 1157.

[22]Mitchel, N.J., Bowers, E., Hurburgh, C., Wu, F., 2016, Potential economic losses to the US corn industry from aflatoxin contamination, Food Addit Contam Part A Chem Anal Control Expo Risk Assess, 33(3):540-50. doi: 10.1080/19440049.2016.1138545

[23]Omotayo, O.P., Omotayo, A.O., Mwanza, M., Babalola, O.O., 2019, Prevalence of Mycotoxins and Their Consequences on Human Health. Toxicological Research, 35(1), 1–7. doi:10.5487/tr.2019.35.1.001

[24]Paulk, C., Truelock, C., 2021, Mycotoxins in poultry feed. https://www.world-grain.com/articles/16274-mycotoxins-in-poultry-feed, Accessed on 20 October 2023.

[25]Pinotti, L., Ottoboni, M., Giromini, C., Dell'Orto, V., Cheli, F., 2016, Mycotoxin Contamination in the EU Feed Supply Chain: A Focus on Cereal Byproducts. Toxins 8(2):45. doi: 10.3390/toxins8020045.

[26]Pitt, J.I., et al., 2012, Economics of Mycotoxins: Evaluating Costs to Society and Cost-Effectiveness of Interventions. IARC Scientific Publications, Lyon, 119-129. http://www.ncbi.nlm.nih.gov/pubmed/23477200

[27]Pozzo, L., Cavallarin, L., Nucera, D., Antoniazzi, S., Schiavone, A., 2010, A survey of ochratoxin A contamination in feeds and sera from organic and standard swine farms in Northwest Italy. J. Sci. Food Agric, 90, 1467–1472

[28]Smith, G.W., 2018, Veterinary Toxicology (Third Edition), Academic Press, Elsevier Inc., doi.org/10.1016/C2016-0-01687-X.

[29]Sobrova, P., Adam, V., Vasatkova, A., Beklova, M., Zeman, L., Kizek, R., 2012, Deoxynivalenol and its toxicity. Interdiscip Toxicol. (3):94-9. doi: 10.2478/v10102-010-0019-x.

[30]Stoev, S.D. 2023, Foodborne diseases due to underestimated hazard of joint mycotoxin exposure at low levels and possible risk assessment. Toxins, 15, 464, https://doi.org/10.3390/toxins15070464

[31]Tandon, A., 2022, Climate change made 2022's northern-hemisphere droughts 'at least 20 times' more likely. https://www.carbonbrief.org/climate-change-made-2022s-northern-hemisphere-droughts-at-least-20-times-more-likely/. Accessed on October 28, 2023

[32]Van Es-Sahota, S., 2023, Professor Rudolf Krska: "Challenges need to be faced with cutting edge research" https://www.dairyglobal.net/specials/professor-rudolf-krska-challenges-need-to-be-faced-with-cutting-edge-research. Accessed on October 30, 2023

[34]Vlachou, M., Pexara, A., Solomakos, N., Govaris, A., 2022, Ochratoxin A in Slaughtered Pigs and Pork Products. Toxins:14, 67. doi:10.3390/toxins14020067

[35]Wexler, P., 2014. Encyclopedia of Toxicology, Third Edition. Academic Press, Elsevier Inc. p

[36]WHO, 2023, Mycotoxins, https://www.who.int/news-room/fact-sheets/detail/mycotoxins. Accessed on October 26, 2023

[37]Xu, R., Kiarie, E.G., Yiannikouris, A., Sun, L., Karrow, N.A., 2022, Nutritional impact of mycotoxins in food animal production and strategies for mitigation. J Animal Sci Biotechnol 13, 69, doi:10.1186/s40104-022-00714-2

[38]Yu, J., Pedroso, I.R., 2023, Mycotoxins in Cereal-Based Productsand Their Impacts on the Health of Humans, Livestock Animals and Pets. Toxins, 15, 480. https://doi.org/10.3390/toxins15080480

[39]Zachariasova, M., Dzuman, Z., Veprikova, Z., Hajkova, K., Jiru, M., Vaclavikova, M., Hajslova, J., 2014, Occurrence of multiple mycotoxins in European feeding stuffs, assessment of dietary intake by farm animals. Anim. Feed Sci. Technol, 193, 124–140.

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ASSESSING ROMANIA'S FOOD SECURITY STATUS IN 2022: A COMPARATIVE ANALYSIS WITH REGIONAL PEERS

Maria BOBEICĂ, Georgiana Armenița ARGHIROIU, Silviu BECIU

University of Agricultural Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd., District 1, 011464, Bucharest, Romania, E-mails: maria.colpos18@gmail.com, armenitaarghiroiu@gmail.com, beciu.silviu@managusamv.ro

Corresponding author: armenitaarghiroiu@gmail.com

Abstract

Food security, defined as the availability, accessibility, utilization, and stability of food, is a critical concern in the context of global sustainability and human well-being. The COVID-19 pandemic has further exacerbated existing challenges, putting additional strain on food systems and exacerbating vulnerabilities. The current world status demands a thorough evaluation of the food security situation in Romania and other Eastern European countries. We must take into account various elements that influence this extremely intricate subject. Our approach involves analyzing data from reputable sources whose main purpose is to support nations in finding solutions for a sustainable future, such as FAO, EU or UN. Our goal is to acquire a detailed insight into how world events impacted the food security of Eastern European countries. Moreover, we investigated the role of social and economic inequalities that contribute to food insecurity, as well as the consequences of climate change on food systems' stability. Through this rigorous analysis, we seek to contribute to the existing body of knowledge and inform policy and decision-making processes towards achieving sustainable and resilient food security in the region.

Key words: *food security, social disparities, food price index, climate changes*

INTRODUCTION

At the end of the XX century, in the Italy capital, within the World Food Summit, the state leaders, United Nation, and FAO pronounced the “Rome Declaration on Food Security” [15]. According to this declaration, we can discuss about food security for people, if they have both physical and economic access to enough safe and nutritious food to acquire their alimentary needs and individual food options for a vivid and joyful life. In other words, food needs to be available to people, to be easily accessed, to be consumed accordingly and all three above should not fluctuate in time and should not have differences among regions [2, 8, 28]. However, in the past 4 years, the course of history took a never-before-seen turn and the dynamic global events that occurred influenced the outlook on food security all over the world [36]. We have seen climate changes and extreme weather events that damaged crops and negatively affected agricultural production. The outburst of the COVID-19 pandemic was an unprecedented crisis that disrupted the supply chains and outlined the vulnerability of millions [24]. Lockdowns directly affected livelihoods, especially for people working in agriculture and food supply chains. The repercussions of the geopolitical turmoil caused by COVID and the rising inflation have had a profound impact on the stability of food systems, exacerbating the already existing challenges. Consequently, the interplay between geopolitical dynamics [34] and food security has become a critical area of concern, necessitating comprehensive analysis and strategic interventions to mitigate the adverse consequences on global sustenance.

The COVID-19 pandemic has not been the only factor contributing to food insecurity in the studied countries. The rising prices of essential food items have also played a significant role, making it harder for families to access nutritious meals. Moreover, climate changes and extreme weather events have had a severe impact on food production, leading to shortages and higher prices. Finally, social inequality has exacerbated the issue, as vulnerable demographics have been hit the hardest by the pandemic and its aftermath. These elements have added to the complexity of the food security challenge and require a comprehensive approach to address them effectively, which is why we chose this topic for our study as a first step.

MATERIALS AND METHODS

Since food security is a widely interesting topic, numerous private and public institutions provide data and reports on the current world situation. Our paper combines data offered by reports and studies presented by public entities such as the European Union, FAO, World Bank, The Economist, and Food Security Information Network, and offers a multi-faceted perspective on food security. We compared data available for Romania and the neighbouring countries and tried to provide context as to why the situation presents itself as such. We chose for comparison the countries included in the Eastern Europe region by the UN methodology [37] that are also part of the European Union. These countries are Romania, Bulgaria, Hungary, Poland, Slovakia and Czech Republic. National sources such as National Statistics Offices for each country were utilized and data was extracted for this paper.

RESULTS AND DISCUSSIONS

Disruption of food supply chains – the aftermath of COVID-19

In December 2019, the city of Wuhan, China reported an outbreak of pneumonia cases of unknown origin. On January 5, 2020, WHO made the first public international media report [38] of what would become one of the greatest challenges of the 21st century so far. Nobody could have predicted the intricate implications of this global event. According to the IMF, since the beginning of the pandemic by the end of 2022, more than 272 billion EUR were infused in world economies to rebalance the economic environment with an additional 461 billion EUR approved for providing liquidities to countries in need of financial recovery [15]. According to the same report, Romania spent around 7.59 % of its GDP on COVID-related fiscal measures. Romania's percentage is significantly lower than its regional counterparts, but in terms of value, almost 3 times larger than Bulgaria's. Even with the quick global response to the pandemic, lockdowns and travel restrictions led to supply chain blockages. The migrant workforce was stuck in their respective countries, which caused a labor market shortage. Circulation restrictions led to discontinuation in the transport of goods, which in turn led to a shortage of products available on the markets. International trade in agriculture faced disruptions due to border closures and restrictions, affecting both the importation of essential inputs (such as seeds, fertilizers, and pesticides) and the export of agricultural products. Fluctuations in demand and supply, combined with market uncertainty, led to price volatility for various agricultural commodities. With the shutting of sectors like tourism or HORECA, many people faced a sudden drop in their income.

Table 1. Cost of fiscal measures to minimize COVID-19 impact on the selected countries

	GDP 2021 (bil. EUR)	% of GDP spent for COVID-19 fiscal measures	Value of COVID-19 fiscal measures (Bil. EUR)
Poland	574.7	11.28	64.8
Czech Republic	238.25	24.7	58.8
Romania	241.3	7.59	18.3
Bulgaria	71.1	9.19	6.5

Source: IMF, Fiscal Monitor Database of Country Fiscal Measures in Response to the COVID-19 Pandemic, Oct.2021 [25].

As a result, the drop in income coupled with the rise in food prices led to food insecurity for a large share of the population.

However big the share of funds allotted to counteract the effects of COVID-19, the impact on the food supply chain and subsequently on food security was significant. The inflation took a quick turn upward, the evolution of the Harmonized Index of Consumer Prices (HICP) pictured in Figure 1 being the most relevant proof.

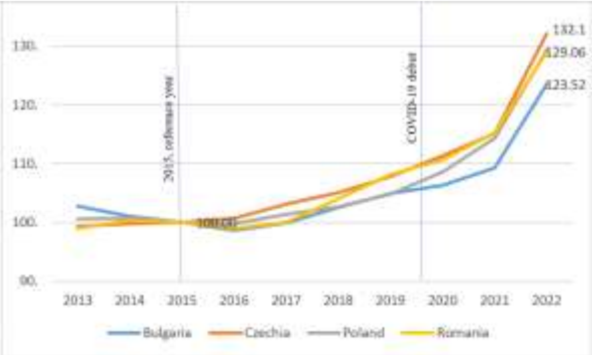

Fig. 1. Evolution of HICP between 2013 and 2022
Source: European Commission, Harmonized Index of Consumer Prices (HICP) annual data, Sept 2023 [13].

Changes in consumer behavior, such as increased demand for locally produced food and a surge in online sales, influenced the way agricultural products were distributed and marketed. There was tremendous support for locally produced goods, and those who saw the opportunity thrived. Therefore, the pandemic accelerated the adoption of technology in agriculture, including the use of automation, drones, and digital platforms for marketing and sales. Still, many small-scale and subsistence farmers faced heightened economic vulnerability, as they lacked the resources to adapt to the rapidly changing circumstances even with governments around the world implementing various policies to support farmers and stabilize the agricultural sector. The pandemic underscored the importance of building resilience in the agricultural sector. Some farmers adapted by diversifying crops, adopting sustainable practices, and exploring new markets or even by increasing awareness in their own local communities. This global event emphasized the vulnerability of food systems and their dependence on the well-oiled machine that is international trade. Cheaper products, coming from countries like Ukraine, Turkey, Moldova, or other Balkan Countries outside of the EU lower the demand for their European counterparts [22]. Farmers from Eastern Europe expressed their discontent with the excessive quantities of food imports, thereby illustrating the challenges encountered in upholding unity and effectively managing the surplus. This situation sheds light on the interdependencies within the agricultural dynamics of the region. Although food insecurity is not currently a pressing concern in Europe, the potential failure or financial unattractiveness of European farmers, if left unprotected, could have far-reaching consequences. Over time, this could lead to escalating prices, and inflation, ultimately contributing to food insecurity [23][31][9].

The impact of rising prices of essential food items on food security for Romania and its regional peers

As we have seen in Figure 1, all around Europe the cost of living increased due to inflation and the abrupt rise of prices. Romania and its neighbors were no exceptions, and as we see below in Table 2, the increased cost of a healthy diet caused larger percentages of people who cannot afford a healthy diet.

Table 2. Cost progress for a healthy diet and the impact on the % of the population that can afford it or not

	Cost of a healthy diet				People unable to afford a healthy diet			
	EUR per person per month				Total number (thousand people) & Percentage of total population			
	2017	2018	2019	2020	2017	2018	2019	2020
Europe	94.8	96.9	96.9	100.5	18,300 (2.6%)	15,200 (2.2%)	13,700 (2%)	14,600 (2.1%)
Bulgaria	119.4	121.8	123	129.6	800 (11.3%)	600 (9%)	600 (8%)	600 (8.5%)
Czechia	91.5	92.1	92.1	93.6	38 (0.4%)	19 (0.2%)	19 (0.2%)	19 (0.2%)
Hungary	104.4	106.8	106.5	110.1	300 (3.3%)	200 (2.3%)	200 (1.9%)	200 (2%)
Poland	91.8	94.2	96	100.2	400 (1%)	500 (1.4%)	300 (0.8%)	400 (1%)
Romania	92.1	93.3	95.1	100.8	2,300 (11.9%)	1,300 (6.9%)	1,600 (8.3%)	1,700 (8.8%)
Slovakia	95.1	98.1	98.1	99.6	100 (2%)	100 (2.4%)	100 (1.2%)	100 (1.2%)

Source: FAO [19].

In 2021, 21% of the total Europeans who could not afford the cost of a healthy diet were from Eastern Europe.

A closer look at the evolution of the real wage growth compared with the yearly inflation (Figure 2) tells us exactly why the financial security of Romanians is currently in jeopardy and subsequently, the affordability in terms of access to food is in danger. The spike in inflation in 2022 did not match with a comparable wage growth. So, while the net income for Romanians grew in 2022, the people did not feel this growth because prices grew even more. Middle and lower-income families are thus forced to choose cheaper and lower-quality foods in order to make ends meet. This creates the perception of a more insecure environment regarding food. Because even though food is readily available in stores, the customer needs to think twice about whether he can afford it or not. Extensive research [27], [1], [3], has firmly established a strong correlation between food insecurity, which arises from the constraints imposed by poverty on accessing nutritious diets, and the heightened prevalence of obesity, particularly among adult females and in affluent nations.

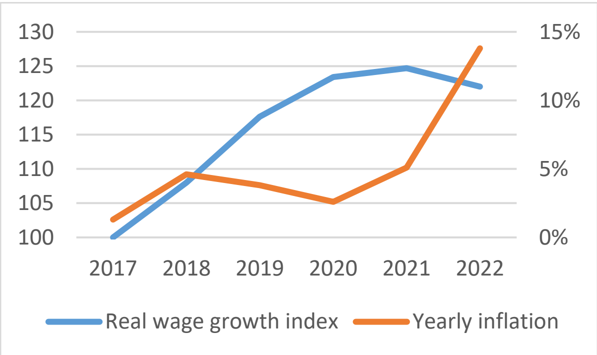

Fig. 2. Comparison between real wage growth index and yearly inflation in Romania
Source: NIS [32].

Climate change and extreme weather events that affected the agricultural productivity and food security in Eastern Europe

Recent years, like 2021 and 2022, have seen record-breaking extreme weather events in Europe, triggering catastrophic flooding and heat waves [17]. These events cause massive damage to the crops, resulting in food scarcity and rising prices. While poorer countries from around the world feel the shock of weather events more powerful, in Europe, the main impact is on the volatility aspect of the food supply chain [29] Floods in Europe have devastated crops, especially in the southern part (Italy and Greece) [20]. In the meanwhile, drought affects the rest of Europe. Figure 3 shows the extent of drought-affected territories in 2022 in Europe. As we can see, Eastern Europe, the area of interest for this study is mostly in the red, with the most damage caused by drought. As of September 2023, 40.4% of Romanian lands are reported as affected by long-lasting drought [12]. Projections of The JRC PESETA II Project [6] state that if we do not fight to limit climate change, by 2100 crop yields will drop by at least 10%. In time, the estimated rise in global temperatures and altered precipitation patterns will reduce crop yields and affect livestock productivity, posing a threat to the global food supply [11]. Water supply will also be impacted, leading to water scarcity, affecting irrigation and water availability for crops and livestock

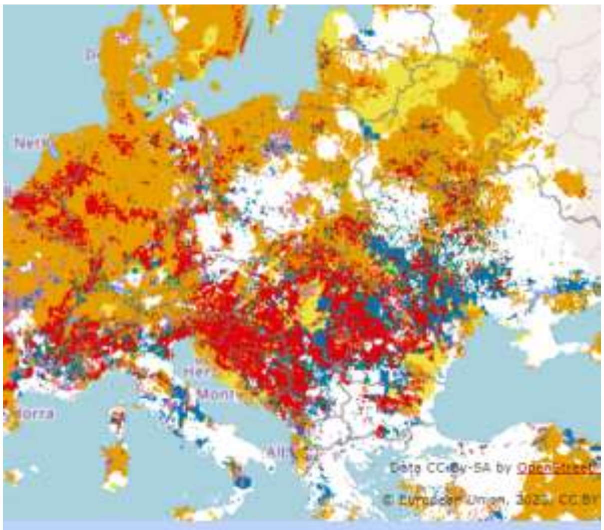

Fig. 3. Drought-affected territories in Eastern Europe in 2022. In red – areas with the most damage.
Source: European Commission Drought Observatory [12].

The phenomenon of climate change has the capacity to engender food insecurity through a range of mechanisms, including the amplification of food costs, the reduction of overall food production, the creation of water scarcity for agricultural purposes, the intensification of land competition, and the occurrence of sudden declines in agricultural productivity as a consequence of extreme weather events [18].

Social inequality and food security

FIES (Food Insecurity Experience Scale) as a tool developed by FAO, offers great insight into the extent of food insecurity and the damage that it causes. According to the FAO et al. study [21], there is a strong interdependence between the aspect of food insecurity and malnourishment, as measured on the FIES scale. The intensity of this relationship varies from country to country, especially because the magnitude of the malnourishment rate varies greatly as well. While there are multiple studies on this matter, [5] [26] [33], they provide limited but compelling evidence that childhood wasting (observed through a low weight-for-height ratio) is closely attached to food insecurity. Regarding adult obesity, there is persuasive data, with moderate agreement, that food insecurity resulting from poverty and restricted access to nutritious diets is correlated with higher obesity rates. This connection is particularly evident in high-income countries and among adult females [35]. Furthermore, a separate meta-analysis conducted by Kim and von dem Knesebeck [27] focuses on research conducted in Europe and North America, where their findings indicate a negative relationship between income and obesity, suggesting that low income may contribute to obesity, and vice versa.

As part of the European Union, the six countries selected for this study are benefiting from the strategic advantages such as location, climate, social and economic development. This is why, the percentage of the population that is subjected to malnourishment is lower than in other parts of the world. However, between the six, a larger percentage is noted in the two countries that have the lowest rank of Human Development. Low societal and economic development leads to inequalities not only between countries facing similar contexts (Table 3) but within regions of the same country as well (Table 4).

Table 3. Percentage of people as share from the total population facing undernourishment and food insecurity by country

	Undernourishment (%)		**Severe food insecurity (%)**		**Moderate food insecurity (%)**	
	2004–2006	**2019–2021**	**2014–2016**	**2019–2021**	**2014–2016**	**2019–2021**
Eastern Europe	<2.5	<2.5	1.5	1.3	11.2	9.7
Bulgaria	4.9	3	1.9	2.9	14.9	15.5
Czechia	<2.5	<2.5	0.7	1.6	5.8	5.8
Hungary	<2.5	<2.5	1.4	2.1	11.3	10.6
Poland	<2.5	<2.5	1.8	0.9	8.9	7.4
Romania	<2.5	<2.5	5.6	3.7	19.3	13.4
Slovakia	5.5	3.8	1.1	1.6	6.2	7.7

Source: FAO [21].

Table 4. Regional disparities in Romania – differences in net nominal wages per month

	Romania	North West	Centre	North East	South East	South - Muntenia	Bucharet-Ilfov	South Oltenia	West
Net nominal wage 2022 (RON)	3,801	3,635	3,489	3,349	3,173	3,355	5,110	3,247	3,650

Note: Average Exchange Rate Euro/Leu in 2022 = 4.93127 Lei
Source: NIS [32].

The cost of living at the country level is mostly the same. Usually, prices and inflation have the same tendencies of rising/decreasing. But when disparities in individual incomes are this great as in the example provided in Table 4, it will become inevitable for the whole population to afford the same quantity and quality of food and have the same purchasing power. In Romania's case, the difference in net nominal wage between the highest earning area and the lowest is more than 15% (excluding the capital city region). And if we take into consideration the capital city region (B-IF) and the lowest income region(South East) then the inequality is even greater, with a 60% difference. This means that people in poorer regions while earning less money have mostly the same expenses as those in richer areas. This will lead to inequality in affordability, directly increasing food insecurity. Another concern when discussing social inequality refers to gender inequality [10]. National and European statistics align with the findings of the FAO, with Bulgaria and Romania ranked among the top European Union member states in terms of food insecurity and poverty risks Furthermore, the data exposes substantial discrepancies in wages and opportunities between genders, leading to a greater number of women experiencing poverty, social exclusion, and consequent food insecurity in contrast to men. Bulgaria has the highest gap between men and women (5.4%) surprisingly followed by the Czech Republic (4.3%). Romania comes in third among the six with 3.1%.

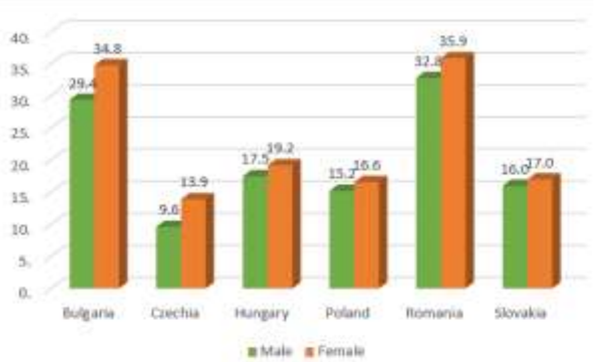

Fig. 4. Persons at risk of poverty or social exclusion by gender
Source: Eurostat [14].

A possible explanation for Czechia's score might be the fact that, even though the economic situation is good overall on a country level, the financial resources for women are quite low, due to lower employment and lower career prospects even though the percentage of educated women is quite large [39]. In the same statistics, Romania is at the bottom of the list, being only slightly above Greece. Food insecurity rooted in gender inequality is also the result of the fact that prevalently, women are in charge of the care aspect of households [4]. Traditionally, women procure groceries, cook, and are mostly in charge of growing their own food where possible [16]. This leads to a higher impact on them felt directly and acutely when the environment changes. Any issues caused by prices, availability of products, or even climate changes will directly force women to react and adapt the households' food systems [7]. Consequently, the burden of food insecurity falls disproportionately on women, exacerbating the existing gender inequality. This gendered division of labor within households [4][7][30] perpetuates a cycle where women are not only more vulnerable to the impacts of food insecurity but also face limited opportunities for economic empowerment and decision-making power regarding food choices. Thus, addressing gender disparities and promoting gender equality is crucial in tackling the multifaceted challenges of food insecurity and its implications for women's well-being.

CONCLUSIONS

The escalation of food insecurity, heightened by global occurrences such as the COVID-19 pandemic climate change or geopolitical instability, has emerged as a critical matter of concern. Their immediate consequences include notable surges in worldwide food and fertilizer prices, alongside higher volatility of the agricultural supply chain. Effectively addressing these issues necessitates prompt and timely actions, as underscored by insights gleaned from evaluations conducted during the COVID-19 pandemic. These evaluations emphasize the significance of early intervention to prevent the need for costly emergency food responses. In light of the escalating acute food insecurity on a global scale, it is imperative to bolster preparedness responses and prevention strategies. It is important to note that the exacerbation of food insecurity extends beyond conflict zones, exerting ripple effects that impact individuals already grappling with insecurity on a larger scale.

REFERENCES

[1]Akbari, M., Foroudi, P., Shahmoradi, M., Padash, H., Parizi, Z.S., Khosravani, A., Ataei, P., Cuomo, M.T., 2022, The Evolution of Food Security: Where Are We Now, Where Should We Go Next? Sustainability,14,3634,https://doi.org/10.3390/su14063 63.

[2]Alexandri, C., Luca, L., Food and nutrition security in Romania in the post-accession period, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol.16(2), 11-18.

[3]Ben Abdallah, M., Fekete-Farkas, M., Lakner, Z., 2021, Exploring the Link between Food Security and Food Price Dynamics: A Bibliometric Analysis, Agriculture, 11, 263. https://doi.org/10.3390/agriculture11030263

[4]Breen, R., Cooke, L. P., 2005, The Persistence of the Gendered Division of Domestic Labour, European Sociological Review, 21(1), 43–57. http://www.jstor.org/stable/3559583.

[5]Burman, J., Paul, B., Sembiah, S., Parida, D., Negi, R., Vantepaka, S., Subbakrishna, N., 2022, Association Between Household Food Insecurity and Nutritional Status Among Children of age <5 years: A Community-based Study in a Slum of Kolkata, Eastern India. J Family Med Prim Care, Jul;11(7):3885-3890. doi: 10.4103/jfmpc.jfmpc_635_21. Epub 2022 Jul 22. PMID: 36387641; PMCID: PMC9648303.

[6]Ciscar, J.C., Feyen, L., Soria, A., Lavalle, C., Raes, F., Perry, M., Nemry, F., Demirel, H., Rozsai, M., Dosio, A., Donatelli, M., Srivastava, A., Fumagalli, D., Niemeyer, S., Shrestha, S., Ciaian, P., Himics, M., Van Doorslaer, B., Barrios, S., Ibáñez, N., Forzieri, G., Rojas, R., Bianchi, A., Dowling, P., Camia, A., Libertà, G., San Miguel, J., de Rigo, D., Caudullo, G., Barredo, J.I., Paci, D., Pycroft, J., Saveyn, B., Van Regemorter, D., Revesz, T., Vandyck, T., Vrontisi, Z., Baranzelli, C., Vandecasteele, I., Batista e Silva, F., Ibarreta, D., 2014, Climate Impacts in Europe. The JRC PESETA II Project. JRC Scientific and Policy Reports, EUR 26586EN

[7]Cohen, P. N., 2004, The Gender Division of Labor: "Keeping House" and Occupational Segregation in the United States, Gender and Society, 18(2), 239–252.

[8]Derunova, E., Kireeva, N., Pruschak, O., 2019, Typology of regions according to the level of food security: Methodological approaches and solutions, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol.19(1), 135-145.

[9]Drynochkin, A., 2022, Food Security of Eastern European Countries in the Current Situation (On the Example of the Countries of the Visegrad Group and Albania). Available at http://dx.doi.org/10.2139/ssrn.4262901, Accessed on 2 October 2023.

[10]Dudek, H., Myszkowska-Ryciak, J., 2022, Food Insecurity in Central-Eastern Europe: Does Gender Matter? Sustainability, 14, 5435. https://doi.org/10.3390/su14095435

[11]Environmental Protection Agency, EPA, US, Climate change impacts on agriculture and food supply, https://www.epa.gov/climateimpacts/climate-change-impacts-agriculture-and-food-supply#topc, Accessed on 05 October 2023.

[12]European Commission, EDO European Drought Observatory, https://edo.jrc.ec.europa.eu/edov2/php/index.php?id=11 12, Accessed on 05 October 2023.

[13]European Commission, Database Harmonized Indices of Consumer Prices (HICP) annual data, https://ec.europa.eu/eurostat/web/hicp/database, Accessed on 03 Sept 2023.

[14]Eurostat, 2023, People at risk of poverty or social exclusion in 2022, https://ec.europa.eu/eurostat/web/products-eurostat-news/w/DDN-20230614-1, Accessed on 03 Sept 2023.

[15]FAO, 1996, Rome Declaration on World Food Security, Rome, World Food Summit, https://www.fao.org/3/w3613e/w3613e00.htm, Accessed on 02 October 2023.

[16]FAO, 2023, The status of women in agrifood systems, Rome, https://doi.org/10.4060/cc5343en

[17]FAO, IFAD, UNICEF, WFP and WHO, 2023, The State of Food Security and Nutrition in the World 2023, https://www.fao.org/3/cc3017en/online/cc3017en.html, Accessed on 07.10.2023.

[18]FAO, IFAD, UNICEF, WFP and WHO, 2018, The State of Food Security and Nutrition in the World 2018, Building climate resilience for food security and nutrition. Rome, FAO, Licence: CC BY-NC-SA 3.0 IGO.

[19]FAO, IFAD, UNICEF, WFP and WHO, 2022, In Brief to The State of Food Security and Nutrition in the World 2022.Repurposing food and agricultural policies to make healthy diets more affordable. Rome, FAO, https://doi.org/10.4060/cc0640en"

[20]FAO, IFAD, UNICEF, WFP and WHO, 2022, The State of Food Security and Nutrition in the World 2022, https://www.fao.org/3/cc0639en/cc0639en.pdf, Accessed on 03 October 2023.

[21]FAO, IFAD, UNICEF, WFP and WHO, 2023, The State of Food Security and Nutrition in the World 2023. Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum. Rome, FAO, https://doi.org/10.4060/cc3017en

[22]GRFC, FSIN and Global Network Against Food Crises, 2023, Rome.

[23]Iglesias, A., Quiroga, S., Diz, A., 2011, Looking into the future of agriculture in a changing climate. European Review of Agricultural Economics, 38(3), 427–447. https://doi.org/10.1093/erae/jbr037

[24]International Monetary Fund, IMF, Crisis upon crisis, IMF Annual report 2022, https://www.imf.org/external/pubs/ft/ar/2022/download s/imf-annual-report-2022-english.pdf, Accessed on 03 October 2023.

[25]International Monetary Fund, IMF, 2021, Database of fiscal policy responses to Covid-19, https://www.imf.org/en/Topics/imf-and-covid19/Fiscal-

Policies-Database-in-Response-to-COVID-19, Accessed on 02 October 2023.
[26]Jyoti, D. F., Frongillo, E. A., Jones, S. J., 2005, Food insecurity affects school children's academic performance, weight gain, and social skills. The Journal of nutrition, 135(12), 2831–2839. https://doi.org/10.1093/jn/135.12.2831
[27]Kim, T.J., von dem Knesebeck, O., 2018, Income and obesity: what is the direction of the relationship? A systematic review and meta-analysis, BMJ Open, doi: 10.1136/bmjopen-2017-019862
[28]Maxwell, S., 1996, Food security: a post-modern perspective. Food Policy, 21, 155-170.
[29]Mbow, C., Rosenzweig, C., Barioni, L.G., Benton, G., Herrero, M., Krishnapillai, M., Liwenga, E., Pradhan, P., Rivera-Ferre, M.G., Sapkota, T., Tubiello, F.N., Xu, Y., 2019, Food Security. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems https://doi.org/10.1017/9781009157988.007"
[30]Modiri, F., Sadeghi, R., 2021, Gendered Division of Domestic Labour and Childbearing Intentions in Tehran, Iran, J Family Reprod Health, 15(4):220-228. doi: 10.18502/jfrh.v15i4.7887. PMID: 35340796; PMCID: PMC8897814.
[31]Mostova, E., Hutorov, A. 2023, Food security in the countries of Central and Eastern Europe: state and strategic directions of provision. Ekonomika APK. 30. 20-29. 10.32317/2221-1055.202301020. found on https://www.researchgate.net/publication/370042550_Food_security_in_the_countries_of_Central_and_Eastern_Europe_state_and_strategic_directions_of_provision Accessed on 07.10.2023
[32]National Institute of Statistics (Institutul Național de Statistică), www.insse.ro, Accessed on 07.10.2023.
[33]Osei, A., Pandey, P., Spiro, D., Nielson, J., Srestha, R., TalikDer, Z., Quinn, V., Haselow, N., 2010, Household Food Insecurity and Nutritional Status of Children Aged 6 to 23 Months in Kailali District of Nepal, Food and Nutrition Bulletin, 31(4):483-494. doi:10.1177/156482651003100402
[34]Rabbi, M.F., Ben Hassen, T., El Bilali, H., Raheem, D., Raposo, 2023. Food Security Challenges in Europe in the Context of the Prolonged Russian–Ukrainian Conflict, Sustainability 15, no. 6: 4745. https://doi.org/10.3390/su15064745
[35]Román, A., 2023, Food security in 2023: EU response to an evolving crisis, EPRS - European Parliamentary Research Service.
[36]Sumsion, R.M., June, H.M., Cope, M.R., 2023, Measuring Food Insecurity: The Problem with Semantics. Foods, 12, 1816. https://doi.org/10.3390/foods12091816
[37]UN, 1999, Standard country or area codes for statistical use (M49), https://unstats.un.org/unsd/methodology/m49/, Accessed on 02 October 2023.
[38]World Health Organization, Disease outbreak news, Pneumonia of unknown cause- China, 2020, https://www.who.int/emergencies/disease-outbreak-news/item/2020-DON229 Accessed on 03 October 2023.
[39]World Health Organization, WHO, Gender Inequality Index (GII), https://www.who.int/data/nutrition/nlis/info/gender-inequality-index-(gii), Accessed on 07 October 2023.

MAIZE PRODUCTION AND TRADE AND SCIENTIFIC-TECHNOLOGICAL SOLUTIONS TO MITIGATE CLIMATE CHANGE IMPACT IN UKRAINE

Petro BOIKO[1], Nataliia KOVALENKO[2*], Yevgen YURKEVYCH[3], Serhii ALBUL[3], Nataliia VALENTIUK[4]

[1]National Scientific Center «Institute of Agriculture NAAS», 2-B, Mashynobudivnykiv Street, Kyiv region, 08162, Ukraine
[2]Institute of Plant Physiology and Genetics of the NAS of Ukraine, 31/17, Vasylkivska Street, Kyiv, 03022, Ukraine, E-mail: boikonp@ukr.net
[3]Odessa State Agrarian University of the Ministry of Education and Science of Ukraine, 13, Panteleimonivska Street, Odesa, 65039, Ukraine, E-mail: yevgen21@ukr.net
[4]Institute of climate-smart agriculture of the NAAS, 24, Maiatskadoroha Street, Odesaregion, 67667, Ukraine

Corresponding author: boikonp@ukr.net

Abstract

The article examines the prospects of Ukraine on the world grain market and ways to increase the efficiency of maize cultivation using environmentally safe technologies in the conditions of the negative impact of climate change and other stress factors. The methodological approach takes into account the peculiarities of agrarian production based on the use of data of the Food and Agriculture Organization of the United Nations, United States Department of Agriculture, United Nations, Ministry of Agrarian Policy and Food of Ukraine and State Statistics Service of Ukraine. The dynamics of world production and export of maize grain, sown areas, production and yield of maize in Ukraine are demonstrated, which directly focuses attention on the competitiveness of Ukrainian maize on the world grain market. These arguments are confirmed by analytical results, which show that in 2022, among the world leaders of maize grain producers, Ukraine took fifth place, and among exporters – fourth. In order to mitigate the impact of climate change and other stress factors on the effective production and export of Ukrainian maize, adaptation measures are proposed, which consist in the application of modern technologies, which include: optimization of the structure of sown areas and scientifically based crop rotations with the effective use of competitive varieties and hybrids of agricultural crops, the introduction of organic and mineral fertilizers and plant protection products, the use of soil protective tillage, sideration and mulching, irrigation systems, and also the productive use of plant residues with the application of modern biodestructors. Their comprehensive implementation will contribute to the development of maize yield, grain quality, preservation of biodiversity and the solution of the grain-food problem in the world.

***Key words*:** *maize, production, trade, climate change, scientific-technological solutions to sustain yield, Ukraine*

INTRODUCTION

Nowadays, the application of environmentally safe technologies based on biologization elements, which ensure the reduction of negative impact on the environment and the preservation of natural resources, and also satisfy the consumers of the world market with high-quality agricultural products, is gaining importance in the world [19; 23]. Such technologies during the cultivation of grain crops contribute to the regeneration of quality components of the environment due to self-recovery processes, and also provide a solution to the grain-food problem, especially in connection with climate changes [18; 20; 21; 24].

To reduce the negative impact of climatic changes, Ukrainian and foreign scientists have proposed environmentally safe technologies that ensure the diversification of agrarian production and reduce the riskiness of its management in different soil-climatic conditions. In particular, for adaptation to climate changes, the effective use of modern varieties and hybrids of agricultural crops with high genetic potential for productivity and quality, stable resistance to diseases, pests and other adverse environmental factors has been established [4; 13; 22; 26; 33; 35]. Optimization of the structure of sown areas and crop rotation, which are one of the main elements of biologization, contributing to the accumulation, preservation and rational use of soil moisture, and also the regulation of the nutrient regime of the soil, was carried out [9; 10; 11; 19; 34; 36; 37]. In order to solve the problem of reproduction of soil fertility, attention is focused on the optimal application of organic and mineral fertilizers [14; 32; 39], the use of soil protective tillage [12; 45]. The effectiveness of using the natural mass of plant residues – straw of grain crops, tops and stems of maize and sunflower, husks of root crops, and also siderates has been established [2; 3; 17]. At the same time, further research into the effectiveness of the destruction of plant residues using biodestructors, which accelerate the recovery processes in the soil, is of great importance in the context of climate change.

The purpose of the article is to establish the long-term dynamics and ways of increasing the production and yield of maize in Ukraine based on the application of modern technologies, which including: optimization of the structure of sown areas and scientifically based crop rotations with the effective use of competitive varieties and hybrids of agricultural crops, the introduction of organic and mineral fertilizers and plant protection products, the use of soil protective tillage, sideration and mulching, irrigation systems, and also modern biodestructors, which contribute to the maximum use of the natural mass of plant residues, especially in the conditions of the negative impact of climate change and other stress factors.

MATERIALS AND METHODS

The information base includes a large array of information: scientific articles and statistical data of the Food and Agriculture Organization of the United Nations, United States Department of Agriculture, United Nations, Ministry of Agrarian Policy and Food of Ukraine and State Statistics Service of Ukraine.

Comparative analysis and the calculation-constructive method were used to identify the trends of changes in the main indicators of the study: world production and export of maize grain; production, yield and sown areas of maize in Ukraine during 1990–2022, which are graphically illustrated.

The abstract-logical method was used – for generalization and critical analysis, and also for the formation of conclusions regarding the effectiveness of the use of plant residues in maize crops with the use of biodestructors.

The directions of the development of environmentally safe technologies for the efficient production of maize grain in Ukraine under the conditions of climate change are highlighted.

RESULTS AND DISCUSSIONS

Maize position in the global grain production and export

Analyzing the structure of world grain production, it can be proven that maize is the leader among grain crops. In particular, in 2022, the largest share falls on grain production: maize – 42%, wheat – 28%, rice – 18%, barley – 6%, other grain crops – 6% [27]. After all, maize is a highly productive crop that is widely used in various branches of agriculture and industry around the world. For example, for the production of food products, as a high-energy feed for livestock and poultry farming, as a raw material for the production of biofuel and biogas, in the pharmaceutical, chemical and other industries, and also as a nutritious green fertilizer [1]. Thus, the valuable properties of maize ensure its steadily growing demand on the world market.

Another important factor in the increase in the production and export of maize grain is the stable growth of its global consumption due to the increase in the number of the planet's population, which during 1950–2022 has increased more than 3 times and amounts to 8.0 billion people, and in 2050, according to UN forecasts, it will increase to 9.7 billion people [30]. In particular, during 2011–2021, there is a trend of a 33% increase in world production of maize grain, which in 2021 amounted to 1,21 billion tonnes. During this period, the world export of maize grain increased by 71% and amounted to 0.20 billion tonnes in 2021 (Fig. 1). Therefore, this trend of increasing the world production and export of maize grain indicates the ability to satisfy the demand of mankind in the products of its processing.

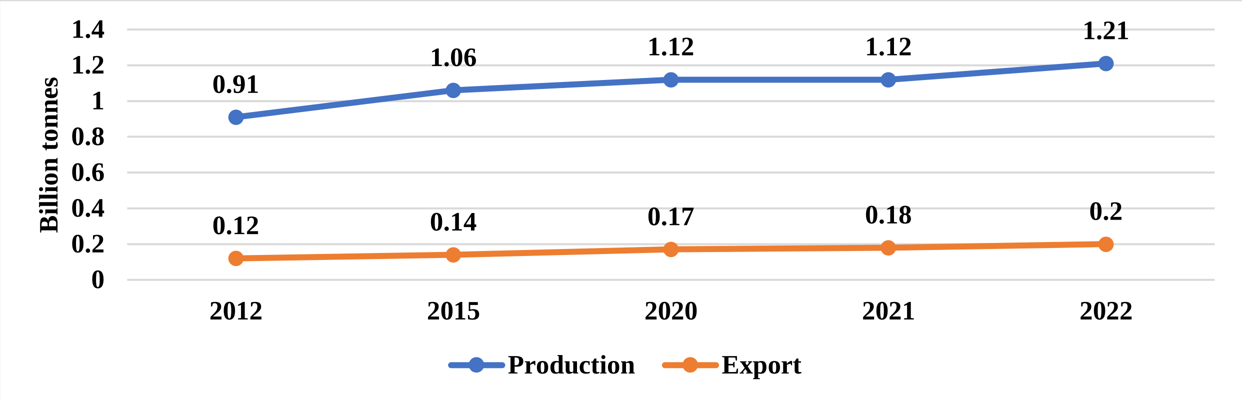

Fig. 1. Dynamics of world production and export of maize, 2012–2022
Source: Own design based on the data from [27].

However, the negative impact of climate change, which can restrain the further growth of global production of maize grain, has increased now [23; 45]. In this context, the implementation of environmentally safe technologies for the production of maize grain, the cultivation of which is widespread in 166 countries of the world, due to its high level of productivity, and also adaptability to different soil-climatic conditions, is relevant [20].

The position of Ukraine among the top maize grains producing and exporting countries

The role of Ukraine in the world market of maize grain production is becoming more significant.

If until 1992 Ukraine was not included in the top twenty at all, then in 2010 it was established in the top ten world producers of maize grain, overtaking Italy, Canada, Romania and Hungary [31].

In 2021, Ukraine entered the top five world leaders in the production of maize grain, including the USA, China, Brazil and Argentina (Fig. 2).

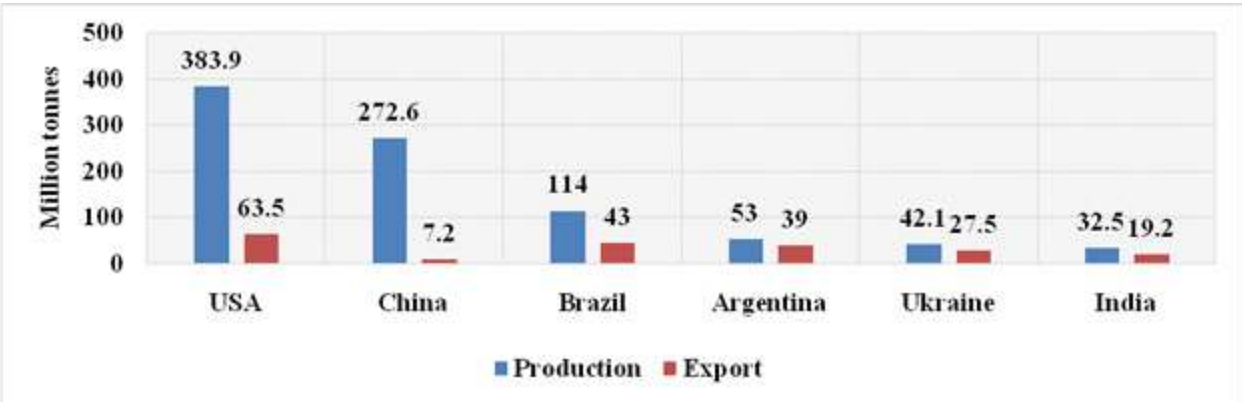

Fig. 2. Position of Ukraine among the leading countries producing and exporting maize grains, 2021
Source: Own design based on the data from [31].

After all, the total volume of maize grain production of these countries is 823.5 million tonnes or 68% of the global indicator. At the same time, Ukraine overtook maize grain production: India with 32.5 million tonnes, Mexico with 27.6 million tonnes, South Africa with 16.3 million tonnes, France with 15.4 million tonnes. In addition, in 2021

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Ukraine, together with the USA, Brazil and Argentina, joined the group of the world's largest exporters of maize grain, which provided more than 85% of the export of this crop.

Ukraine's maize export and import trade partners

During 2010–2021, Ukraine expanded its activities on foreign markets by 1.5 times – from 30 to 46 countries, to which it exported maize worth more than 10 thousand dollars USA.

Every year, up to 95% of Ukrainian maize is sold on foreign markets [29]. In particular, in 2021, Ukraine exported 94.4% of maize grain to the following countries: China – 32.1%, EU – 30.4%, Egypt – 8.95%, Iran – 6.81%, Turkey – 4.38%; Israel, Great Britain – 2.39–2.72%; Libya, Korea, Tunisia, Algeria – 1.29–1.99% (Fig. 3).

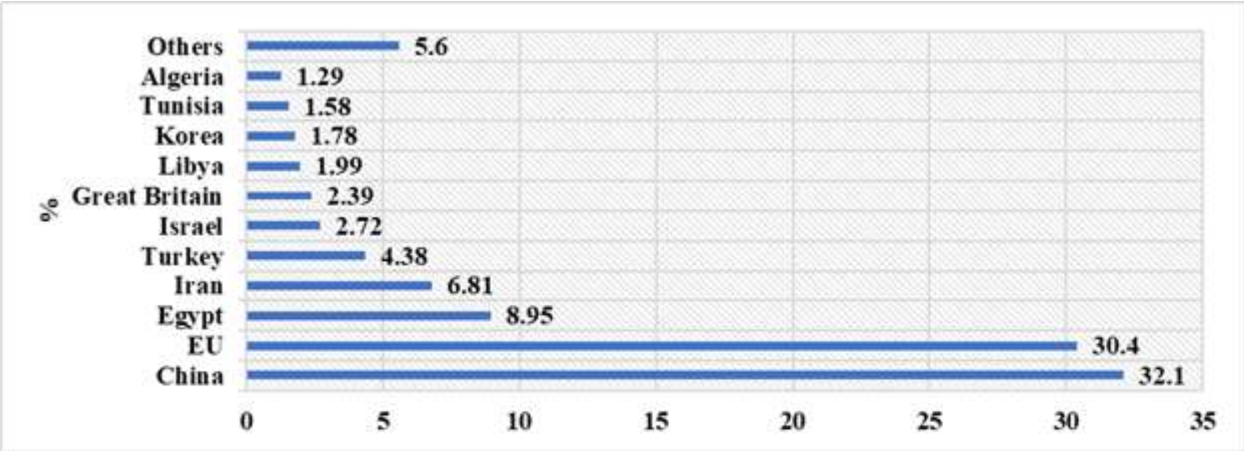

Fig. 3. Leading importing countries of Ukrainian maize, 2021
Source: Own design based on the data from [29].

China is the most promising importer and the largest maize market for Ukraine. Over the past decade, China's annual demand for maize has been constantly grown, reaching almost 300 million tonnes in 2022. Compared to other countries, in 2021 China became the main importer of Ukrainian maize – by 1.87 billion dollars USA or 32.1% [29]. In 2013, Ukraine supplied maize to China for the first time, and in 2015 it became its largest exporter (Fig. 4).

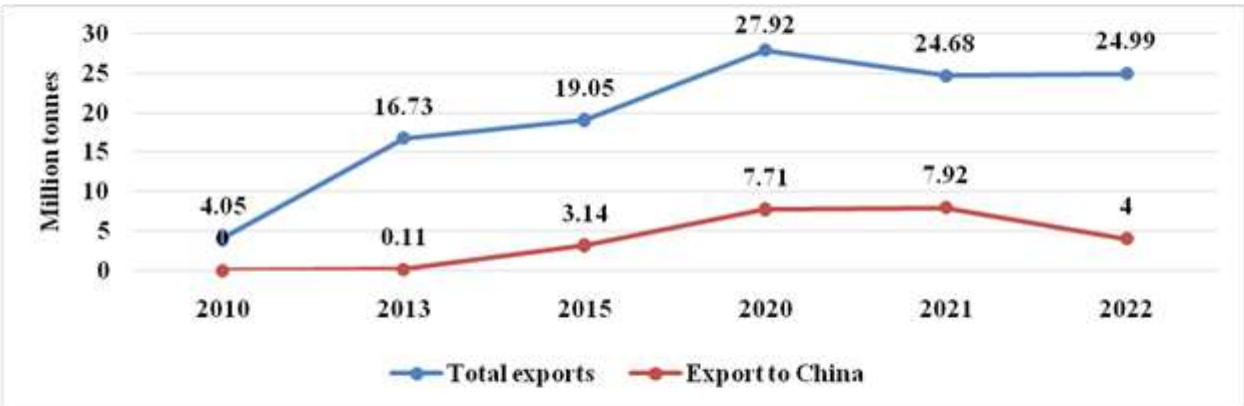

Fig. 4. Dynamics of export potential of Ukrainian maize, 2010–2022
Source: Own design based on the data from [29].

China practically did not stop buying Ukrainian maize, with the exception of February 2020, when the peak of the Covid-19 epidemic took place in the country. During 2013–2021, the total export of Ukrainian maize to China increased 70 times. In 2021, the volume of maize supplies to China became the highest in the history of

Ukrainian-Chinese agrarian trade, when China bought 28.4 million tonnes of maize on world markets, of which 7.92 million tonnes came from Ukraine. Therefore, Ukraine turned out to be the largest supplier of maize to China, providing almost 30% of imports. In 2022, maize imports into China amounted to 9.2 million tonnes, of which only 4 million tonnes were of Ukrainian origin. In 2022, China experienced a shortage of Ukrainian maize supplies, which it eliminated by using the accumulated reserves.

The growing demand of the European Union countries for Ukrainian maize is justified by their close location, which greatly facilitates logistics (Fig. 5).

Turkey, which is geographically closest to Ukraine, has become a promising market for the sale of maize grain for Ukrainian farmers. So, today Ukrainian production of maize grain is in great global demand thanks to relatively low prices and the optimal geographical location of Ukraine relative to the leading importing countries.

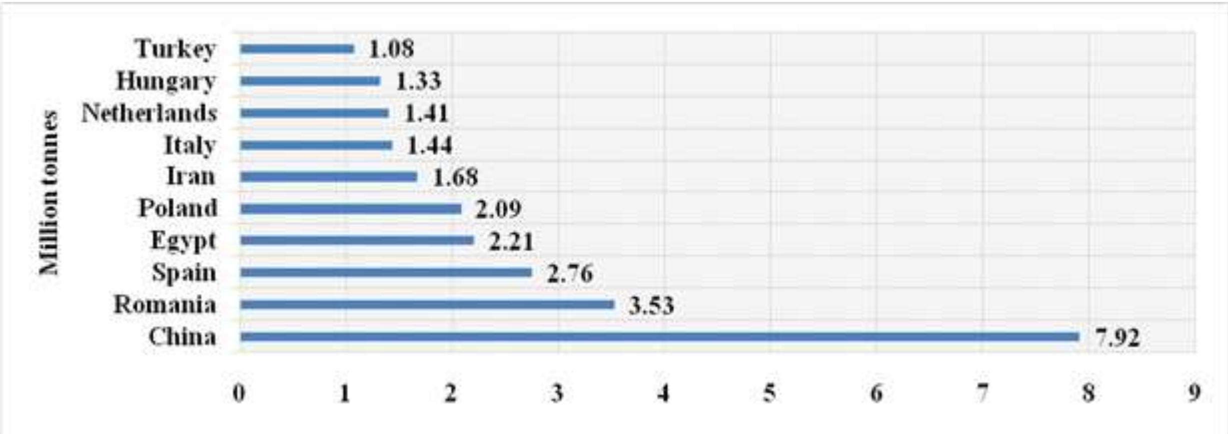

Fig. 5. Leading importing countries of Ukrainian maize, 2021
Source: Own design based on the data from [29].

Ukraine's area and population compared to other European countries

The Ukraine is the largest country in Europe by area (Fig. 6). Its land fund is 60.3 million hectares, which occupies 6% of the territory of Europe and 0.5% of the globe [25]. Ukraine guarantees efficient agrarian production, because most of its territory is occupied by humus-rich chernozem soils [5].

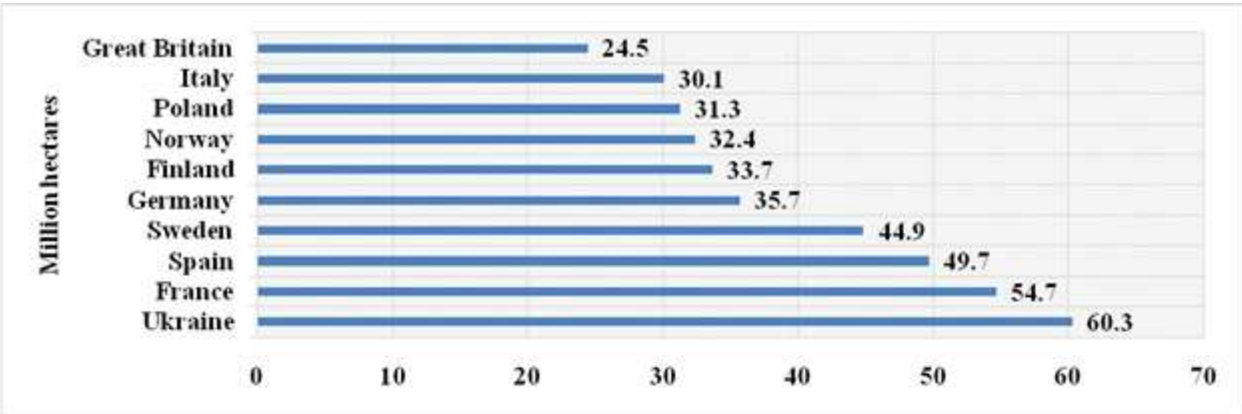

Fig 6. European countries with the largest areas of territory, 2021
Source: Own design based on the data from [25].

They provide Ukraine with a leading place in the production of wheat, barley, sunflower, maize and rapeseed. Its fertile lands can feed 600 million people [6], which is 150 million more than the population of the EU [40].

Cultivated area with maize, production and yield in Ukraine

We will analyze the dynamics of sown areas, yield and production of maize grain in Ukraine during 1990–2021. During this period, the sown areas of grain, technical and fodder crops were characterized by instability and a significant change. In particular, due to an increase of more than 4.5 times in the area of grain maize, there was an 8.9% growth in the sown areas of grain crops. Due to an increase in the areas of sunflower and rapeseed, there was by 2.5 times growth in the sown areas of technical crops (Fig. 7). At the same time, the decrease in areas of perennial and annual grasses, maize for silage and green fodder led to a reduction in the sown areas of fodder crops by 8 times [29]. Thus, during 1990–2021, the structure of grain, technical and fodder crops sown areas underwent significant changes, which caused a violation of the use of better predecessors and periods of crop return to the previous place of cultivation in crop rotations. Such an unjustified transformation led to a reduction in soil moisture reserves, a decrease in its fertility, the spread of weeds, diseases and pests, which caused a decrease in the yield of agricultural crops [45].

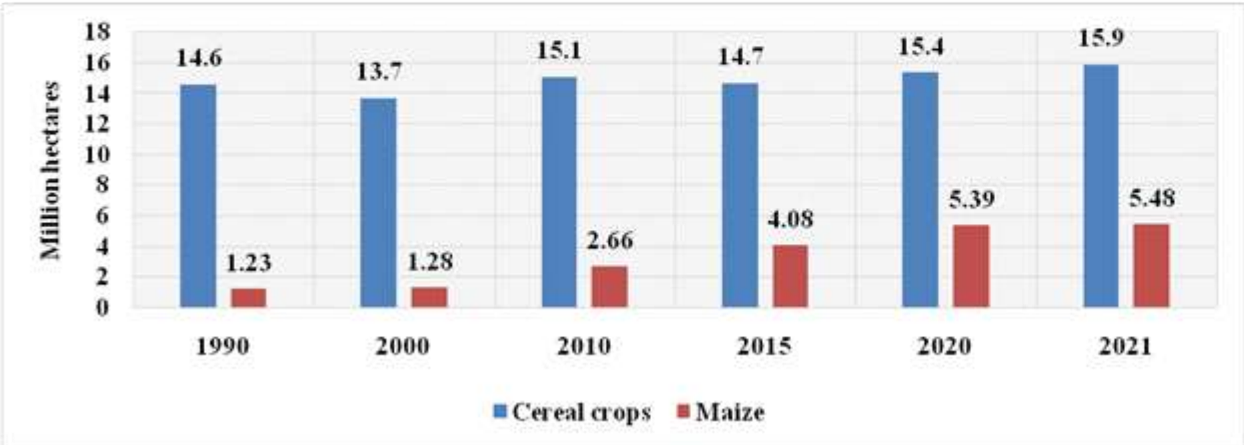

Fig. 7. Dynamics of cultivated areas of cereal crops and maize in Ukraine, 1990–2021
Source: Own design based on the data from [29].

During 1990–2021, Ukrainian agrarians developed and implemented innovative cultivation technologies that increased the national production of grain crops by 69% [29]. During this period, the production of grain maize increased almost 9 times, but due to the expansion of sown areas (Fig. 8).

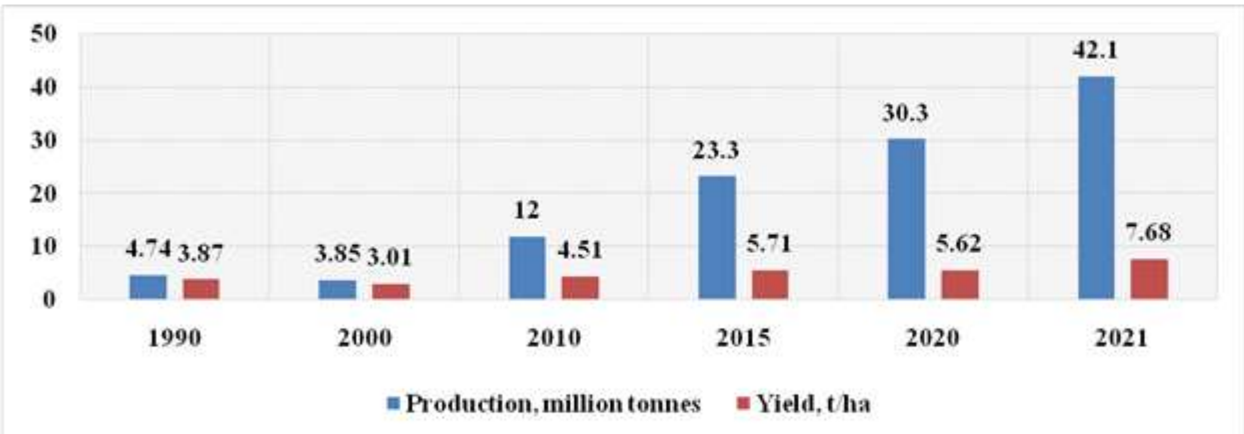

Fig. 8. Dynamics of production and yield of maize in Ukraine, 1990–2021
Source: Own design based on the data from [29].

Due to the violation of crop rotations, soil degradation increased, which negatively affected the yield of grain maize, which increased only 2 times and in 2021 was 7.68 t/ha, which is much lower than the potentially possible level in the EU countries – 10 t/ha [27].

In 2022, the sown area of grain crops decreased to 11.7 million hectares, maize – to 4.63 million hectares, which negatively affected production. Only 53.1 million tonnes of grain crops were collected with a yield of 4.54 t/ha, including maize grain – 25.6 million tonnes with a yield of 5.53 t/ha [28].

These are the lowest indicators in the last ten years, which were negatively affected a decrease in the sown and harvested areas.

Challenges in agriculture due to climate change and scientific-technological solution to mitigate their impact

There are also negative factors: climatic conditions – rainy summer and autumn, destabilization of fertilizers for plant protection products, and also a shortage of elevators, due to which part of the maize crop was left to winter in the field.

During 1880–2020, the average annual air temperature on the planet increased by 1.1°C. At the same time, in the regional aspect, such an increase occurs unevenly. For example, during this period, the growth rate of the average annual air temperature in Europe is 1.7°C, in Ukraine – 2.2°C, including during 1990–2020 – 1.2°C [16]. Thus, warming in Ukraine occurs at a faster pace, although the average annual precipitation remains practically unchanged: in the Steppe – 350–450 mm, in the Forest-Steppe – 450–550 mm, in the Polissia – 550–650 mm [45]. At the same time, an increase in air temperature increases the evaporation of moisture and causes its redistribution. As a result, excessive moisture evaporates in some regions and droughts intensify. In other regions, moisture condenses and causes frequent downpours and storms that cause flooding risks. For example, during 1990–2020, Ukraine experienced an uneven distribution of precipitation and rainfall intensity, which are torrential in nature and cause inefficient accumulation of moisture in the soil [7]. In particular, when the monthly rate of precipitation falls in a few hours, and in another period there is no rain at all, which increases the intensity and duration of droughts. In addition, an increase in the average winter air temperature by 1–2°C causes a change in the systematicity of seasonal phenomena – snowfall, spring floods, and the beginning of flowering [16].

Due to climate change, long-term and extreme heat waves are spreading around the world. For example, heat records were recorded in the summer of 2019: in Germany – 41.7°C, in Belgium – 41.8°C, in France – 42.6°C. In 2021, a heat wave with a record air temperature of 49.0°C was recorded in Canada. In the summer of 2022, the heat record exceeded 40.0–43.0°C in Great Britain and France, and the highest air temperature was recorded in Portugal, which was 47.0°C [7]. Therefore, heat waves caused by climate change represent the greatest climatic danger and lead to temperature extremes in many countries of the world. It can be concluded that Ukraine belongs to the number of regions of the planet where climatic changes are becoming quite noticeable, especially in the direction of increasing aridity, which reduces the productive potential of agricultural crops.

In 2023, high prices and a shortage of fuel, mineral fertilizers and plant protection products will lead to a decrease in the yield and productions of grain crops, in particular maize. To mitigate the impact of today's global challenges and threats on maize yield and production, a wide range of adaptation measures is proposed:

(a) the use of modern varieties and hybrids of agricultural crops with high genetic potential for productivity and quality, stable resistance to weeds, diseases, pests and other negative environmental factors;

(b) the optimization of the structure of sown areas and scientifically based crop rotations with the cultivation of traditional and rare crops;

(c) the application of effective predecessors of agricultural crops and periods of their return to the previous place of cultivation in crop rotations;

(d) the introduction of organic and mineral fertilizers, which ensure regulation of the nutrient regime of the soil;
(e) the introduction of biological plant protection products against weeds, diseases and pests;
(f) the implementation of soil protective tillage, which contributes to the accumulation, preservation and rational use of soil moisture;
(g) the sideration and mulching;
(h) the irrigation systems;
(i) the productive use of the natural mass of plant residues – straw of grain crops, tops of maize and sunflower, husks of root crops;
(j) the use of modern biodestructors for transforming plant residues into organic matter destined to nourish the soil and improve its fertility.

In this respect, environmentally safe technologies for growing maize include the application of modern biodestructors to accelerate recovery processes in the soil based on the decomposition of plant residues [8; 15; 41]. Modern biodestructors include preparations of Ukrainian production: Cellulad of mushroom origin – developed by specialists of «Enzim-Agro» Trading House LLC [3], Ekostern of bacterial origin – developed by specialists of «BTU-Center» company [38]. These biodestructors simultaneously suppress pathogenic microflora and improve the soil, enriching plant remains with useful and viable microorganisms, fungi and bacteria at low and high temperatures [42; 43; 44]. Thanks to their complex application with organic and mineral fertilizers and siderates in scientifically based crop rotations, the level of soil fertility and productivity of agricultural crops increases by 10–30% [3]. In arid conditions, the degree of destruction of plant residues when using irrigation increases by 2.2–2.6 times [3].

CONCLUSIONS

It can be concluded that thanks to the increase in the number of the planet's population and the valuable properties of maize grain, a stable growth in its global consumption has been ensured. On the basis of a comparative analysis, it was established that during 2011–2021, the world production of maize grain increased by 33%, export – by 71%. The calculations showed that in 2021, Ukraine entered the top five world leaders of producers and the top four world leaders of exporters of maize grain. It has been proven that due to relatively low prices and optimal geographical location, China and the countries of the European Union: Romania, Spain, Poland, Italy, Netherlands and Hungary became the leading importers of Ukrainian maize.

The comparative analysis showed that during 1990–2021, the production of grain crops in Ukraine increased by 69% due to an increase in the production of maize grain by almost 9 times – from 4.74 to 42.1 million tonnes due to a 4.5-fold increase in its sown area – from 1.23 to 5.48 million hectares. Due to high competition in the foreign market, the sown areas of technical crops increased by 2.5 times thanks to the expansion of sunflower and rapeseed. At the same time, the sown areas of fodder crops decreased by almost 8 times due to the rapid decrease in the sowing of perennial and annual grasses, maize for silage and green fodder.

Based on the calculations, it was found that the violation of scientific technologies, along with the negative impact of climate change and other stress factors, caused a decrease in the yield of grain maize. These arguments are supported by analytical results, which show that during 1990–2021, the yield of maize grain in Ukraine increased only 2 times – from 3.87 to 7.68 t/ha and is significantly lower than the potentially possible level.

The comparative analysis showed that in 2022, it was recorded a sharp decrease in the yield of maize grain reaching the lowest level in the last ten years – 5.53 t/ha, which, along with a reduction in the sown area by 15%, caused a decrease in the production of maize grain by 1.7 times.

A number of adaptation measures are proposed to overcome the negative impact of climate change and other stress factors, which consist in the use of environmentally safe technologies for the cultivation high-yielding maize and include the application of modern biodestructors to accelerate recovery processes in the soil based on the decomposition of plant residues. The effectiveness of the use of modern biodestructors increases along with the introduction of scientifically based crop rotations, the introduction of organic and mineral fertilizers, plant protection products, the application of soil protective tillage with sideration and mulching, irrigation systems, which will ensure the competitive production of maize grain in different soil-climatic conditions of Ukraine and the world, especially in connection with climate changes.

REFERENCES

[1]Boiko, P. I.,1990, Maize in intensive crop rotations,Kyiv: Urozhai, 142.
[2]Boiko, P. I., Kovalenko, N. P., 2017, How to choose and use siderates, Propozytsiia, Vol. 1, 104–107.
[3]Boiko, P., Kovalenko, N., Yurkevych, Ye., Valentiuk, N., Albul, S., 2023, The history, current state and prospects for the implementation of elements of biologization for the efficient cultivation of corn in organic farming of the Southern Steppe of Ukraine, International Journal of Ecosystems and Ecology Science (IJEES), Vol. 13(1), 39–58. https://doi.org/10.31407/ijees13.106.
[4]Borodai, I., Kovalenko, N., 2022, Contribution of scientists of Saint Volodymyr University in the development of physiological science in the second half of the 19th – the beginning of the 20th century, East European historical bulletin, 25, 92–107. https://doi.org/10.24919/2519-058X.25.269531.
[5]Boyko, P., Litvinov, D., Demidenko, O., Rasevich, V., 2019, Prediction humus level of black soils of Forest-Steppe Ukraine depending on the application of crop rotation, fertilization and tillage, International Journal of Ecosystems and Ecology Science (IJEES), Vol. 9/1, 135–162. https://doi.org/10.31407/ijees9118.
[6]Chernozems of Ukraine can feed more than half a billion people – expert, Korrespondent.net, https://korrespondent.net/business/economics/1571914-chernozemy-ukrainy-mogut-prokormit-bolee-polu-milliarda-chelovek-ekspert, Accessed on Feb.25, 2023.
[7]Climate change in Ukraine and the world: causes, consequences and solutions for countermeasures, Ecoaction, https://ecoaction.org.ua/zmina-klimatu-ua-ta-svit.html, Accessed on Feb.25, 2023.
[8]Dar, D. H., 2009, Soil Microbiology and Biochemistry, New IndiaPublishing Agency, 513.
[9]Demidenko, O., Boiko, P., Tsimbal, Ya., Kovalenko, N., 2020, Management of moisture resource potential in agrocenoses of Forest-Steppe of Ukraine, International Journal of Ecosystems and Ecology Science (IJEES), Vol. 10/4,733–746. https://doi.org/10.31407/ijees10.423.
[10]Demydenko, O. V., Boyko, P. I., Velychko, V. A., 2018, Long-term dynamics of humus content under different technologies of soil tillage, Agricultural Science and Practice, Vol. 5 (1), 3–16. https://doi.org/10.15407/agrisp5.01.003.
[11]Demydenko, O. V., Boiko, P. I., Blaschuk, M. I., Shapoval, I. S., Kovalenko, N. P., 2019, Crop rotation and fertility of chernozem of the Left-Bank Forest-Steppe: monograph, Smila: Chornobayivske KPP, 484.
[12]Didenko, N., Lavrenko, S., Lavrenko, N., Sardak, A., Didenko, S., 2022, Economic efficiency of corn grain cultivation with the new technologies of tillage and irrigation, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(3), 187–194.
[13]Dunareanu, I., Bonea, D., 2022, Comparative performance and stability of some maize hybrids in the agroclimatic conditions of Craiova, Dolj County, Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(3), 203–209.
[14]Falola, A., Mukaila, R., Mahmud, M., 2022, Are small-scale organic maize farmers technically efficient? Evidence from Nigeria, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(4), 217–224.
[15]Hossain, M., Fragstein, P., Niemsdorff, P., 2017, Effect of Different Organic Wastes on Soil Properties and Plant Growth and Yield, Sc. Agr. Boh., Vol. 48 (4), 224–237. http://doi.org/10.1515/sab-2017-0030.
[16]Ivaniuta, S. P., Kolomiiets, O. O., Malynovska, O. A., 2020, Climate change: consequences and adaptation measures: analytical report, Kyiv: NISD, 110.
[17]Kovalenko, N. P., 2012, Historical aspects of the origin and development of scientific knowledge about sidereal crop rotations, Rural host, Vol. 11–12, 27–33.
[18]Kovalenko N. P., 2012, Ecologically balanced crop rotations in the system of alternative agriculture: historical aspects, Agroecological journal, Vol. 4, 95–99.
[19]Kovalenko, N. P., 2014, Becoming and development of scientifically and organizational bases of application of domestic crop rotations in the systems of farming (the second half of the 19th – the beginning of the 21st centuries): monograph, Kyiv: TOV «Nilan-LTD», 490.
[20]Kovalenko, N. P., 2019, Ecologization of agricultural production: development of implementation of innovative technologies in Ukraine at the beginning of the 21st century, Modern Problems of History of Science and Biographical Study: col. mon., Lviv: Liha-Pres, 41–64. https://doi.org/10.36059/978-966-397-148-3/41-64.
[21]Kovalenko, N., Bey, R., 2021, Southern Branch of the VASHNIL (1969–1990) as a model of organization of agrarian science in the Ukrainian and Moldovan

SSR, East European historical bulletin, Vol. 20, 162–170. https://doi.org/10.24919/2519-058X.20.240032.
[22]Kovalenko, N., Borodai, I., Shchebetiuk, N., 2021, The development of biochemical research to improve the physiology of crop nutrition in Ukraine in the second half of the 20th century, International Journal of Ecosystems and Ecology Science (IJEES), Vol. 11(2), 299–310. https://doi.org/10.31407/ijees11.214.
[23]Kovalenko, N., Hloba, O., 2021, The model of regional development of agrarian science in Ukraine: the relationship between a centenary past and today, International Journal of Ecosystems and Ecology Science (IJEES), Vol. 11/4, 845–856. https://doi.org/10.31407/ijees11.423.
[24]Kovalenko, N., Yehorova, S., 2022, The history of development and the perspectives of implementation of innovative technologies for the environmentally safe use of water and land resources in Ukraine at the beginning of the 21st century, International Journal of Ecosystems and Ecology Science (IJEES), Vol. 12/1, 87–100. https://doi.org/10.31407/ijees12.110.
[25]Land directory of Ukraine for 2021, Research of the NSC «Institute of Agrarian Economics of the NAAS», 2021, 30.
[26]Morhun, V. V., Shvartau, V. V., Konovalov, D. V., Mykhalska, L. M., Skryplov, V. O., 2022, Club of 100 centners. Modern varieties and systems of nutrition and protection of winter wheat: scientific edition, Kyiv: Vistka, Vol. 11, 106.
[27]Official website of the FAO of the UN, http://www.fao.org/faostat/en/#data/QCL, Accessed on Feb.25, 2023.
[28]Official website of the Ministry of Agrarian Policy and Food of Ukraine, https://minagro.gov.ua/news/vijna-zminyuye-strukturu-posivnih-ploshch-pershi-prognozi-urozhayu-2023-roku, Accessed on Feb.25, 2023.
[29]Official website of the State Statistics Service of Ukraine, https://www.ukrstat.gov.ua, Accessed on Feb.25, 2023.
[30]Official website of the UN, https://www.un.org/en/academic-impact/97-billion-earth-2050-growth-rate-slowing-says-new-un-population-report, Accessed on Feb.25, 2023.
[31]Official website of the USDA, https://usda.library.cornell.edu/concern/publications/zs25x844t?locale=en, Accessed on Feb.25, 2023.
[32]Orekhivskyi, V., Kryvenko, A., Kovalenko, N., Burykina, S., Parlikokoshko, M., 2022, Efficiency of using organo-mineral biopreparations as elements of biologization in chickpea cultivation technologies in the arid Southern Steppe of Ukraine, International Journal of Ecosystems and Ecology Science (IJEES), Vol. 12(4), 15–26. https://doi.org/10.31407/ijees12.403.
[33]Popescu, A., 2015, Analysis of the evolution and distribution of maize cultivated area and production in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 15(3), 253–260.
[34]Popescu, A., 2018, Maize and wheat – top agricultural products produced, exported and imported by Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 18(3), 339–352.
[35]Popescu, A., Dinu, T. A., Stoian, E., Serban, V., 2020, Variation of the main agricultural crops yield due to drought in Romania and Dobrogea region in the period 2000–2019, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 20(4), 397–416.
[36]Popescu, A., Stanciu, M., Serban, V., Ciocan, H. N., 2022, Cereals production and price in the European Union, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(4), 565–578.
[37]Popescu, A., Tindeche, C., Marcuta, A., Marcuta, L., Hontus, A., 2022, Cereals production between climate change and price boom in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(4), 579–594.
[38]Stubble biodestructors are a guarantee of soil fertility: recommendations, 2014, BTU Center, 14.
[39]Terrer, C., 2019, Nitrogen and phosphorus constrain the CO_2 fertilization of global plant biomass, Nature Climate Change, Vol. 9, 684–689.
[40]The EU population has been declining for the second year in a row due to COVID-19, European truth, 2022, July 11, Monday. https://www.eurointegration.com.ua/rus/news/2022/07/11/7142993, Accessed on Feb.25, 2023.
[41]Wittgenstein, V., Neil, J. B., Hawkins, B. J., 2014, Evolutionary classification of ammonium, nitrate, and peptide transporters in land plants, BMC Ecology and Evolution, Vol. 14, 11. http://www.biomedcentral.com/1471-2148/14/11, Accessed on Feb.25, 2023.
[42]Yurkevych, Ye. O., Alzhaiem, Kh., 2016, Influence of different systems of basic tillage on productivity of short-term crop rotations in the conditions of biologization of agriculture, Agrarian Bulletin of the Black Sea Coast, Vol. 79, 93–102.
[43]Yurkevych, Ye. O., Bierov, Ye. D., 2016, Mineralization of basic pea tillage in organic farming of the Southern Steppe of Ukraine, Agrarian Bulletin of the Black Sea Coast, Vol. 79, 85–93.
[44]Yurkevych, Ye., Mamenko, P., Bierov, Ye., 2017, Stubble destructors: pros and cons, The Ukrainian Farmer, Vol. 8 (92), 72–73.
[45]Yurkevych, Ye. O., Boiko, P. I., Kovalenko, N. P., Valentiuk, N. O., 2021, Scientific-technological and agrobiological bases of highly productive agroecosystems of Ukraine: mon., Odessa: Publishing House LLC «Publishing Center», 654.

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ANALYSIS OF GENOME EDITING APPLICATIONS IN THE CREATION OF NEW MAIZE GERMPLASM

Dorina BONEA

University of Craiova, Faculty of Agronomy, 19, Libertatii Street, Dolj County, Romania, Phone/Fax: +40 251 418 475, E-mail: dorina.bonea@edu.ucv.ro

Corresponding author: dbonea88@gmail.com

Abstract

The main concern of today's scientists is the sustainable development of agriculture to achieve global food and nutrition security. Genome editing technology is recognized worldwide for its potential for sustainable agricultural intensification. In this paper, applications of genome editing in maize were analyzed and exemplified, based on statistical data collected from the EU-SAGE Database from January 1996 to July 2023. In addition, the existing regulations for this new technology were also discussed. The results showed that, so far, 51 applications of maize genome editing have been reported in the EU-SAGE database, and the CRISPR/Cas system was the most used genome editing tool with the potential to rapidly generate new genotypes with high yield, improved quality, and stresses resistance. Most applications were developed in China and the USA. Due to current GMO legislation and political indecision regarding the authorization of genome-edited products, the European Union is not yet able to use and cultivate these new improved genotypes.

Key words*: *CRISPR/Cas, genome-edited products, improved traits, maize

INTRODUCTION

The continuous growth of the global population, which is estimated to reach 10 billion people in 2050, requires a proportional increase in food production [16].

In order to more quickly obtain cultivars resistant to current threats and increase the amount of food, it is necessary to use efficient and safe molecular tools [19].

Maize *(Zea mays*) is one of the most important crops that provide a major source of food globally, having multiple uses (food for humans, fodder, raw material for various industries, biofuel) [7, 39].

The current climate changes threaten the global production of maize and other major agricultural crops. For example, in years of severe drought, Europe (the third largest maize-producing region in the world after the Americas and Asia) recorded a reduction in total maize production of 37.9 million tons in 2015, of 24.1 million tons in 2016 and 30.9 million tons in 2017 compared to 2021, and Americas recorded reductions of 70.4 million tons in 2015, of 15.9 million tons in 2016, of 13.9 million tons in 2017 compared to 2021 [10].

A recent IPCC report [18] shows that to reduce future losses in maize yield, improved agricultural practices by developing new cultivars with good genetic adaptation are needed. To overcome these challenges and improve its production and quality, scientists have used various new biotechnological tools.

Genome editing techniques comprise a set of tools developed to precisely modify genomes using variants of SDN (site-directed nuclease) technologies and ODM (oligonucleotide-directed mutagenesis). Thus, new SDN systems based on Zinc Finger Nucleases (ZFN), Meganucleases, and Transcription Activator-Like Effector Nucleases (TALEN) have been successfully used to generate targeted genomic changes in various crops [28]. However, these tools are considered very expensive and time- and labor-consuming. Relatively recently, a new SDN system, namely Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)/CRISPR associated protein (Cas) began to be used for the rapid improvement of agricultural crops, including for maize [2, 17].

Unlike transgenic plant modification that produces involuntary gene insertions, genome editing techniques produce well-defined mutations, and new genotypes can be used reliably without major concerns [34].

Transgenic crops and foods are a solution to the limitations of conventional breeding and ensuring food security, but they are strictly regulated regarding their use and marketing, and some international markets do not accept them at all [1]. According to [14], the changes generated by the application of genome editing tools are identical to those derived from conventional breeding or natural/induced mutations. As a result of the acceptance as non-GM of the cultivars developed by genome editing both in the countries that produce about 80% of the global crops, as well as in other countries, it is expected that this new technology will contribute to the democratization of agricultural biotechnology for the benefit of sustainable food production [16].

New germplasm developed through genome editing tools promise opportunities and benefits for farmers, consumers and society [32]. This paper presents information about genome editing applications in maize, one of the most important crops worldwide with implications for ensuring food security.

MATERIALS AND METHODS

This paper was carried out using statistical data collected from the EU-SAGE Database [9] for the period January 1996 to July 2023 and other sources.

The main aspects addressed were: the distribution of maize genome editing applications according to genome editing tools, SDN type, countries and different traits categories. The obtained results were synthetically illustrated in graphs and tables.

Recent examples of applications to improve the main traits in maize were presented.

Also, the existing regulations in different countries for these new technologies were summarized and discussed.

RESULTS AND DISCUSSIONS

The distribution of genome editing applications in maize

So far, genome editing has been applied to more than 63 crops from 25 countries [5].

As shown in Figure 1, between January 1996 and July 2023, a number of 757 applications were reported, the largest shares in the structure of the studied crops occupying rice (32%), tomatoes (14%), maize (7 %) soybean (6%) and wheat (6%). Maize registered 51 applications.

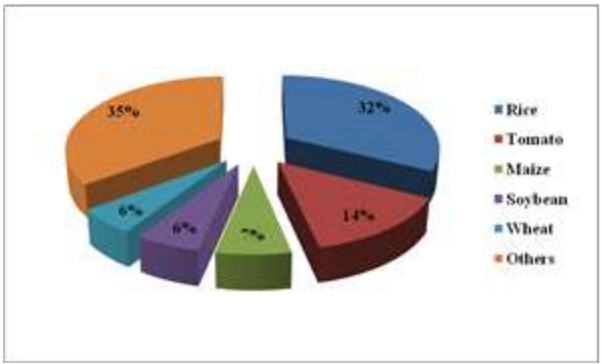

Fig. 1. The distribution of genomic editing applications by studied crops
Source: Own design and processing based on the data from [9].

Regarding genome editing tools, the use of the CRISPR/Cas system was reported in 38 applications out of a total of 51 maize applications, being the most used tool in the creation of new improved genotypes, compared to ZFN and other tools (Figure 2).

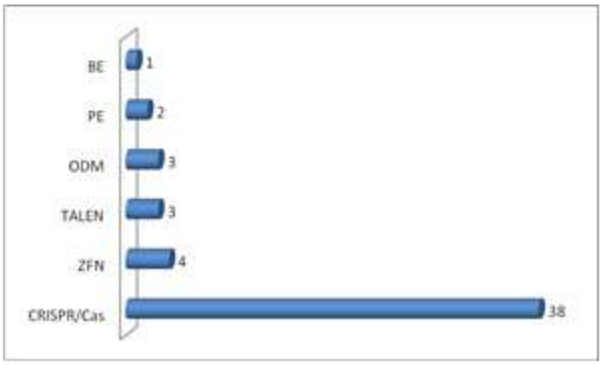

Fig. 2. The distribution of genomic editing applications in maize by genome editing tools
Legend: BE = Base Editing; PE = Primary Editing; ODM = Oligonucleotide-Directed Mutagenesis; TALEN= Transcription Activator-Like Effector Nucleases; ZFN = Zinc Finger Nucleases; CRISPR/Cas = Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)/CRISPR associated protein (Cas)
Source: Own design and processing based on the data from [9].

The CRISPR system was discovered in 1987 by Ishino and his colleagues when they were studying the iap gene in the *E. coli* genome [34]. The working principle of the innovative CRISPR/Cas9 tool was elucidated in 2012 [20], and since 2013 it has been applied in several fields, including crops both to increase the efficiency of gene knockout and to enable multiple genes knockouts [41].

ZFNs (Zinc-Finger-directed nuclease) were discovered in 1996 by [21], and in 2009 they were successfully used by researchers from the USA in maize to reduce phytate [35].

TALENs (Transcription Activator-Like Effector Nucleases) were discovered in 1989 in a bacterium called *Xanthomonas* [3], and in 2013 it was used in maize to reduce phytic acid (PA) synthesis in seeds, this acid being considered an anti-nutritional factor because it chelates the micronutrients in food thus preventing their absorption [25].

The efficiency of genome editing mediated by chimeric oligonucleotides (ODM) in maize was reported in a 1999 study by [42].

Since 2020, base editors (BE) and primary editors (PE) based on dCas9 and nCas9 have been frequently used in plant genome editing, being 10 to 100 times more efficient than homology-directed repair (HDR) [41].

Until now, the use of directed base editing (BE) of a target cytosine to thymine (C to T) has been reported in a single case in maize for generated sulfonylurea herbicide-resistant, but it is believed that the improvement of this technique will become a basic tool in precision crop breeding [22].

There are three categories of genetic changes generated by genome editing, namely three types of site-directed nuclease (SDN) 1/2/3, and according to the European Commission, SDN1 genetic changes are called "targeted mutagenesis", being considered similar to changes that they can appear spontaneously or due to conventional breeding [5].

Figure 3 shows that the highest percentage of maize applications was based on genetic changes belonging to the SDN1 type (93%).

The highest number of maize applications was reported in China (26) and USA (21), but research on maize genome editing also appeared in Europe (Figure 4).

For maize, the most important group of applications addresses yield and growth of plant (25%), industrial utilization (25%), food/feed quality (20%) and herbicide tolerance (18%) (Table 1).

All these improvements in targeted traits are related to the climatic, economic and agronomic challenges faced by farmers.

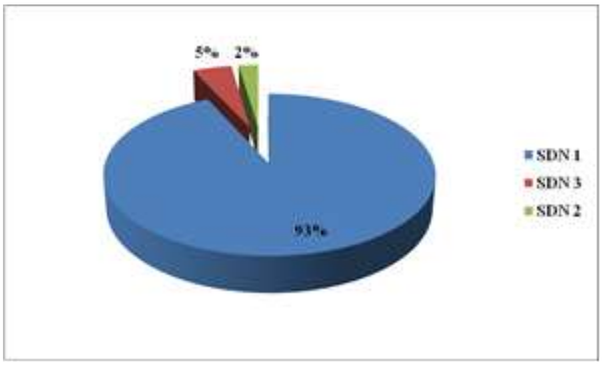

Fig. 3. The distribution of genomic editing applications in maize by SDN type

Source: Own design and processing based on the data from [9].

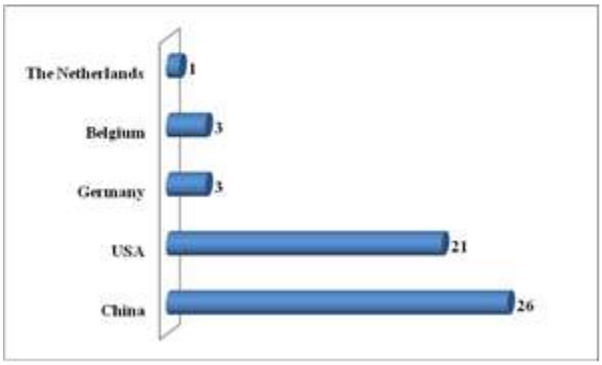

Fig. 4. The distribution of genomic editing applications in maize by countries

Source: Own design and processing based on the data from [9].

Improvement of grain yield

Improving crop yield is a major objective of breeding programs.The main traits related to yield are number, weight and grain size.

Recent research has shown the importance of new genomic techniques/tools in increasing the yield of maize and other crops.

For example, by using CRISPR/Cas9 technology, [26] created weak promoter alleles of CLE genes with increased grains per ear and maize yield.

Tassel branch number is another important agronomic trait for seed production because it provides pollen for hybridization. Over the course of modern breeding, male inflorescence (tassel) size and branch number have been reduced [12].

Table 1. The distribution of genome editing applications in maize by different traits

Categories of traits	Modifications	No.	%
Traits related to increased plant yield and growth	Improved field performance and increased plant yield due to architectural changes	13	25
Traits related to industrial utilization	Generating male sterility lines (MLS); enhanced haploid induction; trait stacking.	13	25
Traits related to improved food/feed quality	Sweeter kernels; reduced phytic acid (PA) synthesis in seeds; aromatic maize, modified composition, etc	10	20
Traits related to herbicide tolerance	Herbicide resistance	9	18
Traits related to biotic stress tolerance	Fungal resistance; visual detection of maize chlorotic mottle virus (MCMV); resistance to ear rot caused by *Fusarium verticillioides*	4	8
Traits related to abiotic stress tolerance	Drought tolerance	2	4

Source: Own design and processing based on the data from [9].

Recently, [15] showed that loss of *ZmPAT7* function induced significant increases in tassel branch number.

Doubled haploid technology based on haploid induction in vivo is frequently used in maize breeding for the development of homozygous lines in 2-3 generations [33].

For example, [24] reported that the CRISPR/Cas9 system generated mutant of *Zea mays PHOSPHOLIPASE D3 (ZmPLD3)* could increase haploid induction in maize, and [33] showed that the generation of mutants for the *ZmPLA1* gene in the maize inbred line LM13 by CRISPR/Cas9 technology can increase the rate of haploid induction. Using CRISPR/Cas9 technology, [23] created double knockout mutants of *ZmPHYC1* and *ZmPHYC2* that showed a moderate early flowering phenotype under long-day conditions, providing valuable target genes to breeding high-density tolerant maize genotypes. Also, [13] created CRISPR-waxy hybrids that are agronomically superior to introgressed hybrids, producing on average 5.5 bushels per acre more.

Improvement of quality

The physical characteristics (color, size, texture, etc.) as well as the content in bioactive substances (flavonoids, carotenoids, etc.) and specific nutrients (protein, lipids, starch, etc.) influence the quality of the crops.

Sweet and waxy maize has recently recorded increasing demands from the consumer market [36].

By using CRISPR/Cas tool and editing the *ZmSH2* and *ZmWAXY1* genes, [6] produced sweet and waxy compound maize.

Also, by simultaneously editing the genome of the two BADH2 genes (*ZmBADH2a* and *ZmBADH2b*), [38] generated a double mutant capable of accumulating between 0.028 and 0.723 mg/kg 2AP (2-acetyl-1-pyrroline), which is the first aromatic maize in the world.

Improvement of resistance to biotic stress

Bacterial, fungal and viral diseases can significantly reduce the yield and quality of maize crops if pesticides are not applied. These pesticides are expensive and harmful to the environment and biodiversity. It is estimated that fungal diseases and lepidopteran pests can cause damage of more than 20% or 30% of maize yield [39].

Fusarium ssp. causes fusarium ear rot in maize, a dangerous fungal disease that leads to significant yield reductions but also to contamination with mycotoxins that endanger animal and human health. It can also cause fusarium head blight in wheat for maize-wheat rotation systems [27].

Research into the applications of new genomic techniques to improve resistance to bacteria, fungi and viruses is numerous.

For example, [27] showed that the targeted generation of null mutants in *ZmFER1* in maize by using the CRISPR/Cas9 system could confer resistance to *Fusarium verticillioides*. Another recent application of CRISPR/Cas 9 system in maize aimed at the generation of mutations with the loss of function of the LOX3 gene, the mutant plants manifesting resistance to *Ustilago maydis* which causes galls on all aerial parts of the plant [31].

Improvement of tolerance to abiotic stress

Efforts to improve crop yield and quality are hampered by numerous abiotic stresses (drought, heat, salinity, soil pollution).

It is estimated that the annual yield loss due to drought is over 20% of the maize area, and due to high temperatures the global yield loss is 7.4% for every 1°C increase [39].

Research carried out in maize by editing the *ZmNUDX2* and *ZmNUDX8* genes mediated by the CRISPR/Cas9 system showed an improvement in drought tolerance [30]. Also, a mutation of the *ZmLBD5*, which is involved in the regulation of growth and response to drought by affecting the synthesis of gibberellin (GA) and abscisic acid (ABA), can improve the drought resistance of maize [11].

Improvement of herbicide tolerance

Yield and plant growth are often limited by weed competition. Weed management is based on the use of herbicides, but their overuse and the lack of new active ingredients has led to the growth of resistant weeds. An economic and ecological approach to combating them is the use of cultivars resistant to herbicides. Recent research has shown that the use of new genome editing techniques can accelerate the development o genotypes tolerant to various herbicides.

For example, the CRISPR/Cas9 system was used to generate a homozygous *ZmALS1* mutation or a *ZmALS1* and *ZmALS2* double mutation in maize that produce plants tolerant to chlorsulfuron, a sulfonylurea herbicide commonly used in agriculture [22].

Improvement of traits to industrial utilization

For hybrid seed production, creating male-sterile genotypes is very important, saving labor and time.

As a result, researchers have used CRISPR/Cas9 tool to develop new crop genotypes, including genotypes of maize.

For example, [4] constructed a CRISPR/Cas9 vector that targeted the MS8 gene mutation in maize. The mutations generated showed male-sterile phenotypes that were stably inherited in subsequent generations. [29] targeted the editing of the gene *Zm00001d043909 (ZmCals12) in* maize. In addition to male sterility, the obtained maize ms39 mutant also showed plant dwarfing.

Combining haploid technology with CRISPR/Cas system has successfully generated various haploid inducers for industrial use. Thus, mutations of *ZmPLD3* [24] and *ZmDMP* [40] led to an increase in the rate of haploid induction.

Regulatory status of genome-edited products

The main limitations of genome editing products are legal regulation and consumer acceptance.

To legally classify SDN genome editing applications, the SDN 1/2/3 terminology was used. According to [28], these three types of SDNs are explained as follows:

- SDN 1: the induction of single point mutations or InDels;
- SDN 2: short insertions or editing of a few base pairs by an external DNA template sequence
- SDN 3: the insertion long DNA fragments (e.g. transgenes, cisgenes).

The scientific community considers that the mutations generated by SDN 1 and SDN 2 do not differ from those induced by conventional breeding or natural mutations, therefore they should not be subject to the existing regulation for GMOs. In general, SDN-3s are subject to GMO regulations because they introduce foreign genes [28]. However, opinions differ from country to country. For the main countries that regulate genome-edited products developed by SDN 1 and SDN 2, [37] described two general positions each with two approaches (Table 2).

The USA has different regulatory approaches depending on the use of genome editing for crops, animals or food. Also, in Australia genome editing techniques that are considered SDN 1 are exempt from regulation, while SDN 2 are subject to regulation. It is noted that most countries apply approaches 2 and 3.

Table 2. Position and approaches for regulation of genome-edited products by countries

Position	Approaches	Countries
I. GMO regulations are applied as it is to genome-edited products	Approach 1: Applying GMO regulations as they are, requiring prior government safety assessment and approval.	EU, New Zealand, USA - for animals through the Food and Drug Administration (under review).
	Approach 2: Simplified GMO regulations	Australia (SDN 1), China, India, New Zealand
II. Genome-edited products are exempt from GMO regulations	Approach 3: Requires confirmation by the government before placing the product on the market	Argentina, Brazil, Chile, Colombia, Paraguay, Philippine, USA - for food through the Food and Drug Administration
	Approach 4: Prior confirmation is not required by the government	Australia (SDN 2), USA - to regulate crops through the USDA and Environmental Protection Agency (under review).

Source: [37].

In European Union, in 2018, the Court of Justice (CJEU) has clarified that those organisms from new genome editing techniques fall within the scope of EU GMO legislation. Before 2018, they were not subject to GMO legislation, with member states free to create their own policies. However, in 2021 the European Commission published a study on the status of new genomic techniques under EU legislation, and based on the results of this study, initiated a political action involving an impact assessment, including a public consultation through which a proposal for a new regulation on plants produced by certain new genomic techniques. The proposal, adopted on 5 July 2023, is part of a package of legislative proposals to support EU farm-to-food and biodiversity strategies [8].

CONCLUSIONS

Consumers are the final recipients of crops and foods obtained through new genomic techniques, which is why they need to have up-to-date information on the progress of genome editing applications and their safety. Increasing consumer confidence and resolving political issues will enable new genomic techniques to contribute more to agricultural sustainability.

So far, 51 genome editing applications in maize have been reported in the EU-Sage database. Most genome editing applications (38) have been carried out using the CRISPR/Cas system, and China is the world leader in these research and applications.

These applications promise opportunities and benefits not only for consumers (due to improved nutritional value and food safety) but also for farmers (due to increased resistance to drought, heat, diseases, pests, and weeds) as well as for society (due to the protection of biodiversity in agricultural systems)

Due to current GMO legislation and political indecision regarding the authorization of genome-edited products, the European Union cannot yet use and cultivate these new genotypes.

REFERENCES

[1]Bhatta, B.P., Malla, S., 2020, Improving horticultural crops via CRISPR/Cas9: Current successes and prospects. Plants, 9(10):1360. doi: 10.3390/plants9101360.

[2]Bonea, D., 2022, Applications of the CRISPR/cas9 technique in maize and wheat breeding. Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series, 52(1):51-58.

[3]Bonas, U., Stall, R.E., Staskawicz, B., 1989, Genetic and structural characterization of the avirulence gene *avrBs3* from *Xanthomonas campestris pv. vesicatoria*. Mol. Gen. Genet., 218(1):127-136. doi: 10.1007/BF00330575.
[4]Chen, R., Xu, Q., Liu, Y., Zhang, J., Ren, D., Wang, G., Liu, Y., 2018, Generation of transgene-free maize male sterile using CRISPR/Cas9 system. Front. Plant Sci., 9:1180. Doi:10.3389/fpls.2018.01180.
[5]Dima, O., Heyvaert, Y., Inze, D., 2022, Interactive database of genome editing applications in crops and future policy making in the European Union. Trends in Plant Science, 27(8): 746-748.
[6]Dong, L., Qi, X., Zhu, J., Liu, C., Zhang, X., Cheng, B., Mao, L., Xie, C., 2019, Supersweet and waxy: meeting the diverse demands for specialty maize by genome editing. Plant Biotechnol. J., 17(10):1853-1855. doi: 10.1111/pbi.13144.
[7]Dunareanu, I.C., Bonea, D., 2022, Evaluation of maize hybrids for grain yield and quality traits under field conditions from Southwestern Romania. Scientific Papers. Series A. Agronomy, LXV(2): 201-207.
[8]European Commission (EU), 2023, New techniques in biotechnology.
https://food.ec.europa.eu/plants/genetically-modified-organisms/new-techniques-biotechnology_en,
Accessed on 6 August, 2023.
[9]European Sustainable Agriculture Throught Genome Editing, 2023, EU-SAGE DATABASE.
https://www.eu-sage.eu/, Accessed on 1 August, 2023.
[10]FAOSTAT., 2023, Crops and livestock products, https://www.fao.org/faostat/en/#data/QCL, Accessed on 29 July, 2023.
[11]Feng, X., Xiong, J., Zhang, W., Guan, H., Zheng, D., Xiong, H., Jia, L., Hu, Y., Zhou, H., Wen, Y., Zhang, X., Wu, F., Wang, Q., Xu, J., Lu, Y., 2022, *Zmlbd5*, a class-ii lbd gene, negatively regulates drought tolerance by impairing abscisic acid synthesis. Plant J., 112(6):1364-1376.
https://doi.org/10.1111/tpj.16015.
[12]Gage, J.L., White, M.R., Edwards, J.W., Kaeppler, S., de Leon, N., 2018, Selection signatures underlying dramatic male inflorescence transformation during modern hybrid maize breeding. Genetics, 210(3):1125-1138. doi: 10.1534/genetics.118.301487.
[13]Gao, H., Gadlage, M. J., Lafitte, H. R., Lenderts, B., Yang, M., Schroder, M., Farrell, J., Snopek, K., Peterson, D., Feigenbutz, L., Jones, S., Clair, G., Rahe, M., Sanyour-Doyel, N., Peng, C., Wang, L., Young, J.K., Beatty M., Dahlke, B., Hazebroek, J., Greene, TW., Cigan, A.M., Chilcoat, N.D., Meeley, R.B., 2020, Superior field performance of waxy corn engineered using CRISPR-Cas9. Nat. Biotechnol., 38 (5):579-581. doi: 10.1038/s41587-020-0444-0.
[14]Grohmann, L., Keilwagen, J., Duensing, N., Dagand, E., Hartung, F., Wilhelm, R., Bendiek, J., Sprink, T., 2019, Detection and identification of genome editing in plants: challenges and opportunities. Front. Plant Sci., 10:236. doi: 10.3389/fpls.2019.00236.
[15]Guan, H., Chen, X., Wang, K., Liu, X., Zhang, D., Li, Y., Song, Y., Shi, Y., Wang, T., Li, C., Li, Y., 2022, Genetic variation in *ZmPAT7* contributes to tassel branch number in maize. Int. J. Mol. Sci., 23(5):2586. doi: 10.3390/ijms23052586.
[16]Hernandes-Lopes, J., Yassitepe, J.E.C.T., Koltun, A., Pauwels, L., Silva, V.C.H.D., Dante, R.A., Gerhardt, I.R., Arruda, P., 2023, Genome editing in maize: Toward improving complex traits in a global crop. Genet. Mol. Biol., 46(1 Suppl 1):e20220217. doi: 10.1590/1678-4685-GMB-2022.
[17]Hillary, V.E., Ceasar, S.A., 2019, Application of CRISPR/Cas9 genome editing system in cereal crops. The Open Biotechnology Journal, 13:173-179. http://dx.doi.org/10.2174/1874070701913010173
[18]Intergovernmental Panel on Climate Change (IPCC), 2022, Climate Change 2022: Impacts, adaptation, and vulnerability. Sixth Assessment Report. https://www.ipcc.ch/report/ar6/wg2/, Accessed on 2 August, 2023.
[19]ISAAA., 2021, Breaking Barriers with Breeding: A Primer on New Breeding Innovations for Food security. ISAAA Brief No. 56. ISAAA: Ithaca, NY.
[20]Jinek, M., Chylinski, K., Fonfara, I., Hauer, M., Doudna, J.A., Charpentier, E., 2012, A programmable dual-RNA-guided DNA endonuclease in adaptive bacterial immunity. Science, 337: 816-821.
[21]Kim, Y.G., Cha, J., Chandrasegaran, S., 1996, Hybrid restriction enzymes: Zinc finger fusions to *FokI* cleavage domain. Proc. Natl. Acad. Sci. USA, 93(3):1156–1160. doi: 10.1073/pnas.93.3.1156.
[22]Li, Y., Zhu, J., Wu, H., Liu C., Huang, C., Lan, J., Zhao, Y., Xie, C., 2020, Precise base editing of non-allelic acetolactate synthase genes confers sulfonylurea herbicide resistance in maize. The Crop Journal, 8(3):449-456. https://doi.org/10.1016/j.cj.2019.10.001.
[23]Li, Q., Wu, G., Zhao, Y., Wang, B., Zhao, B., Kong, D., Wei, H., Chen, C., Whang, H., 2020, CRISPR/Cas9-mediated knockout and overexpression studies reveal a role of maize phytochrome c in regulating flowering time and plant height. Plant Biotechnol. J., 18(12):2520–2532.
doi: 10.1111/pbi.13429.
[24]Li, Y., Lin, Z., Yue, Y., Zhao, H. M., Fei, X. H., Lizhu, E., Cheng, L., Chen, S., Lai, J., Song, W., 2021, Loss-of function alleles of *ZmPLD3* cause haploid induction in maize. Nat. Plants, 7:1579-1588. doi: 10.1038/s41477-021-01037-2.
[25]Liang, Z., Zhang, K., Chen, K., Gao, C., 2014, Targeted mutagenesis in *Zea mays* using TALENs and the CRISPR/Cas system. J. Gen. Gen., 41:63-68.
[26]Liu, L., Gallagher, J., Arevalo, E.D., Chen, R., Skopelitis, T., Wu, Q., Bartlett, M., Jackson, D., 2021, Enhancing grain- yield-related traits by CRISPR-Cas9 promoter editing of maize CLE genes. Nat. Plants, 7(3):287-294. doi:10.1038/s41477-021-00858-5
[27]Liu, C.L., Kong, M., Zhu, J.J., Qi, X.T., Duan, C.X., Xie, C.X., 2022, Engineering null mutants in *ZmFER1* confers resistance to ear rot caused by *Fusarium verticillioides* in maize. Plant Biotechnol. J., 20:2045–2047. https://doi.org/10.1111/pbi.13914.
[28]Menz, J., Modrzejewski, D., Hartung, F., Wilhelm, R., Sprink, T., 2020, Genome edited crops touch the

market: A view on the global development and regulatory environment. Front. Plant Sci., 11. doi: 10.3389/fpls.2020.586027

[29]Niu, Q., Shi, Z., Zhang, P., Su, S., Jiang, B., Liu, X., Zhao, Z., Zhang, S., Huang, Q., Li, C., Yu, T., Yi, H., Rong, T., Cao, M., 2022, *ZmMS39* encodes a callose synthase essential for male fertility in maize (*Zea mays* L.). The Crop Journal, 11:394-404. https://doi.org/10.1016/j.cj.2022.08.012.

[30]Njuguna, E., Coussens, G., Aesaert, S., Neyt, P., Anami, S., Van Lijsebettens, M., 2018, Modulation of energy homeostasis in maize and Arabidopsis to develop lines tolerant to drought, genotoxic and oxidative stresses. Afrika Focus, 30(2). https://doi.org/10.21825/af.v30i2.8080.

[31]Pathi, K.M., Rink, P., Budhagatapalli, N., Betz, R., Saado, I., Hiekel, S., Becker, M., Djamei, A., Kumlehn, J., 2020, Engineering smut resistance in maize bu site-directed mutagenesis of LIPOXYGENASE 3. Front. Plant Sci., 11:543895. doi:10.3389/fpls.2020.543895.

[32]Pixley, K.V., Falck-Zepeda, J.B., Paarlberg, R.L., Phillips, P.W.B., Slamet-Loedin, I.H., Dhugga, K.S., Campos, H., Gutterson, N., 2022, Genome-edited crops for improved food security of smallholder farmers. Nat. Genet., 54:364-367. https://doi.org/10.1038/s41588-022-01046-7.

[33]Rangari, S.K., Sudha, M.K., Kaur, H., Uppal, N., Singh, G., Vikal, Y., Sharma, P., 2023, DNA-free genome editing for *ZmPLA1* gene via targeting immature embryos in tropical maize. GM Crops Food, 5:1-7. doi: 10.1080/21645698.2023.2197303.

[34]Razzaq, A., Saleem, F., Kanwal, M., Mustafa, G., Yousaf, S., Imran-Arsha, H.M., Hameed, M.K., Khan, M.S., Joyia, F.A., 2019, Modern trends in plant genome editing: An inclusive review of the CRISPR/Cas9 toolbox. Int. J. Mol. Sci., 20(16):4045. doi: 10.3390/ijms20164045.

[35]Shukla, V., Doyon, Y., Miller, J., DeKelver, R., Moehle, E., Worden, S., Mitchell, J., Arnolg, N., Goplan, S., Meng, X., Choi, V., Rock, J., Wu, YY., Katibah, G., Zhifang, G., McCaskill, D., Simpson, M., Blakeslec, B., Greenwalt, S., Butler, H., Hinkley, S., Zhang, L., Rebar, E., Gregory, P., Urnov, F., 2009, Precise genome modification in the crop species *Zea mays* using zinc-finger nucleases. Nature, 459:437-441. https://doi.org/10.1038/nature07992

[36]Song, Q., Liang-Liang, K., Jun-Feng, L., Yao, Z., Yue-hua, Y., 2018, Creation method and identification technology for sweet-waxy maize of double recessive genotype. China Veg., 5:28-32.

[37]Tachikawa, M., Matsuo, M., 2023, Divergence and convergence in international regulatory policies regarding genome-edited food: How to find a middle ground. Front. Plant Sci., 14:1105426. doi: 10.3389/fpls.2023.1105426.

[38]Wang, Y., Liu, X., Zheng, X., Wang, W., Yin, X., Liu, H., Ma, C., Niu, X., Zhu, J.K., Wang, F., 2021, Creation of aromatic maize by CRISPR/Cas. J. Integr. Plant Biol., 63(9):1664-1670. doi: 10.1111/jipb.13105.

[39]Wang, Y., Tang, Q., Pu, L., Zhang, H., Li, X., 2022, CRISPR-Cas technology opens a new era for the creation of novel maize germplasms. Front. Plant Sci., 13:1049803. doi: 10.3389/fpls.2022.1049803.

[40]Zhong, Y., Liu, C.X., Qi, X.L., Jiao, Y.Y., Wang, D., Wang, Y.W., Liu, Z., Chen, C., Chen, B., Tian, X., Li, J., Chen, M., Dong, X., Xu, X., Li, L., Liu, W., Jin, W., Lai, J., Chen, S., 2019, Mutation of *ZmDMP* enhances haploid induction in maize. Nat. Plants, 5(6):575-580. doi: 10.1038/s41477-019-0443-7.

[41]Zhou, J., Luan, X., Liu, Y., Wang, L., Wang, J., Yang, S., Liu, S., Zhang, J., Liu, H., Yao, D., 2023, Strategies and methods for improving the efficiency of CRISPR/Cas9 gene editing in plant molecular breeding. Plants,12:1478. https://doi.org/10.3390/plants12071478.

[42]Zhu, T., Peterson, D.J., Tagliani, L., St Clair, G., Baszczynski, C.L., Bowen, B., 1999, Targeted manipulation of maize genes in vivo using chimeric RNA/DNA oligonucleotides. Proc. Natl. Acad. Sci. USA, 96(15):8768-73. doi: 10.1073/pnas.96.15.8768.

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COMPETITIVE ADVANTAGES OF THE VITICULTURE AND WINE SECTOR WITHIN THE BULGARIAN REGIONS

Petar BORISOV[1], Teodor RADEV[1], Kamen PETROV[2], Rezear KOLAJ[3], Ekaterina ARABSKA[4]

[1]Agricultural University of Plovdiv, Department of Management and Marketing,12, Mendeleev Street, Plovdiv 4003, Bulgaria, Phone: +359894627260; E-mails: peterborisov@gmail.com, radev_1974@abv.bg
[2]University of National and World Economy – Sofia, Faculty "Management and Administration", Department "Regional Development", Students Town, UNWE, Sofia 1700, Bulgaria, Phone: +359 2 8195 647, E-mail: petrovk@abv.bg
[3]Agricultural University of Tirana, Department of Economics and Rural Development Policies, 1025, Paisi Vodica Street, Tirana 1001, Albania, Phone: +355682020279; E-mail: rkolaj@ubt.edu.al
[4]University of Agribusiness and Rural Development, Department of Management, 78, Dunav Boulevard, Plovdiv 4003, Bulgaria, Phone:+359896778586; E-mail: earabska@uard.bg

Corresponding author: peterborisov@gmail.com

Abstract

The current study is focused on evaluation of competitive advantage of the wine sector as main driver of economic development of rural areas in Bulgaria. The rural development and specialization of viticulture in Bulgarian rural areas are evaluated in chronological aspect. The Porter's model of determinants of competitive advantage is used as main methodological tool in the current study. The basic factors, which are situated as determinants of competitiveness of rural regions are those that boost the regional development of viticulture and wine industry in rural regions of the country. The specific between industry links, which are the basis for sustainable development and competitiveness, are derived and the comparative advantages are assessed by deriving a comparative index of export advantages, a comparative index of import advantages and an index of relative trade advantages. A comprehensive analysis of the constraints and opportunities for competitive development of viticulture and wine industry in the rural areas has been made. Using the approach of focus groups of experts the main determinants for rural development of the sectors is outlined. The analysis of the competitiveness of the wine sector is considered by taking into account the impact of the processes of specialization, concentration and integration of industries in the sector. As a result of these processes in the sector, specific inter-industry relations are determined, which are the basis for sustainable development of competitiveness.

Key words**:** *viticulture, management, development, regions, competition, Bulgaria*

INTRODUCTION

The current development of the regional economy of Bulgaria in the XXI century passes through the assessment and analysis of sectors and industries that may be important for economic development. In this regard, the fact that Bulgaria is a country dominated by rural areas. According to the National Institute of Statistics, of a total of 266 municipalities in Bulgaria, 232 are designated as rural municipalities. As a member of the European Union, Bulgaria must work for rural development, which is in fact the "second pillar" of the Common Agricultural Policy (CAP), which strengthens the "first pillar" of income support and market measures by strengthening social, environmental and economic sustainability of rural areas. This makes rural areas in the focus of attention of a wide range of researchers, specialists from different fields, who aim to study the spatial patterns at the regional level in countries such as Bulgaria (Loorbach, D. 2010) [14].

The present study focuses on the wine-growing sub-sector, which may be of significant importance in the development of rural municipalities, which are located in the six planning regions in Bulgaria. The analysis of rural areas is usually based on those local territorial units when it comes to the delineation of sustainable areas, which can be classified as rural or urban and in which agricultural sectors are developing.

The wine sector has traditions and play traditional role in economic development of rural areas in Bulgaria. The industry generates significant share of GDP, creates employment, provide opportunities for better life for rural population, and play role as a buffer against demographic problems like inner migration and process of depopulating. In addition, the sector promotes sustainable agricultural development, diversification of the local economy. This determines the purpose of this exhibition to illustrate the opportunities for their economic development and regional growth through the analysis of competitive advantages of the wine sector within rural areas in the country. The main task of this analysis is to outline the main barriers and prospects for the development of the wine sector through the prism of strategic planning in the development of wine in Bulgaria. In addition, the main task of policymakers for future development of viticulture is to effectively adapt to European spatial development policies in order to raise public awareness of the competitiveness and sustainable development of the local economy.

The role of the wine sector is extremely important for promoting the interaction between the different agricultural and non-agricultural sectors on the territory and for the development of integrated projects in order to make better use of available resources. The wine sector can support the development of industries such as the food industry, information technology, tourism and transport, in the context of the regional development of planning regions.

In this regard, the wine sector can create favourable conditions for the development of businesses models across different economic sectors at the regional level or initiate such interplay processes with neighbouring municipalities with developed viticulture and related industries (OIV, 2016a and b) [23, 24].

Historical and current perspectives on the development of viticulture in Bulgaria. The start point of development of viticulture in Bulgaria is considered to be after 1927, when the production of table grapes began. At the end of the 1930s, Bulgaria was one of the main exporters of table grapes in Europe (50,000 tons per year), although viticulture at that time was mostly small, fragmented and technically backward. According to the systematic development of viticulture, it has been occurring since the 1950s, when block vineyards were built. It is important to note that a streamlined organization of grape production has been created through 917 main cooperative and agricultural farms, which are grouped in about 4,000 blocks of vineyards with an average size of 25 to 35 hectares. In practice, the derivation of the ecological factors for the first zoning of the vineyards in 1962 is extremely important for the development of viticulture in the country. Thanks to this zoning, a new high-quality dessert (Cardinal, Queen of the Vineyards, etc.) and wine (Merlot, Cabernet Sauvignon, Rkaticelli, Juni Blanc and others) varieties are needed. The production of rootstock cuttings is also increasing - about 200 million, and of grafted rooted vines - about 100 million.

Shortly before 1970, the vineyards in Bulgaria reached 203,000 ha, of which dessert - 53,500 ha, and wine - 149,500 ha. A total of 1,336,000 tons of grapes were produced (1). In the middle of the 80s of the XX century Bulgarian viticulture became established on the international market. By area of vineyards Bulgaria reaches 14th place in the world, in some years we reach the top places in the production of table grapes and in absolute wine production (Vagionis, N. 2010) [29]. This peak values ended with the beginning of the economic transformation of the Bulgarian agriculture in the early 90s of XX century. The restoration of private land ownership is associated with the fragmentation of the massifs - many large and small plots are created, which leads to the inevitable fragmentation of production and deterioration of the quality of land cultivation. This has a negative effect on the quality and quantity of the product produced - there is no way to achieve homogeneity of production and, accordingly, the market is also fragmented, whether it is about grape varieties or finished wine (Borisov, P., T. Radev, D. Dimitrova 2014) [4].

The big wine cellars are starting to be privatized or go bankrupt, from which the grape producers are losing, because there is no one to buy their products. Preparations for accession (including pre-accession funds and in particular SAPARD) and Bulgaria's membership in the EU are the next stages related to significant changes in the wine sector. Many Bulgarian winemakers and foreign investors manage to implement their projects for modern wineries and vineyards. This gradually began to change the face of the entire wine industry for the better, with production gradually recovering to over 100 million litters of wine per year. On the one side, subsidies for agriculture, including viticulture, give a powerful boost to its development, but on the other - a range of restrictive regulations for Bulgarian producers and requirements for the production process, the qualities of the final product and the conditions for its realization on foreign markets. The lack of comparative advantages leads to further modification of the regional structure of viticulture. For example, between 1998 and 2014, the area occupied by vineyards in Bulgaria decreased three times - according to National Statistical Institute data from 150,867 hectares to 53,251 hectares. The reasons for the significant reduction of vineyards are numerous - from the ongoing land reform and fragmentation of plots in the country to the unfavourable age and variety structure of plantations, lack of sufficient funding for proper agronomic measures and some EU policy decisions for the sector. Another trend in terms of area reduction and production is strong restructuring in terms of the predominant vine varieties. For example, in the period 2000/2014 the total area of red wine varieties decreased from 64.7 thousand ha to 20.3 thousand ha, ie. by 68.6%. However, the areas with red varieties are decreasing at a slower rate compared to the overall rate of reduction of the areas under vines and significantly slower than the reduction of white and dessert varieties (Simeonov, I., 2016) [27]. This is due to the favourable soil and climatic conditions for the cultivation of red varieties in most areas, the higher degree of mechanization in their processing, the existing traditions of red wine consumption in the country and good opportunities for sales in foreign markets. In the period 2017-2021 a new impetus of the wine sector in Bulgaria is observed.

Of course, the Covid-19 pandemic has had a very negative impact on the development of viticulture in Bulgaria, but the policies that have been outlined in the last few years have had a significant benefit. It is important to note that according to the Ministry of Agriculture and Food, in 2017 the country ranked 23rd in the world in terms of the number of vineyards and 21st in terms of wine production. The area of planted vineyards in Bulgaria totals 67 thousand hectares, with just over 16 thousand new plantations. There are 3,217 registered vineyards in the country, of which 263 are wineries, which produce 160 thousand tons of wine grapes or 1.3 million hectolitres. 19 new cellars are under construction. Exports are 600 thousand hectolitres, mostly to the EU countries, and imports are only 50 thousand hectolitres. The Bulgarian wine is exported in over 45 countries. Intra-EU exports are mostly to Poland, followed by the Czech Republic, Sweden and the United Kingdom. Outside the EU, wine is exported to Russia, China, Albania, Azerbaijan, Australia, the United States and Japan. Observations in the sector are that Bulgaria is exporting to Poland and Russia in the low-priced segment, with red wines predominating. However the share of sales of more expensive wines to different markets, including EU and such countries as China, USA and Japan, is gradually rising. A quarter of Bulgaria's vineyards are of local varieties and 55 wines have a protected geographical indication. Revenues of the largest 100 wineries are estimated at BGN 250 million, with about a quarter of the quantities exported abroad. This makes

Bulgaria the eighth-largest producer of grapes and the tenth-largest producer of wine in the EU. The restructuring of the wine sector is one of the most important and long-term goals set out in the National Strategy. The first task for the implementation of the vision is "Building a modern structure of the sector" to ensure efficient use of resources. Differences in the natural and climatic conditions of the different districts of the country lead to differentiation of the parameters characterizing the production potential of viticulture, as well as to the presence of territorial features in its specialization and concentration.

Zoning in the wine sector of Bulgaria is an important prerequisite for the development of modern viticulture and increasing the efficiency of production and marketing of products. Zoning is the territorial distribution of vine varieties, with the aim of ensuring good terror - the most suitable soil, relief, climatic and economic conditions for cultivation. The first modern zoning in Bulgaria was made in 1951, with a decree of the Council of Ministers, according to which the country is divided into North Bulgarian, Rila-Rhodope, Sub-Balkan, Black Sea and Melnik wine regions. In the following years, a comprehensive study of the wine-growing regions, vine collections and soil-climatic conditions was carried out, and the most suitable varieties for them were determined. Based on many years of research on the set of natural and climatic conditions, technological characteristics and agro biological properties of vine varieties and experience gained in the process of grape production and processing into wine, 4 wine regions are distinguished: Eastern, Southern, Northern and Southwestern. and a total of 116 neighborhoods.

In this context, the purpose of the paper is to evaluate the competitive advantage of the Bulgarian viticulture and wine industry according to their role in regional development.

MATERIALS AND METHODS

The methodology is based on logical analysis and synthesis of data on the status of viticulture and wine production at national, regional, and local levels, including the use of situational analysis to determine the place of viticulture and wine production in agriculture and the overall economy at the level of planning regions in Bulgaria. A synthesis of the challenges and opportunities for viticulture and wine at the regional level is also presented. It is important to note that the wine industry at the national level has a great potential for export and expansion of markets around the world, increases competitiveness and revenue in the overall economy, improves its comparative advantage, and boost the rural development of other economic industries.

In order to reveal the relevant competitive advantages of the wine sector, it is also necessary to point out its inherent characteristics at the level of the enterprise and the sector. This implies drawing out the competitive advantages of organizations in the industry and a method that allows us to force them on economically active people. Therefore, the analysis of the competitiveness of the sector must take into account the impact of the processes of specialization, concentration and integration of economically active people in the industry (Dimitrova, D. and I. Simeonov, 2016) [7]. Because of these processes in the wine industry are determined by specific links between industries, which are the basis for sustainable development and competitiveness of the sector as a whole. Comparative advantages are assessed by the following indicators: (1) Export Advantage Comparative Index (RXA); (2) Comparative index of import advantages (RIA) and (3) Index of relative trade advantages (RTA), which derive the relevant features of the wine industry (Borisov, P., T. Radev, D. Dimitrova, 2014) [4]. In geo-economics' terms, this means that we need to assess the index of export advantages that can be developed by economically active people within the Bulgarian operators in the wine sector.

Comparative index of export advantages - RXA is calculated according to the formula:

$RXA = \frac{(Xdi|Xd)}{(Xwi|Xw)}$ ....(1)

where:
Xdi - the value of wine exports from the country;
Xd - the value of total exports of the agricultural sector of the country;
Xwi - the value of wine exports of the leading wine-producing countries;
Xw - the value of total exports of the agricultural sector of the leading wine-producing countries.

Comparative index of import advantages - RIA is determined using the following formula:

$RIA = \frac{(Xdi|Xd)}{(Xwi|Xw)}$ ....(2)

where:
Xdi - the value of wine imports from the country;
Xd - the value of total imports of the agricultural sector of the country;
Xwi - the value of wine imports of the leading wine-producing countries;
Xw - the value of total imports of the agricultural sector of the leading wine-producing countries.

Index of Relative Trade Advantages - RTA is determined by the difference between RXA and RIA:

$RTA = RXA - RIA$ ....(3)

In addition, it is important to assess the index of import advantages and the index of trade advantages in order to bring out the emerging market niche and added value of production by companies operating in the wine sector.

To gather the necessary information for the calculation of the indicators characterizing the degree of specialization, concentration as well as comparative advantages of the industry, the following official documents from annual review documents are used, such as Agrarian Report of the Ministry of Agriculture and Food (MAF) [16], reports of the National Vine and Wine Chamber (NLVK) [20], reports of the Executive Agency for Vineyards and Wine (EAVW) [9], reports of the International Organization of Vine and Wine (OIV) [23, 24], database of the Food and Agricultural Organization of the United Nations (FAO) [10].

In addition to identifying the competitive advantages of the wine industry, the approach of Michael Porter is applied, which is adapted for Bulgarian economically active persons by applying the concept of "diamond of the determinants of national advantages" (Porter 1990) [25].

In addition, due to the indisputable quality of statistical information at the regional level on trends and developments in viticulture, we refer to expert assessment. In our conditions, it is a reliable tool because we rely on recognized experts in the industry who reach their conclusions based on managerial and technological experience in the wine industry (Velev, 2007) [30].

In addition, the majority of experts use a map to assess the competitive advantages of the sector based on five main determinants. These determinants are considered through the prism of factor conditions, conditions, indicators and based on their formation of an overall assessment of the competitive advantages of the industry (Table 1).

Each determinant is considered as a set of several factors that are determined along the way Each factor is assessed by N number of indicators, which are also determined by experts. Expert assessment is carried out through the following stages:

1) Establishment of an expert council. Representatives of all participants/ organizations /in the wine sector take part in this council;
2) The Expert Council, based on its knowledge and experience, develops a preliminary list of factors and indicators determining the competitive advantages of the sector;
3) Drawing up a table (map) of the expert opinion. It reflects the expert assessment of the importance of each indicator within a factor of competitive advantage in the Porter model [25] (Table 1).

4) Determining a scale for evaluation of the indicators in the map of the expert evaluation. A score is assigned to each indicator. A 9-point rating scale is used.
The scale is as follows: 0 - extremely negative value; 1 - very weak negative value; 2 - slightly negative value; 3 - does not matter; 4 - weak positive value; 5 - moderate positive value, 6 - strong positive value;7 - very strong positive value and 8 - extremely positive value of the indicator for the factor determining the competitive advantages of the studied sector.
5) Conduct your own research. The specially designed map is completed by a focus group composed of organizations involved in the value chain. The aim is to cover more stakeholder representatives involved in the sector.
6) Aggregation of the expert assessments of each expert (respondent) in one general map of the expert opinion. It reflects the general expert opinion on the sources of competitive advantages of the sector.
7) Analysis of the expert evaluation and formulation of findings. The expert summary scorecard determines the average value of each metric. The higher the value of the indicator, the higher the significance of the determinant within the framework that frames the competitive advantages of the industry. In this way, the weight of each indicator, factor and determinant in the Porter model is determined.
In the reference to the expert assessment, 112 individual participants were interviewed, who are a representative sample of all 336 wine producers according to the data of the Executive Agency for Vine and Wine.
For comparison, in 2020 they were 311, and a year earlier - 282 organizations in the wine sector. The focus group of experts is formed at random.

Table 1. The experts' opinion for evaluation of the determinants and factors of competitiveness of the wine sector

Determinants	**Factors**	**Indicators**	**Assessment of the importance for the competitive advantages of the sector**
I. FACTOR CONDITIONS	**1. Workforce**	1. Availability of skilled labor	
		2. Workforce mobility	
		3. Age structure of the workforce	
		4. Experience and accumulated knowledge	
		5. Presence of an entrepreneurial factor	
		Arithmetic mean of the assessment	N1
	2. Natural resources	1. Existence of appropriate natural and climatic conditions for the development of the sector	
		2. Access of participants in the sector to natural resources	
		3. Gifted with natural resources	
		4. Preservation of natural resources	
		Arithmetic mean of the assessment	N2
	3. Knowledge base - scientific, technical and market	1. Existence of organizations performing the research and development activities necessary for the development of the sector	
		2. Availability of technology transfer	
		3. Implementation of innovations	
		4. Existence of cooperation and strategic alliances	
		Arithmetic mean of the assessment	N3
	4. Capital	1. Access to capital	
		2. Desire of the banking sector to lend to the activities of the sector	
		3. Availability of investments	

		4. Growth in investments	
		5. Return on equity	
		Arithmetic mean of the assessment	N4
	5. Infrastructure	1. Availability of appropriate road infrastructure	
		2. Availability of an appropriate irrigation system	
		3. Availability of appropriate logistics	
		4. Availability of e-commerce	
		5. Availability of adequate housing and communal infrastructure	
		Arithmetic mean of the assessment	N5
Arithmetic mean of the assessment of factor conditions			Average (N1:N5)
II. CONDITIONS RELATED TO SEARCH	**1. Internal marke**	1. Availability of demand	
		2. Growth in demand	
		3. Loyalty of demand	
		4. Existence of a surplus on the market	
		5. Existence of market deficit	
		Arithmetic mean of the assessment	N1
	2. Foreign markets	1. Availability of demand	
		2. Growth in demand	
		3. Loyalty of demand	
		4. Existence of a surplus on the market	
		5. Existence of market deficit	
		Arithmetic mean of the assessment	N2
Arithmetic mean of the assessment of demand-related conditions			Average (N1:N2)
III. RELATED AND SUPPORTING INDUSTRIES	**1. Suppliers of raw materials and know-how**	1. Availability of suppliers	
		2. Competitiveness of suppliers	
		3. Sustainability of relationships with suppliers	
		Arithmetic mean of the assessment	N1
	2. Trade intermediaries	1. Availability of commercial intermediaries	
		2. Competitiveness of commercial intermediaries	
		3. Sustainability of relations with trade intermediaries	
		Arithmetic mean of the assessment	N2
	3. Relationships between industries in the sector	1. Existence of inter-branch connections	
		2. Increasing the dependence of the industries between them	
		3. Presence of a synergistic effect	
		Arithmetic mean of the assessment	N3
Arithmetic mean of the assessment of the factors taking into account the related industries			Average (N1:N3)
IV. COMPANY STRATEGIES AND COMPETITION	**1. Barriers to entry into the sector**	1. Low initial costs	
		2. Lack of administrative barriers	
		3. There are no secret cartels	
		Arithmetic mean of the assessment	N1
	2. Management and strategies	1. Existence of a production strategy	
		2. Existence of a marketing strategy	
		3. Existence of a financial strategy	
		4. Existence of a strategy for human resources management	
		5. Existence of an innovation strategy	
		Arithmetic mean of the assessment	N2
	3. Competition	1. Existence of competition	
		2. Intensification of competition	
		3. Opportunity for the emergence of new competitors / substitute products	
		Arithmetic mean of the assessment	N3
Arithmetic mean of the assessment of the factors taking into account the company's strategies			Average (N1:N3)
V. GOVERNMENT INTERVENTION	**1. Political and**	1. Existence of a state strategy for the development of the sector	

	legal conditions	2. Effectiveness of public policy affecting the sector	
		3. Lack of corruption	
		4. Degree of control by the state	
		Arithmetic mean of the assessment	N1
	2. Macroeconomic situation	1. Existence of economic growth	
		2. Presence of inflation	
		3. Employment growth	
		4. Increasing purchasing power	
		Arithmetic mean of the assessment	N2
	3. Government support	1. Educational support	
		2. Support in research and development	
		3. Support in export production and export	
		Arithmetic mean of the assessment	N3
Arithmetic mean of the assessment of factors taking into account government intervention			Average (N1:N3)

Source: Adapted according to the methodologies established by Milusheva, 2012 [15], Atanasov, 2016 [1], and Vachevska, 2013 [28].

RESULTS AND DISCUSSIONS

The evaluation of the results shows that the wine industry is attracting interest, but the accumulated technological experience and organizational skills are still at a satisfactory level. According to expert estimates, wine producers do not have the corresponding advantages in wine exports and imports, but attempts are being made to improve the technological base and plant new grape varieties. Based on expert assessment, it can be concluded that the country has specialized in the production and trade of bulk wines (Razzaq, A. R. A., Mustafa, M. Z. & Suradin, A. 2012) [26]. Bulgarian producers prefer to import mainly bottled wines and to export bulk table wines, which are positioned in the low price segments of the international market. The structural determining country in the import of wines on the Bulgarian market is Northern Macedonia, and in recent years' parts of Romania. The main consumer of Bulgarian wines is Russia. About 64% of the Bulgarian exports go to the Russian market. These are mainly table wines and bottled wines. Another structure-determining country for Bulgarian exports is Poland, which accounts for 22% of total wine exports (Eurostat 2021) [8]. In recent years, the specialization of Bulgarian viticulture has focused on the production of grapes from vine varieties that are popular on the international market, such as Cabernet Sauvignon, Merlot and Rkatsiteli. Cabernet and Merlot wines. Going back to the period before Covid-19, it is noted that in the period from 2008 to 2018 the comparative advantages of our country in wine exports reduced the values of the index from 2.18 to 1.58 in 2018. This proves that Bulgaria is lagging behind in wine exports to the international market due to strong competition. In the euro area, Bulgaria ranks slightly ahead of Hungary in terms of index value - comparative export advantages in the wine trade. In general, the trend of decreasing the comparative advantage in the export of products of the domestic wine sector is one-way with the tendency of decreasing the comparative advantage in the export of EU wine. In comparison, almost all EU countries, major exporters of wine on the world market, are reducing their comparative advantages. The weakening of market positions of most countries in Europe is caused by the processes of restructuring of their wine sectors in the context of the new EU agricultural policy (Welke, J. E., Manfroi, V., Zanus, M., Lazzarotto, M., Cláudia and Zini, A. 2013) [31].

For several years, large surpluses of wine have accumulated on the EU market, which has been reflected in lower prices and a significant contraction in wine and grape production. Within the European Union, agrarian policy has had to be reformed so as to minimize these surpluses and stabilize the wine industry. These reforms have affected most countries, but have also given them the opportunity to look for opportunities to expand the range of grape products produced in the countries. This has led to the implementation of a number of initiatives and projects with research and development activities that will generate new productions of products from the wine industry in the European Union (OECD, 2016) [22]. The new agricultural policy of the Union aims to achieve comparative advantages and competitiveness in the production of products originating in the wine sector and the selection of different types of wines with high quality products and its diversity [11].

The dynamics of the comparative advantages of the main countries exporting wines at the global level is shown in Table 2.

Table 2. Dynamics of the comparative advantages of the main countries exporting wine in the world for 2008 - 2018

Country	2008			2018			Dynamics (2008 base)		
	Index of comparative advantages	Index of comparative advantages	Relative index commercial advantages	Index of comparative advantages	Index of comparative advantages	Relative index commercial advantages	Comparative advantages when exporting	Comparative advantages when importing	Commercial advantages
European Union	1.04	1.03	0.005	0.93	1.05	-0.12	-0.11	0.01	-0.124
France	4.12	0.44	3.69	0.43	0.46	-0.03	-3.69	0.03	-3.720
Italy	2.70	0.30	2.41	2.40	0.37	2.03	-0.31	0.07	-0.378
Australia	0.24	0.47	-0.23	4.38	0.80	3.58	4.14	0.33	3.808
Chile	6.92	0.02	6.90	8.88	0.05	8.83	1.96	0.03	1.931
Spain	2.71	0.14	2.57	2.35	0.29	2.07	-0.36	0.15	-0.507
Germany	0.18	1.09	-0.91	0.19	1.00	-0.81	0.01	-0.09	0.099
USA	0.25	0.80	-0.55	0.19	0.90	-0.70	-0.05	0.10	-0.149
Portugal	4.98	0.52	4.45	3.95	0.42	3.53	-1.02	-0.10	-0.920
South Africa	3.11	0.06	3.06	2.38	0.08	2.30	-0.73	0.02	-0.752
New Zealand	0.33	1.58	-1.25	5.17	1.66	3.51	4.84	0.08	4.760
Argentina	1.73	0.02	1.70	2.22	0.03	2.19	0.49	0.00	0.488
Great Britain	0.16	3.07	-2.91	0.22	3.15	-2.93	0.06	0.07	-0.017
Belgium	0.08	1.18	-1.10	0.17	1.35	-1.17	0.09	0.17	-0.080
Singapore	0.20	0.41	-0.22	0.24	0.03	0.20	0.04	-0.38	0.419
The Netherlands	0.07	0.87	-0.80	0.09	0.27	-0.18	0.02	-0.60	0.617
Switzerland	0.12	2.32	-2.21	0.22	2.42	-2.20	0.10	0.10	0.005
Austria	0.24	0.53	-0.29	0.22	0.56	-0.34	-0.02	0.04	-0.056
Denmark	0.31	2.61	-2.30	0.01	2.86	-2.85	-0.30	0.25	-0.551
Bulgaria	2.18	0.04	2.14	1.58	0.41	1.17	-0.60	0.37	-0.965
Hungary	0.35	0.04	0.31	0.23	0.11	0.12	-0.11	0.07	-0.184
in general	1.52	0.84	0.69	1.74	0.87	0.87	0.21	0.03	0.177

Source: FAO data and own calculations [10].

The complex assessment of the comparative advantages of the Bulgarian wine sector is obtained using the indicator - relative trade advantages. According to the values of this index during the period under review Bulgaria reduces its comparative advantages in the production and trade of wine and wine-cognac materials. Thus, Table 2 shows that for the period 2008 - 2018 the value of the index decreased by 0.97 points. This also means a significant reduction of the comparative advantages of Bulgaria, although the comparative advantages of wine imports increase by 0.37 points. Thus, we can conclude that the comparative advantages of exports generally decrease by 0.60 points. This somewhat reverses the trend in the development of viticulture as Bulgaria becomes a net importer of low value-added wines, which is a sign that domestic consumption is shrinking and reorienting to the consumption of cheaper products. At the same time, the informal sector in the industry remains tangible. Only 55% of the grapes harvested in the country are vinified under industrial conditions. Looking at the situation of the other countries in Table 2 for their export advantages, only South Africa and Portugal are worse off. In addition, the table shows that Bulgaria's market share is within 0.25% of world exports and falls into the group of countries such as Denmark, Hungary and Austria - countries that have less favourable climatic conditions for the development of viticulture. However, we can assume that in the period 2008 - 2018 the market share of the country remains at a decent level. It is important to note that countries such as Australia have lower market shares, and Chile is indeed significantly increasing its competitiveness in wine production and trade. Individually, countries such as Australia have significantly expanded their exports over the last 10 years, ranging from 0.3% to 5.25% of total exports to the world market (Moreno-Arribas, M. V. and Sualdea, B. B. 2016) [18]. In general, the turnover on the world wine market is expanding by almost 26%, as can be seen from Table №1, provided that consumption remains the most sensitive to the "quality-price" relationship. Another important research method is the performed matrix analysis (market share / growth) of the market structure and it is established that the number of countries that are defined as potential centres of profit in the production and trade of wines prevails (Moreno-Arribas, M. V. and Sualdea, B. B. 2016) [18]. These are countries that control less than 5% of the market and achieve market growth of over 30% compared to the previous reporting period. This group includes Germany, New Zealand, Argentina, Great Britain, Belgium, Singapore, the Netherlands, Switzerland, Austria, Denmark and Bulgaria. The wine-growing sectors of the countries: France, Italy, Australia, Chile and Spain are defined as centres of profit. Each of these countries has a significant (over 5%) market share and achieves high market growth (over 30%). The overall picture can be seen in Table 3, which shows the main market shares of the wine exporting countries.

Table 3. Market shares and growth of exports of the main wine exporting countries in the world for the period 2008 - 2018

Country	2008		2018		Market growth in%
	Export of wine in thousands of $	Market share %	Export of wine in thousands of $	Market share %	
European Union	14,505,773	45.78	19,908,032	41.97	137.24
France	6,919,726	21.84	9,254,180	19.51	133.74
Italy	3,550,372	11.20	4,741,609	10.00	133.55
Australia	105,120	0.33	2,488,462	5.25	2367.26
Chile	835,486	2.64	2,414,119	5.09	288.95
Spain	1,835,577	5.79	2,395,881	5.05	130.52
Germany	592,425	1.87	990,021	2.09	167.11
USA	745,256	2.35	902,852	1.90	121.15
Portugal	660,693	2.08	818,494	1.73	123.88
South Africa	533,227	1.68	668,629	1.41	125.39
New Zealand	245,451	0.77	559,343	1.18	227.88
Argentina	221,438	0.70	496,837	1.05	224.37
Great Britain	208,449	0.66	382,942	0.81	183.71
Belgium	95,361	0.30	302,070	0.64	316.76
Singapore	144,317	0.46	285,326	0.60	197.71
The Netherlands	91,847	0.29	200,460	0.42	218.25
Switzerland	53,180	0.17	153,076	0.32	287.85
Austria	105,120	0.33	144,628	0.30	137.58
Denmark	88,619	0.28	120,025	0.25	135.44
Bulgaria	80,189	0.25	118,073	0.25	147.24
Hungary	71,584	0.23	90,180	0.19	125.98
total	31,689,210	100.00	47,435,239	100.00	125.98

Source: FAO data [10].

The wine sectors of countries such as the United States, Portugal, South Africa and Hungary generate products that are exported at a slow pace (below 30% compared to the previous year). The United States owns 1.9% of world wine exports, Portugal 1.73%, South Africa 1.41% and Hungary 0.19% respectively, which is shown in Table 2 and in practice gives us reliable arguments for evaluation. On this basis, we can assume that the specified market share / growth matrix can determine not only which are the centres of profit and potential leaders in the wine market, but also the main competitors of Bulgaria in the production and trade of wines and wines. cognac materials. In the domestic market, the main competitors of Bulgarian wines are Italy and France. Italy, which accounts for 26.8% of imports of bottled wines in Bulgaria, and France respectively 10.7% of imports (NSI, 2020) [19]. On the international market, Bulgarian wines are defined as competitive in Russia, where the import of Bulgarian bottled and bottled wines accounts for 12% of total imports in the country. Despite Bulgaria's membership in the EU, the business manages to sell significant quantities in third countries, but this share in the future is not clear whether it can be maintained. The analysis of the branch specialization of the wine-growing regions in Bulgaria shows that the South-Eastern wine-growing region is closely specialized in the production of red and white table wines. The south-western wine-growing region is closely specialized in the production of red quality wines. At the same time, the North-eastern wine region specializes in the production of quality white wines. Bulgaria clearly stands out on the world market as a country traditionally developing exports of bulk wine, which has low added value (Arche Noah 2017) [21].

Outlining the competitive advantages of viticulture in Bulgaria

In our conditions, the competitiveness of farms in the wine sector is determined by the complex interaction of a number of factors - ranging from the location and size of vineyards and terroir in the area, enterprise size, tangible assets and equity, innovation and mechanization. comes to participation in national and international markets, marketing behaviour and advertising. In practice from Figure 1, which analyzes the processes in the sector.

We can assume that for countries like Bulgaria with large rural areas, viticulture can be one of the most important economic sectors in agriculture, covering both significant areas of arable land and providing livelihoods and work for thousands of producers. In addition, we can say that it is quite an intensified sector, which in view of its functioning and competitiveness. In practice, it uses a significant number of agro-technical measures that have a significant impact on the environment, soils, plants and the rest of the ecosystem. On the other hand, the foundations of the development of the industry are the available vineyards and vineyards. These are the main participants in the wine sector, and the auxiliary ones are all the others, ensuring the production of the raw material and the final product. There is a wide variety of vineyards with different sizes and management strategies, which proves that there are no significant barriers to entry into the sector through the viticulture industry. Figure 1 shows that viticulture is also defined as a highly competitive industry due to the large number of participants who are strictly individual in developing and following their development strategy. Small farms predominate, which is compensated by their risk-taking and the results of negative agro-climatic processes, which may affect the results of vineyards. This determines their lower innovation and investment activity compared to other participants in the sector. In addition, a significant role is played by trade intermediaries in the sale of raw materials - a product of the vilification industry, determine the relationship of this industry with processing. There is no clear competition in this value chain - there are a small number of participants who have a significant impact on the market price. This is one of the reasons for the low marketability of grape growers. Achieving sustainable development in viticulture is a complex process. Demand and market distribution are constantly changing, and planning in the industry takes time - the construction of the vineyard and processing facilities takes several years, after which it may be that the market has changed and there is no interest in the products.

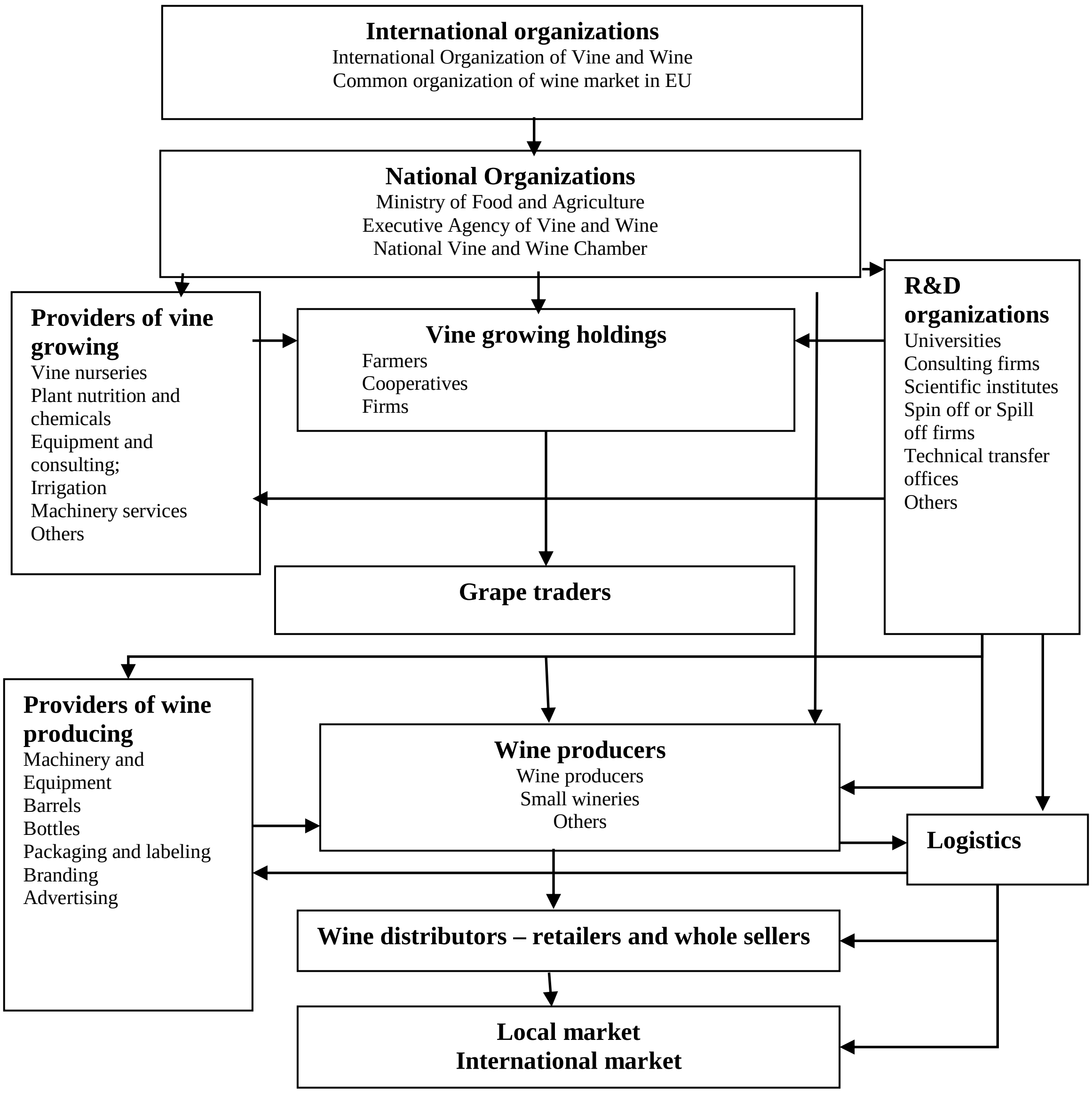

Fig. 1. Participants in the value chain in the sector.
Source: Adapted model of Kirechev, 2012 [13].

This redefines the need to analyze the determinants of the competitive advantages of the industry. The expert assessment shows (Table 2) that within Porter's model, the determinants that most strongly define the competitive advantages of the wine sector are the demand conditions, the competition and the strategies of the players in the value chain (Table 1).

In addition to the above determinants, it is important to note that the related and supportive industries are also significant to the development of the sector's competitive advantages. State intervention is the least significant among the determinants examined. This proves that the wine sector is developing thanks to the entrepreneurial factor, which develops its business model through a strategy in line with market requirements (Belletti, G., Marescotti, A. and Touzard, J.-M.2015) [3].

This brings to the fore and analysis of the importance of different factor conditions as a source of competitive advantage for the sector can be seen in Figure 2. The preserved diversity of natural resources is a major factor determining the competitive advantages of the wine sector (respectively, the average value of the indicator used for this factor is 6.0). The easy access of the participants to natural resources in the cluster determines the leading role of this source of competitive advantage. The availability of skilled labour is the other important source of competitive advantage of the sector (the value of this indicator is 5.4). On the other hand, the respondents determine that the skilled workforce is poorly mobile and this determines the difficult process of selection and retention of staff in vineyards and wine industries. Thanks to the established traditions in wine production, the participants in the sector have gained experience and knowledge base. This is a prerequisite for the existence of organizations engaged in research and development, which is another major source of competitive advantages of the sector.

The research and development activity is carried out mainly by the organizations that are subsidized by the state - these are universities and research institutes. The private sector has little involvement in this type of activity. The main reasons for this are the slow return on research and development costs and the weak protection of intellectual property in Bulgaria.

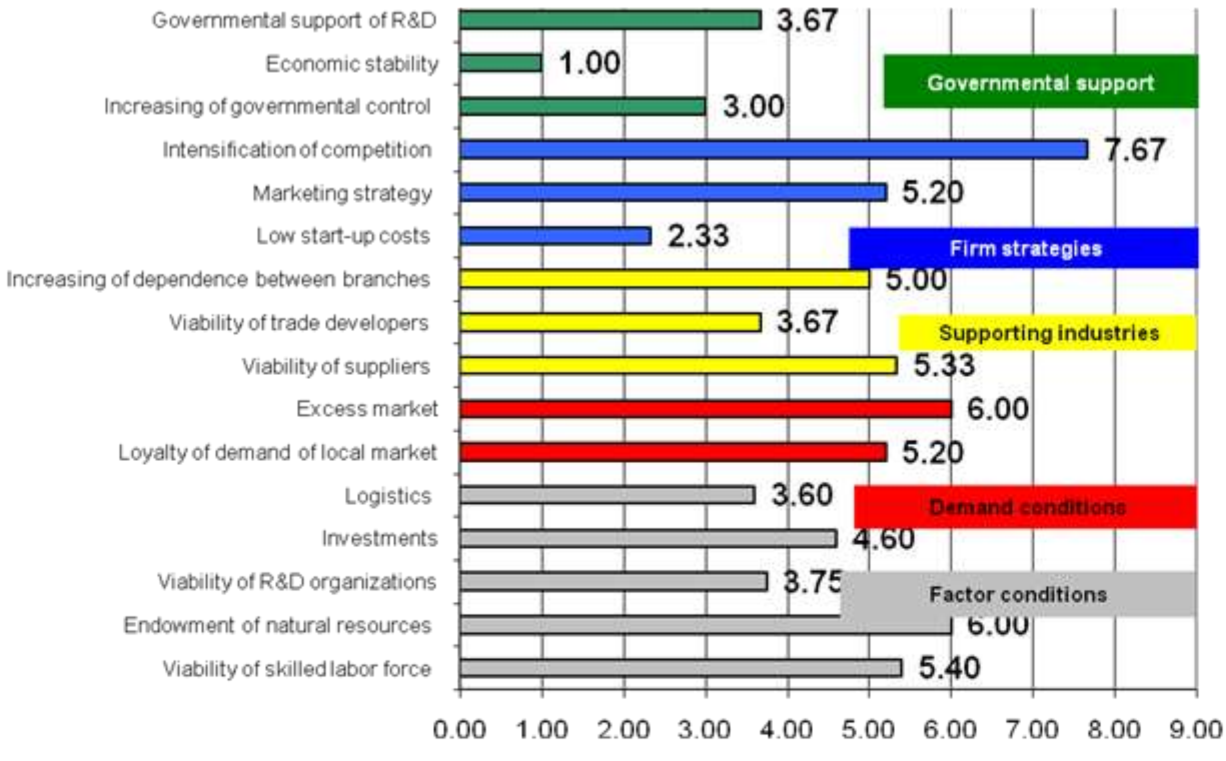

Fig. 2. Significance of the factors determining the competitor's advantages of the wine sector.
Source: Study by P. Borisov and P. Marinov, 2013 [5].

Another important element of the factor conditions is the investment activity of the participants in the sector. This factor is the third most influential (the average value of the indicator is 4.6). According to the surveyed experts, the main part of the investments in the sector are made by the wine industry enterprises for the creation of vineyards and the purchase of buildings, equipment and machinery. They absorb most of the funds provided by national and European financial funds. The main factors limiting investment in the sector is the slow return on investment due to the poor financial performance of participants in the value chain and the weak willingness of the banking sector to lend to the wine sector. The expert assessment points to the established logistics base as another significant source of competitive advantage of the wine sector. It is also defined as a leading factor in facilitating the work of participants in the chain "raw material-end product". The main problems for establishing the competitive advantages of the cluster are the weak technological transfer between the research and development organizations and the producers - vine growers and wine producers. There are also no strategic alliances between science and practice in the process of creating innovations. These are some of the most important sources of sustainable competitive advantage (Jakšiü, D., Ivaniševiü, D., Ĉokiü, V., Tepavac Brbakliü, M. 2015) [12].

The conditions of demand on both domestic and foreign wine markets have been studied. The main factors determining the competitive advantages of the cluster in these markets are fair demand (the indicator is 5.2) and the presence of a surplus. Achieving a loyal demand for the products of the cluster is carried out through the established brand, which is a result of the preserved traditions in production. The presence of a predominance of supply over the demand for wine on the international market determines the intensification of competition Balieva, G. N., M. Huliyan (2015) [2]. The participants in the cluster determine that the presence of such competition has a disciplining effect in following the marketing strategy. According to them, this is a major source of competitive advantage in the wine trade. The main sources of competitive advantages in this group of factors in the studied model are suppliers of raw materials and know-how (average value of the indicator 5.33), strengthening of intersectoral relations (value of indicator 5.00) and trade intermediaries in wine distribution (value of indicator 3.67). It should be noted that the integration of industries is achieved with more investment by wineries. According to the expert assessment, the main problem hindering the strengthening of the influence of this determinant in the model of the competitive advantages of the cluster is the low stability of the relations of grape and wine producers with trade intermediaries.

The presence of intensified competition on the wine market determines the competitive advantages of the cluster (the average value of the indicator is 7.67). Achieving competitive advantages in the market is carried out by developing and following an adequate marketing strategy (the average value of the indicator is 5.2). According to the respondents in the cluster, these are the two most important factors for success in the production and trade of wine. Another important factor is the relatively low initial costs required to start a business. The main problems, according to the owners of the vineyards, are the existence of secret cartels in the purchase of grapes, and according to the wine industry, the significant administrative barriers in the industry. The study shows that wine producers and traders do not impose a strategy for human resource management. They invest more in the purchase of machinery and equipment and cut costs in a crisis in the area of "Staff costs". Thus, the contribution of the cluster to the economic and social development of the region is relatively low (Balieva, G. N., M. Huliyan 2015) [2]. The clustering of the wine sector as an approach to achieving sustainable competitiveness is at an early stage of its development. In this phase there is a combination of production factors in the different industries that form the cluster. This process takes place using different sources to form a competitive advantage. At this stage, the connections between the building blocks of the cluster have already been established, the institutions controlling its development have been formed. The main critical factor for the rapid achievement of a high level of sectoral competitiveness in the cluster is the creation of technology transfer and the attraction of capital that will value this technology transfer in competitive products. An important factor in the management of the wine industry is the evaluation and analysis of government support. The analysis of this determinant of the competitive advantages of the cluster highlights the following more significant factors - state support in research and development (average value of the indicator is 3.67) and strengthening control by institutions (3.00) regulating the activities of industries. Experts have given a very low assessment of macroeconomic stability, as a factor determining the competitive advantages of the wine sector (Belletti, G., Marescotti, A. and Touzard, J.-M. 2015) [3].

Conserving the local identity and traditions of local communities is one of the main lines of economic development in rural areas, particularly in the area of creating value through the development of the wine industry. Value added is not always associated with new and unaffordable financial investments or cost reductions. Often a change of approach, innovation, product specialization and adaptation to new consumer tastes is enough. Also diversification of activities, whether in the agricultural or other field - for example, linking to tourism or the production of other products, the transition to organic production. Sometimes the improvements consist of small steps related to the organization of production or advertising and distribution, in cooperation with other producers or closing the production/processing cycle, creating clusters and regional brands that support the general advertising of the wine industry.

CONCLUSIONS

The analysis of the competitiveness of the wine sector must take into account the impact of the processes of specialization, concentration and integration of industries in the sector. As a result of these processes in the sector, specific inter-industry relations are determined, which are the basis for sustainable development of competitiveness. Given the global trend to create small boutique wineries with their own look and special attitude towards wine, the production of organic wine can be seen as a successful method of differentiating from the competition and adding value. Moreover, we can accept the fact that the combination of viticulture and wine production is at an advanced stage, but a number of conditions and factors still hinder the full integration of these industries (Delord, B., Montaigne, E. and Coelho, A. 2015) [6]. Vineyards are characterized by low stocks due to the small size of vineyards that cultivate small vineyards with diverse varietal composition. As a result, the raw material base in the sector is diverse in variety composition and quality. Wine production needs large batches of homogeneous raw material to enable large-scale production to take place and to use the "economies of scale" effect. The main reason limiting access to native raw materials is the still small capacity of the large number of small vineyards, a factor determining the difficult management of the process of raw material supply by wineries. Possession of young or currently in fruiting vineyards by wine-growing enterprises with low productivity. Impossibility for rhythmic supply of working capital for payment during the grape harvest campaign by the wine enterprises. The seasonality of viticulture requires the allocation of significant financial resources during the grape harvest, while the use of imports of wine and cognac materials in production determines easier financial planning. The market orientation of the branches of the wine sector has been declining in recent years. From the production of quality and table wines are realized only 63% of the quantities produced (for 2018) on the international market. Only 50% of the production of special wines. This determines the relatively low commodity value of the industries measured on the basis of exports of products produced by them. The reasons for this are the high size of domestic wine production, which consumes more than half of the raw material - a product of viticulture. The export of bulk wines, in which Bulgaria specializes within the EU, requires quality raw materials, which are grape products (grapes or grape must), the result of viticulture. We can emphasize that Bulgarian wine producers are hesitant in choosing raw materials for production. On the one hand, in order to comply with quality standards, some wine companies produce grape wines, production from specific local vine varieties, which gives them a competitive advantage on the international market (these companies are the smallest part of the participants in the sector), while others rely on the processing and blending of local varieties with foreign ones, making it difficult to trace the origin of the wines obtained. The added value is in the cooperation between the grape producers, which overcomes the problems with the small private plots, the homogeneity and quality of the production, the purchase price. The production of own brands of wine closes the cycle and increases the profits of all participants. Diversification into wine tourism supports the overall development of the rural region. The links between viticulture and wine production with a view to increasing the competitiveness of the sector have not yet been clarified. The vineyards that provide the raw material base have a low return on investment, which stops their expansion and innovative development. A positive factor is the support of vine growers and winemakers with European funds through the three national viticulture programs and the RDP, as well as the improving in recent years state policy for general advertising of Bulgarian wines and linking them to Bulgaria's tourism product.

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REFERENCES

[1]Atanasov, V., B. Black, 2012, Shock-Based causal inference in Corporate Finance and Accounting Research. Critical Finance Review, 2016, vol.5, pp. 207-304

[2]Balieva, G. N., Huliyan, M., 2015, Production and supply of regional food products - incentives and challenges for small holdings in Bulgaria. International Journal of Science and Research, Vol. 4(2), 576-580.

[3]Belletti, G., Marescotti, A., Touzard, J.-M., 2017, Geographical indications, Public goods and sustainable development: The roles of actors' strategies and public policies.World Development, Vol. 98 (C), 45-57.

[4]Borisov, P., Radev, T., Dimitrova, D., 2014, Comparative advantages of EU Member States in Trade with Wine. Bulgarian Journal of Agricultural Economics and Management, 4/2014, 59-65.

[5]Borisov, P., P. Marinov, 2013, Evaluation of competitive advantages of wine cluster. Agraren Universitet Plovdiv - Nauchni Trudove/Scientific Works of the Agrarian University - Plovdiv 2013 Vol.57, pp.151-158 ref.5

[6]Delord, B., Montaigne, E., Coelho, A., 2015, Vine planting rights, farm size and economic performance: Do economies of scale matter in the French viticulture sector?, Wine economics and policy, Vol.1, pp. 22-34.

[7]Dimitrova, D., Simeonov, I., 2016, Varietal structure as a source of competitive advantage in the wine sector, In: Proceedings of the National scientific conference with international participation „Wine – history and inspiration", Lyuben Karavelov Regional Library, Ruse, pp.130-141 (In Bulgarian), https://www.researchgate.net/publication/319878718_ Regional_aspects _of_ viticulture _and_wine_production_development_in_Bulgaria, Accessed on Feb 22, 2022.

[8]Eurostat, 2021, Wine production and trade. https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20201119-2, Accessed on Feb 22, 2022.

[9]Executive Agency for Vineyards and Wine (EAVW), Report on vineyards – state and perspective, 2021.
http://www.eavw.com/index.php?lg=bg&menuid=5&submenuid=1223, Accessed on Feb 22, 2022.

[10]FAO, Food and Agricultural Organization of the United Nations – database, https://www.fao.org/faostat/en/#home, Accessed on Feb 22, 2022.

[11]Hawkins, D. E., 2004, A protected areas ecotourism competitive cluster approach to catalyse biodiversity conservation and economic growth in Bulgaria. Journal of Sustainable Tourism, 12(3), pp. 219–244. doi:10.1080/09669580408667235.

[12]Jakšiü, D., Ivaniševiü, D., Ĉokiü, V., Tepavac Brbakliü, M., 2015, Wine Atlas. Statistical Office Of The Republic Of Serbia, Belgrade.

[13]Kirechev, D., 2012, Spatial concentration and integration in the wine sector. Izvestia, University of Economics, Varna, 2/2012, 66-75.

[14]Loorbach, D., 2010, Transition management for sustainable development: A prescriptive, complexity-based governance framework. Governance, 23(1), pp. 161–183.

[15]Milusheva, S., 2012, Innovations in US infrastructure financing: An evaluation, 35-36.

[16]Ministry of Agriculture and Food (MAF), Agricultural reports 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, https://www.mzh.government.bg/bg/politiki-i-

programi/otcheti-i-dokladi/agraren-doklad/, Accessed on Feb 22, 2022.
[17]Ministry of Education and Science – Bulgaria, Sofia, National Scientific Program – “Intelligent Plant-growing”, 2021-2024, Home - NNP IR (nnp-ir.bg), Accessed on Feb 22, 2022.
[18]Moreno-Arribas, M. V., Sualdea, B. B., 2016, Wine safety, consumption and human health. Springer.
[19]National Statistical Institute, NSI, 2020, https://nsi.bg/bg/content/766/%D1%81%D1%82%D0%B0%D1%82%D0%B8%D1%81%D1%82%D0%B8%D1%87%D0%B5%D1%81%D0%BA%D0%B8-%D0%B4%D0%B0%D0%BD%D0%BD%D0%B8, Accessed on Feb 22, 2022.
[20]National Vine and Wine Chamber (NLVK), Annual reports, 2018, 2019, 2020, http://bulgarianwines.org/%d0%bf%d1%80%d0%be%d1%83%d1%87%d0%b2%d0%b0%d0%bd%d0%b8%d1%8f/, Accessed on Feb 22, 2022.
[21]Noah, A., 2017, Forbidden fruits: the fabulous destiny of Noah, Othello, Isabelle, Jacquez, Clinton and Herbemont, Brussels and Vienna. bing.com/ck/a?!&&p=1f2cfcb895880d5bJmltdHM9MTY4Nzk5NjgwMCZpZ3VpZD0zOWY0MWNjZS00NzEyLTZkY2QtMDYzNS0wZDJkNDZiNDZjOGImaW5zaWQ9NTE3Mw&ptn=3&hsh=3&fclid=39f41cce-4712-6dcd-0635-0d2d46b46c8b&psq=Noah%2c+A.%2c+2017%2c+Forbidden+fruits%3a+the+fabulous+destiny+of+Noah%2c+Othello%2c+Isabelle%2c+Jacquez%2c+Clinton+and+Herbemont%2c+Brussels+and+Vienna.&u=a1aHR0cHM6Ly93d3cuYXJjaGUtbm9haC5hdC9maWxlcy9hcmNoZV9ub2FoX2FwcmlsXzIwMTZfZGlyZWN0X3Byb2R1Y2Vyc19mb3JiaWRkZW5fZnJ1aXRzX2V4ZWN1dGl2ZV9zdW1tYXJ5LnBkZg&ntb=1, Accessed on Feb 22, 2022.
[22]OECD, 2016, Regional Well-Being: A user’s guide, Paris. Regional-Well-Being-User-Guide.pdf (oecdregionalwellbeing.org), Accessed on Feb 22, 2022.
[23]OIV, 2020a, State of the vitiviniculture world market. Paris. oiv-state-of-the-world-vitivinicultural-sector-in-2020.pdf, Accessed on Feb 22, 2022.
[24]OIV, 2020b, World Vitiviniculture situation. Paris. https://www.oiv.int/public/medias/5029/world-vitiviniculture-situation-2016.pdf, oiv-state-of-the-world-vitivinicultural-sector-in-2020.pdf, Accessed on Feb 22, 2022.
[25]Porter, M, 1990, On competition, Bussines and Economics, First edition, 544 p.
[26]Razzaq, A. R. A., Mustafa, M. Z., Suradin, A., 2012, Community capacity building for sustainable tourism development: Experience from Miso Walai homestay. Business and Management Review, Vol. 2(5), pp. 10–19.
[27]Simeonov, I., 2016, Concise economic description of the basic local grapevine varieties for the Republic of Bulgaria, Phytologia Balcanica, Vol. 22(2), 209-216. (PDF) Regional aspects of viticulture and wine production development in Bulgaria. https://www.researchgate.net/publication/319878718_Regional_aspects_of_viticulture_and_wine_production_development_in_Bulgaria, Accessed on Feb 28, 2022.
[28]Vachevska, D., 2013, State, trends and problems in the development of viticulture in Bulgaria, Annals of the University of Craiova-Biology vol1, 2013, 241-250
[29]Vagionis, N., 2010, Alternative tourism in Bulgaria: Diversification and sustainability. OECD publication. (PDF) Alternative tourism in Bulgaria: diversification and sustainability (researchgate.net)
[30] Velev, M., 2007, Cluster Approach to Increasing Competitiveness. Soft trade Publishing house, Sofia, 245 p.
[31]Welke, J. E., Manfroi, V., Zanus, M., Lazzarotto, M., Alcaraz Zini, C., 2013, Differentiation of wines according to grape variety using multivariate analysis of comprehensive two-dimensional gas chromatography with time-of-flight mass spectrometric detection data, Food Chemistry, Vol.141(4), 3897-3905.

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MODELLING LIFE CYCLE COST ANALYSIS (LCCA) SCENARIOS ON THE USE OF COMPOST IN ORGANIC PEAR ORCHARD IN ROMANIA

Ana Cornelia BUTCARU, Ionela Mițuko VLAD, Cosmin Alexandru MIHAI, Liliana BĂDULESCU, Gina FÎNTÎNERU, Florin STĂNICĂ

University of Agronomic Sciences and Veterinary Medicine Bucharest, 59 Mărăști, District 1, 11464, Bucharest, Romania, Phone/Fax: 00 40 744 6474 10, E-mails: ana.butcaru@qlab.usamv.ro, vlad.ionela@managusamv.ro, cosmin.mihai@horticultura-bucuresti.ro, liliana.badulescu@horticultura-bucuresti.ro, gina.fintineru@usamv.ro, flstanica@yahoo.co.uk

Corresponding author: vlad.ionela@managusamv.ro

Abstract

This study aims to present the life cycle cost (LCC) for 1 kg of pear produced using organic technology in Southern Romania. Two principal stages were depicted: production stage costs (PC) and Transport costs (TC). For each stage, investment and operational costs were determined. Pear orchard establishment (POE), the first I-III years of orchard management (without harvest) (OM.I-III), and IV-XX years of orchard management (OM.IV-XX) were analyzed considering the elemental activities included. Three scenarios were applied for fertilization: (S1) compost produced at the farm level using a composter Oklin GG-50S combined with the one produced on outdoor platform in the farm, mainly from vegetable sources. (S2) compost from the outdoor platform for organic residues, and (S3) acquisition of a commercial organic fertilizer. The total LCC for 1 kg of pear ranged between 0.400 € (S2), 0.481 € (S3), and 0.496 € (S1). Details regarding the LCC components and optimization were presented.

Key words*: l*ife cycle cost analysis, Pyrus communis, composter, Romania

INTRODUCTION

Pear production declined in Romania in the last few years. Although it is a highly profitable crop compared to others, this is not the first option in the farmer's establishment of orchards. Recently, the excessive use of organophosphorus pesticides for pest control in pear orchards led to a massive attack of *Cacopsylla pyri* L. correlated to fumagine. After the 1992 year, when the first fire-blight attack on an orchard from Însurăței, Brăila county in the Southern part of Romania, the pear orchard area decreased dramatically. New resistant or tolerant pear cultivars have been introduced on the market, but there was no signal that the farmer's options were changed. Organic technology applied to pear culture was still a sensitive subject.

In the meantime, at the international level, the total pear production increased steadily, at 25,658,713.07 tons in 2021, compared to 11,309,786.29 tons in 1994. The area for pear orchards stabilized at 1,399,484 ha, although the production increased due to the technology and more productive cultivars [13].

In the USA, in November 2023, the retail price for pear ranged between 0.92-2.75 €/kg in Washington and New York. The export price constantly increased in the last five years, from $1.21 in 2017 to $1.38 in 2021. The prediction for 2023 goes to $1.43 and $1.47 in 2024. For the import price/kg, 2023 is predicted to be around $1.42, and 2024 around $1.44 [23].

DG Agri E2 published in 2022 a study regarding the fruit and vegetable market in Europe [11] with a section on the prices of the pear market in the EU. The prices (€/100kg) were listed monthly (pear producer prices) for 2007-2022 on the main European markets – Italy, Belgium, Netherlands, and Spain. A comprehensive study and trends were made on the Abate Fetel, Conference, and Williams cultivars. In Italy, in 2021-2022, prices (€/100kg) started at 185 in August, climbed to 245 in February, then declined at 165 in May.

Belgium began with 50 in July, went up to 90 in February, and then reached 73 in June. The Netherlands started with 85 in July and increased to 103 in September. In 2019/2020, prices started at 100, went down to 55 in December, and climbed to 115 in June.

In Spain, 95 was the starting point in July, and 105 in June next year, 2022.

Abate Fetel was sold at around 230 €/100kg (producer prices) in February – July 2022, Conference at about 180 €/100kg, and Williams between 77 (Spain) and 230 (Italy) €/100kg.

China is the leading producer in the world, with 12,475 million tons in 2021 (Faostat), and, at the same time, the main exporter. In November 2023, prices on the domestic market ranged between 0.51 – 0.87 $/kg for fresh pear.

In Romania, 49,460 tons were produced in 2021 from 3,170 ha. The import volume was 28.38 million kilograms in 2022 [20].

Pear, just like apple, is a climacteric fruit. The chemical composition of the fruits is rich and varied: carbohydrates 8-15%, pectic substances 0.14-0.71%, organic acids 0.12-0.60%, tanned substances 0.06-0.24%, mineral substances 0.14-0.55%, vitamins C, PP, A, B [1].

There are summer, autumn and winter cultivars, the most appreciated being the winter cultivars, followed by the autumn ones. The harvest moment is usually in the first and second decade of September. The late cultivars need cold rooms for a more extended storage capacity, which can vary between 6 to 8/12 months for some cultivars. Winter pear can be consumed six months after harvesting, coming in the market between January and May, when the new fruit species begin to be harvested [4], [5], and [8].

For the pear orchard establishment, seedlings are available in the nurseries for the main cultivars, the most popular being in Romania Williams, Red Williams, Abate Fetel, and Conference (in some parts of the country). Breeding programs came with more cultivars resistant or tolerant to the main pear diseases, the most well-known being Euras, Tudor, Cristal, Corina, Monica [1], [3], [7], [16], [17], and [21].

The cultivation technology is mainly similar to the apple ones with specific traits regarding the pear characteristics (pest and disease management, fertilization, harvesting). Fertilization is a crucial point in orchard management and a challenge for the organic ones.

The present research analyses three possible scenarios using compost and commercial organic fertilizer. Life Cycle Cost Analysis (LCCA) was used for cost evaluation on each phase activity. LCCA highlighted the overall economic cost of a specific product, service, or system [9], [18] and proved to be a powerful technique for making the most cost-effective decisions at different life cycle stages [2], [10], [14], [15].

In recent studies, it has been widely combined with the Life Cycle Assessment (LCA) (ISO 14040:2006) [12]. Few studies were performed regarding fruit production LCCA [6]. There are more instruments to perform LCC analysis [25].

This study aims to present the life cycle cost for 1 kg of pear produced using organic technology in Southern Romania.

MATERIALS AND METHODS

Life Cycle Cost Analysis (LCCA) is a technique that uses economic analysis principles to evaluate the whole investment performance [25].

The functional unit considered was 1 kg of fresh pear. Table 1 presents the principal evaluated elements. Two principal stages were depicted: Production stage (PC) and Transport costs (TC). For each stage, investment and operational costs were determined. Pear orchard establishment (POE), the first I-III years of orchard management (investment and operational costs in the period without harvest) (OM.I-III), and IV-XX years of orchard management (OM.IV-XX) were analyzed considering the elemental activities included (Table 1).

Three scenarios were applied for fertilization: (S1) compost produced at the farm level using a composter Oklin GG-50S that can transform

125 kg of organic residues daily in compost (it has been considered an average transforming rate of 15%). This compost is combined with the one produced on an outdoor platform in the farm, mainly from vegetable sources.

Oklin composter needs a daily labor force to input the organic residues and, at a specific time, to take the compost. The outdoor compost platform needs equipment attached to the tractor to oxygenate the organic residues, water to maintain the optimum humidity, and a labor force to operate these tasks.

(S2) uses only compost from the platform for organic residues, equipment attached to the tractor to oxygenate the residues, water to maintain the optimum humidity, and labor force to operate these tasks.

(S3) includes only the acquisition of a commercial organic fertilizer for which we considered 1.5 tons/ha twice per year (concentrated poultry fertilizer).

Table 1. LCCA stages and costs elements on the pear production chain

(A) Production stage (PC)
(I) Pear orchard establishment (POE)
(1) Investment costs for orchard establishment (POEinv)
1.1. Field preparation
1.2. Planting
1.3. Fertilisation
POEinv total cost
(1) Operational costs for orchard establishment (POEop)
1.1. Clearing (deforestation) - process
1.2. Field preparation
1.3. Fertilisation
1.4. Planting
1.5. Trelising system
1.6. Irrigation system
POEop total cost
POE total cost
(II) I-III years orchard management (period without harvest) (OM.I-III)
(1) Investment costs in the first 3 years of the orchard (OMI-III.inv)
2.1. Prunning
2.2. Weeds management
2.3. Fertilisation
2.4. Pest and disease
OMI-III.inv total
(2) Operational costs in the first 3 years of the orchard (OMI-III.op)
2.1. Prunning
2.2. Weeds control
2.3. Fertilisation
2.4. Pest and disease
2.5. Irrigation
OMI-III.op total
OMI-III.inv + OM.I-III.op total
(III) IV-XX years orchard management (OM.IV-XX)
(1) Investment costs (OM.IV-XX.inv)
3.1. Prunning
3.2. Weeds management
3.3. Fertilisation
3.4. Pest and disease
OM.IV-XX.inv total
(2) Operational costs (OM.IV-XX.op)
3.1. Prunning
3.2. Weeds management
3.3. Fertilisation
3.4. Pest and disease
3.5. Irrigation
3.6. Harvesting
OM.IV-XX.op cost total
OM.IV-XX.inv + OM.VI-XX.op cost total
Total cost (A) Production stage (PC).inv
Total cost (A) Production stage (PC).op
Total cost (A) Production stage (PC)
(B) Transport costs (TC)
(2) Operational costs (TCop)
2.1. Transport from the field to cold storage
2.2. Transport from the storage to retail
TC.op total cost

Source: Own presentation on costs elements.

Compost is an ancient fertilizer that is mostly forgotten nowadays. The adverse effects of using chemical fertilizers in all crops and, at the same time, the need to capitalize on the organic residues highlighted the importance of composting at the farm level and not only [26].

The primary composting method is having controlled or uncontrolled composting of organic residues in a specific outdoor space.

More researchers studied the particular rate of the included elements, especially between nitrogen and carbon ratios. Different bacteria can be added to speed up the process with positive results on the output parameters. Also, a specific and highly recommended type of composting is vermicomposting, using earthworms [24].

The classical process usually can last 3 to 6 or more months according to the ratio of humidity and oxygen in the compost. More companies provide equipment for rapid composting with more positive traits (eliminating odours, fast decomposition, high-quality compost).

One of the newest and most innovative is the Oklin brand, tested and used in the University of Agronomic Sciences and Veterinary Medicine of Bucharest since 2021.

Research on the compost quality was done [18] and on the influence of pear production (manuscript, unpublished data).

The present study presents a comparison of LCC-based methodology for 1 kg of pear between (S1) compost from two sources (Oklin composter, concentrated and outdoor platform), (S2) compost from the outdoor platform, and (S3) fertilized with a commercial organic product. Microsoft Excel 2016, with a significance level of p = 0.05, was used for the descriptive statistics of the data.

RESULTS AND DISCUSSIONS

The results obtained in the three scenarios were valuable for identifying the life cycle cost (LCC) profile, respectively, hot points where a farm manager can actively intervene to optimize the costs.

The system boundaries were set from the orchard establishment to field production, including harvesting and transport to the storage facility. Total LCC was calculated on the production stage and on the transport stage.

For the production stage, three main periods were determined: pear orchard establishment, orchard management in the first three years (without production), and orchard management in the years IV-XX (with economic production).

Scenario 2 presented the best results considering the costs/functional unit of around 0.400 €/1 kg of pear, where compost from an outdoor platform for composting was used like fertilizer.

This is followed by Scenario 3, acquiring a commercial organic fertilizer with a total LCC of 0.481 €/1 kg. Scenario 1, where a composter (24h) and an outdoor platform for composting were used, had a total LCC of 0.496 €/1 kg of pear (Figure 1).

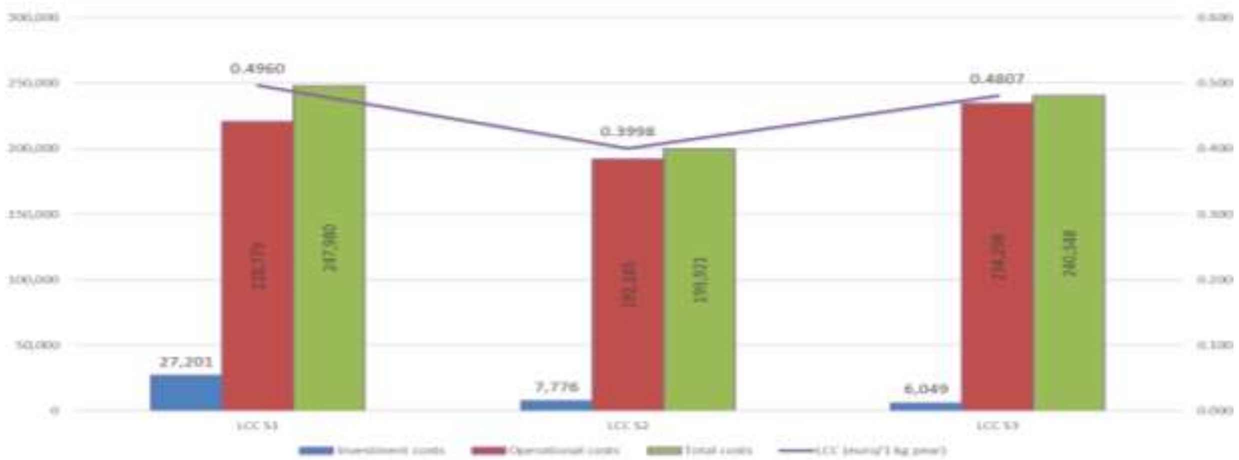

Fig. 1. Total LCC in the three scenarios
Source: own data.

Investment costs were the highest on S1 (0.054 €/1 kg), more than double that of S3 (0.012 €/1 kg) or S2 (0.016 €/1 kg), due to the composter acquisition and equipment usage. S3 had the higher operational costs (0.469 €/1 kg) due to the fertilizer acquisition, followed by S1 (0.442 €/1 kg) and S2 (0.384 €/1 kg) (Figure 1 and Figure 2).

When we analyzed the LCC elements for all scenarios, LCC for the transport stage was similar (0.036 €/1 kg) (Figure 3).

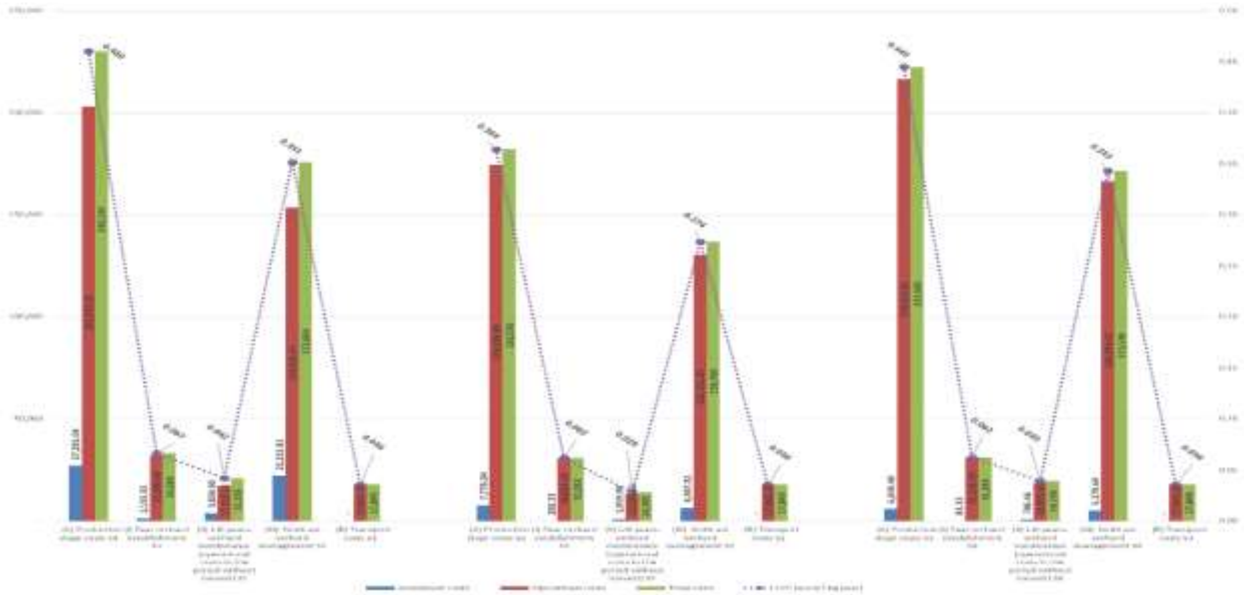

Fig. 2. LCC on the three scenarios detailed in the primary stages
Source: own data.

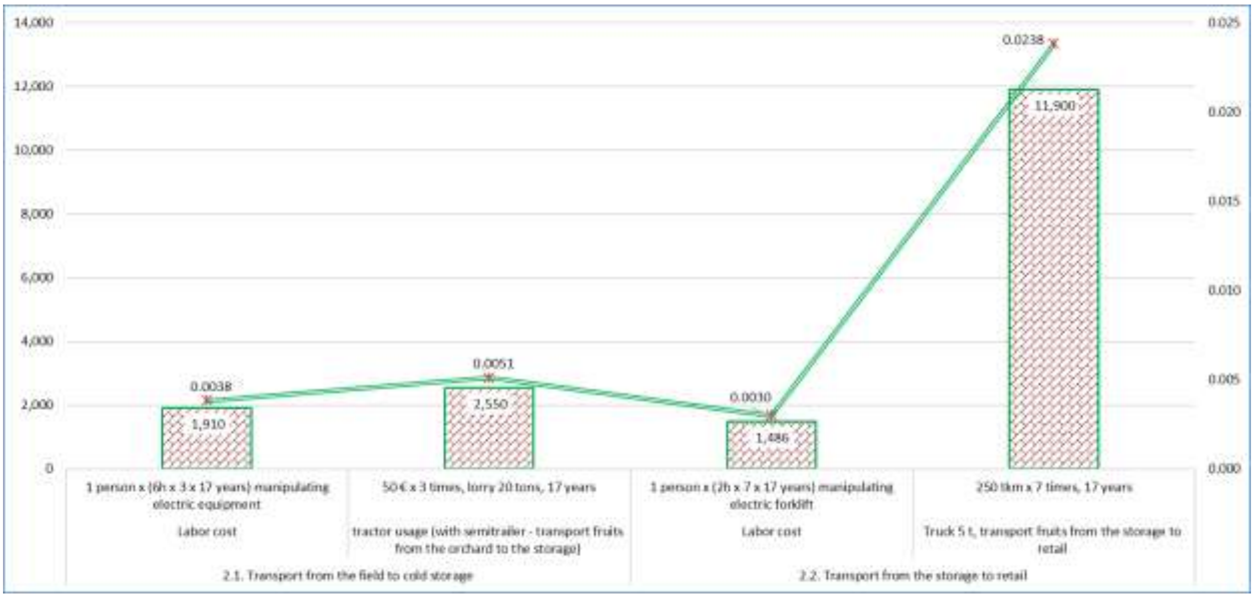

Fig. 3. LCC for the transport stage, Scenario 1
Source: own data.

The principal cost component of the LCC was in the production stage, being analyzed in three main periods: orchard establishment, the first three years of orchard maintenance (where there was no economic production), and the IV-XX years of orchard management (with economic production).

In the **orchard establishment phase**, the main cost in all scenarios was done by irrigation system (0.114 €/1 kg), trellising system (0.027 €/1 kg), and seedlings (0.018

€/1 kg). The costs for the production stage, Scenario 2 are presented below (Figure 4).

In the **first three years**, where no economic production was counted, the main elements in the LCC were at (S1) fertilization (0.121 €/1 kg) and pest and disease (0.014 €/1 kg), at (S2) pest and disease (0.014 €/1 kg) and fertilization (0.004 €/1 kg), and at (S3) pest and disease (0.016 €/1 kg) and fertilization (0.013 €/1 kg).

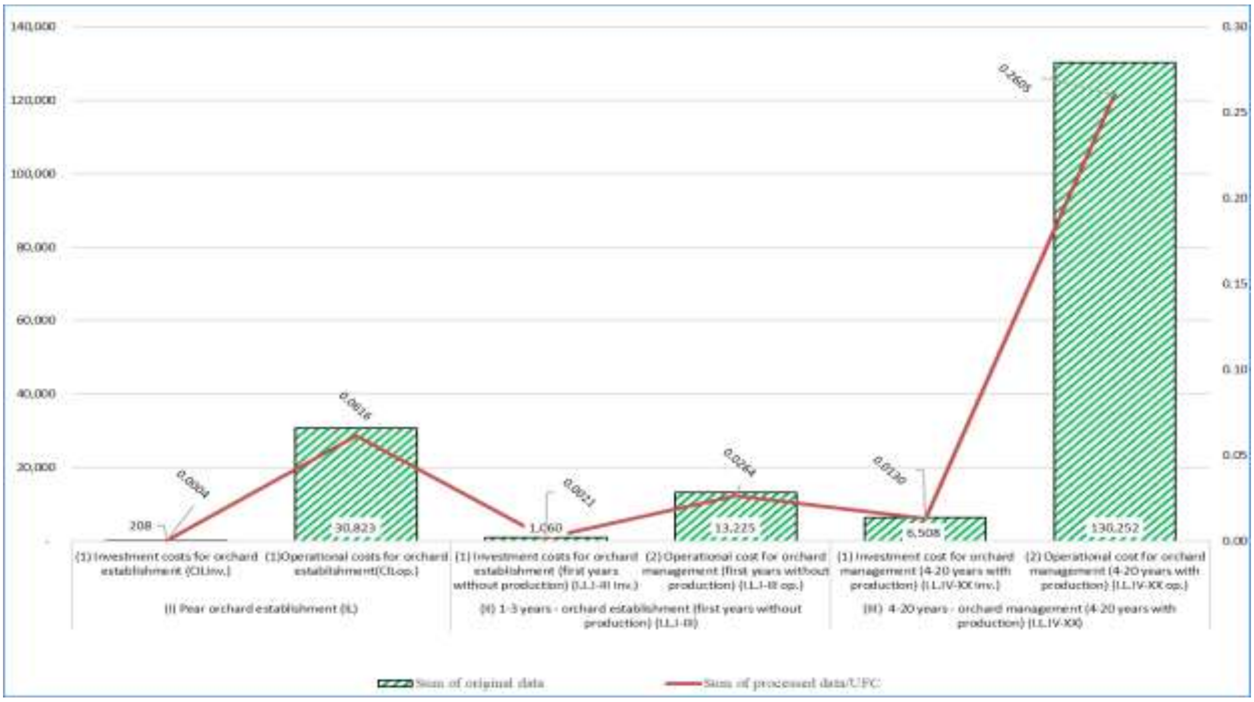

Fig. 4. LCC for the production stage in Scenario 2
Source: own data.

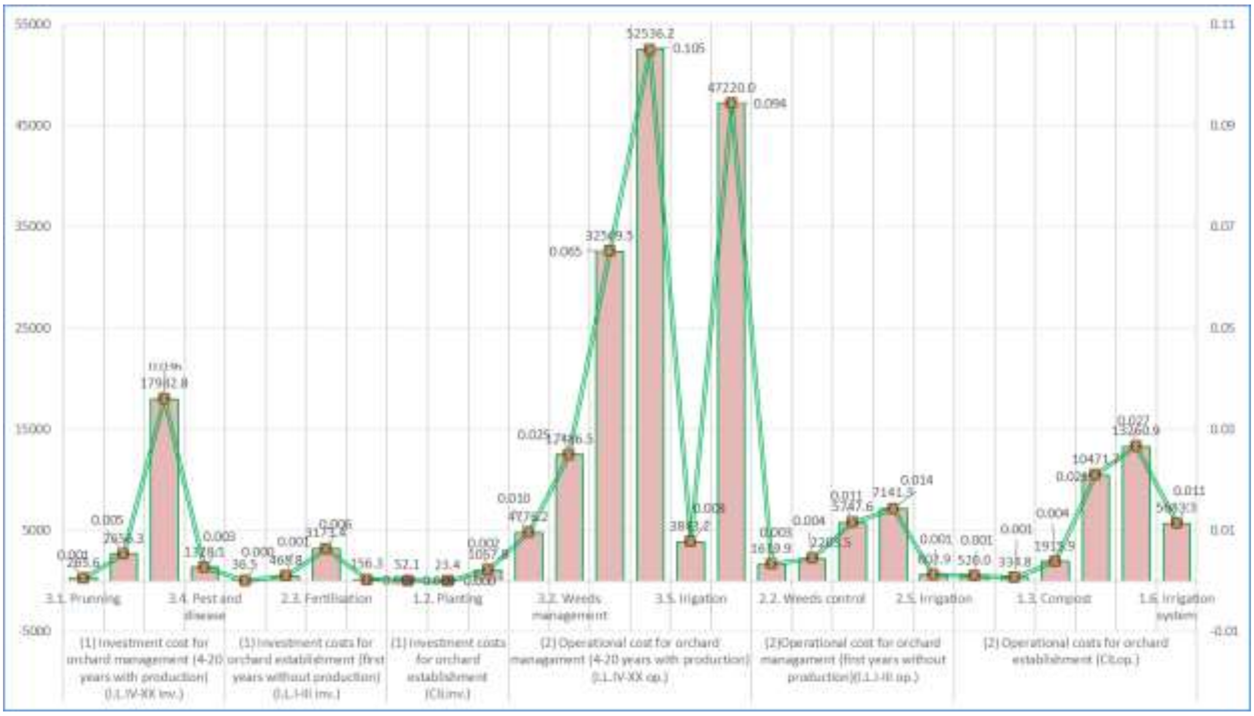

Fig. 5. LCC for the production stage in Scenario 1
Source: own data.

In **the following years (IV-XX)**, the main cost elements were (S1) pest and disease (0.105 €/1 kg), fertilization (0.101 €/1 kg), and harvesting (0.094 €/1 kg). At (S2), the highest values were for pest and disease (0.105 €/1 kg), harvesting (0.094 €/1 kg), and fertilization (0.026 €/1 kg). At (S3), the main costs were due to pest and disease (0.119 €/1 kg), harvesting (0.094 €/1 kg), and fertilization (0.078 €/1 kg) (Figure 4, 5 and 6).

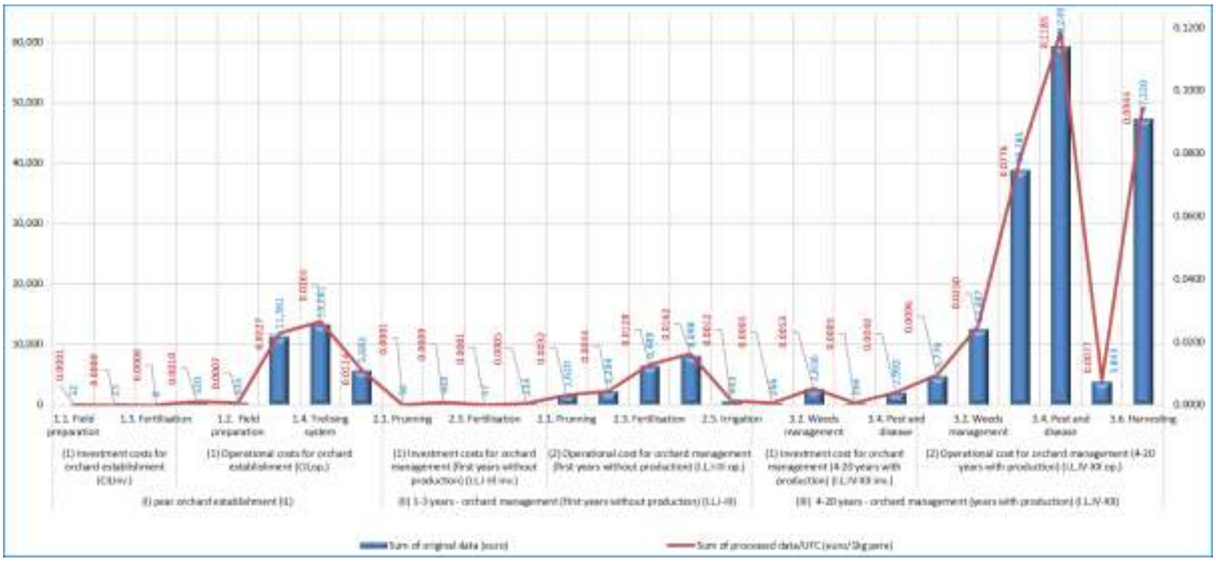

Fig. 6. LCC for the production stage in Scenario 3
Source: own data.

As we can see, the hot points in the LCC analysis were the pest and disease management, fertilization, and harvesting costs in the orchard management periods.

For the harvesting stage, the main operational component was the price for the labor force. At the farm level, for the pear crop, at this moment, we have not found sustainable solutions for optimizing this component. Mechanical harvesting in the pear orchards is in the exploratory stage, and no commercial orchards have included it until now at a large scale. Regarding the fertilization cost, in (S1), the significant component is the labor cost, considering the specificity of the equipment (daily to be fed with organic residues and constantly emptied) and the composter usage. In (S2), the main components are fuel for tractors with equipment and labor force for the compost in the outdoor platform. Optimization had already proceeded; mechanical equipment was being used. In (S3), the most significant component is the price for the fertilizer acquisition. The scenario included an organic fertilizer in a solid state and with agrochemical parameters to be at least similar to the two other scenarios. For optimization, the market price and the source can be thought of in a specific strategy. An essential element of the LCC in the production stage was pest and disease management, with lower values in S1 and S2 and higher in S3.

Mainly in organic agriculture, but not only pests and diseases have to be thought of in correlation with fertilization.

When a comprehensive nutrition program is applied, correlated to growth stages, the plants are healthier, consequently lowering the pest and disease costs.

Compost is a complex fertilizer with specific actions in the plant ecosystem. Many studies highlighted the correlation between compost application in the orchard and the plant status compared to other fertilizers.

In conclusion, for this specific hot point in the LCC, we recommend further specific studies with the two components. Considering the compost specificity, the best scenario for LCC is S2, and after, we can consider S1, although the cost is higher than S3.

Compared to other research results, [22], a study considering 2011 prices in Italy found a total LCC cost of 0.430 €/1 kg of pear for conventional technology, which is very close to our results.

Considering as a prediction of the revenues on the pear market in Romania, we could take into consideration 1.0 – 1.6 €/1 kg of fruits (higher for organic fruits), which can lead to a difference between revenue and LCC at 0.20-0.62 €/1 kg (S1), 0.22-0.64 €/1 kg (S3), and 0.30-0.72 €/1 kg (S2).

CONCLUSIONS

The broad approach to the production life cycle, as well as the scenarios designed in this article, have guided to the conclusion that the results of the work are innovative and fundamental for the fruit market, especially for the pear farm.

Pear crop is considered to be a highly profitable one, and the study results confirmed. Considering one of the most critical aspects of the technology, fertilization, three scenarios were analyzed and based on the LCC. The best results were for (S2) with compost produced in an outdoor platform, followed by (S3) acquisition of an organic fertilizer, and (S1) a mix of compost produced with an innovative composter and with the outdoor platform. Due to the compost qualities and the recirculation of the organic residues, S1 can be considered compared to S2.

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REFERENCES

[1]Andreieș, N., 2017, Achievements in pear breeding obtained at the Research Station for Fruit Growing Voineşti, Voineşti Own Publishing House, 5-48.

[2]Bosona, T., Gebresenbet, G., Dyjakon, A., 2019, Implementing life cycle cost analysis methodology for evaluating agricultural pruning-to-energy initiatives, Bioresource Technology Reports, 6, 54-62, https://doi.org/10.1016/j.biteb.2019.02.006.

[3]Branişte, N., Andreieş, N., Ghidra, V., 2008, Pear genetic breeding to improve the Romanian varieties, Acta Horticulturae, 800, 491-496.

[4]Branişte, N., Budan, S., Butac, M., Militaru, M., 2007, Fruit tree, small fruits and strawberry cultivars released in Romania, Bucharest, Paralela 45 Publishing House, 105-134.

[5]Butcaru, A.C., Mihai, C.A., Barbu (Stan), A., Asănică, A.C., Hoza, D., Stănică, F., 2021, Post-harvest monitoring of pear fruit quality parameters using Da-meter, Annals of the University of Craiova, 26, 21-26.

[6]Butcaru, A.C., Certan, I., Catuneanu, I.L., Stanica, F., Badulescu, L., 2021, A literature review of Life Cycle Cost Analysis technique applied to fruit production, Scientific Papers. Series B, Horticulture, Vol. LXV (2), 19-24.

[7]Chira, L., Chira, A., Delian, E., Ion, L., Nicolae, C., 2020, Studies regarding the economic approach of pear fruits commercialization according to the qualitative aspects, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 20(1), 131-136.

[8]Cimpoieș, G., 2018, Pomicultură specială (Sistematic pomology), Chișinău, Print Caro Publishing House, 96-127.

[9]Davis, M., Coony, R., Gould, S., Daly, A., 2005, A guidelines for Life cycle cost analysis, Stanford University Land and Buildings, 3-27.

[10]Estevan, H., Schaefer, B., 2017, Life Cycle Costing State of the art report, ICLEI – Local Governments for Sustainability, European Secretariat.

[11]European Commission - DG Agri E2, 2022, EU fruit and vegetables market observatory. Pip fruit subgroup. The pear market in the EU Prices, https://agriculture.ec.europa.eu/data-and-analysis/markets/overviews/market-observatories/fruit-and-vegetables/pip-fruit-subgroup_en, Accessed on September 11, 2023.

[12]European Platform on Lice cycle Assessment, 2023, ELCD database, https://eplca.jrc.ec.europa.eu, Accessed on September 11, 2023.

[13]Food and Agriculture Organization (FAO), FAOSTAT, 2023, Crops and livestock products, https://www.fao.org/faostat/en/#data/QCL/visualize, Accessed on September 11, 2023.

[14]Fuller, S., 2010, Life-Cycle Cost Analysis (LCCA), National Institute of Standards and Technology, https://www.nist.gov, Accessed on September 11, 2023.

[15]Hunkeler, D., Lichtenvort, K., Rebitzer, G., 2008, Environmental Life Cycle Costing. USA, Boca Raton, FL, CRC Press, 1-53.

[16]Militaru, M., Branişte, N., Sestraş, A., Andreieş, N., Butac, M., Stanciu, C., 2010, Contributions to the improvement of the Romanian pear varieties in the past 10 years, Scientific Papers, Horticulture, Iaşi, LIII (1), 341-346.

[17]Pândaru, R.C., Butcaru, A.C., Stănică. F., 2019, Behaviour of some new Romanian pear disease

resistant genotypes cultivated in Bucharest area, Scientific Papers. Series B, Horticulture. LXIII (2), 87-94.
[18]Peticilă, A.G., Madjar, R.M., Drăghici, E.M., Stănică, F., Asănică, A.C., Butcaru, A.C., 2023, Results regarding the 24-hour composts (Oklin) composition and their use as fertiliser, Scientific Papers Series B, LXVII (2).
[19]Perera, O., Morton, B., Perfrement, T., 2009, Life Cycle Costing a question of value, International Institute for Sustainable Development (IISD), http://www.iisd.org, Accessed on September 11, 2023.
[20]Selina Wamucii.com, 2023, US Pears Prices, https://www.selinawamucii.com/insights/prices/united-states-of-america/pears/#:~:text=The%20retail%20price%20range%20for%20US%20pears%20in,US%24%200.45%20and%20US%24%200.91%20per%20pound%20%28lb%29, Accessed on September 11, 2023.
[21]Stănică, F., Butcaru, A.C., Pândaru, R.C., Asănică, A.C., Mihai, C.A., Bezdadea-Cătuneanu, I.L., Andrieș, N., 2022, Behaviour of Romanian pear cultivars self-rooted and grafted on pear and quince rootstocks under Parallel U and Trident training systems, Acta Hortic. 1346, 311-318.
[22]Tamburini, E., Pedrini, P., Marchetti, M.G., Fano, E.A., Castaldelli, G., 2015, Life Cycle based evaluation of environmental and economic impacts of agricultural productions in the Mediterranean Area. Sustainability, 7, 2915-2935. https://doi.org/10.3390/su7032915.
[23]Tridge, 2023, Fresh Pear, https://www.tridge.com/intelligences/pear/RO/price, Accessed on September 11, 2023.
[24]Usman, A., Sajid, N., Khalid, A., Riaz, L., Rabbani, M.M., Syed, J.H., Malik, R.N., 2015, A review on vermicomposting of organic Wastes, Environmental Progress & Sustainable Energy, Wiley Online Library, DOI 10.1002/ep.12100, 1-13.
[25]Vlad, I.M., Butcaru A.C., Bădulescu, L.A., Fîntîneru, G., Certan, I., 2022, Review on the tools used in the Life Cycle Cost Analysis, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(4), 807-816.
[26]von Heynitz, K., 2012, Compostul în gospodărie (Compost in the household). Casa Publishing House, 6-92.

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DYNAMICS OF LAND FUND AND STRATEGIES ON SOIL CONSERVATION AND PREVENTION OF SOIL DEGRADATION IN ROMANIA

Cristiana Silvia BUZATU, Iulian Virgil GHIULEANU, Valentina Constanța TUDOR

University of Agronomic Sciences and Veterinary Medicine Bucharest, 59 Marasti Blvd., District 1, 011464, Bucharest, Romania, E-mails: cristianabuzatu@yahoo.com, buzatu.cristiana@managusamv.ro, vghiuleanu@yahoo.com, tudor.valentina@managusamv.ro

Corresponding author: vghiuleanu@yahoo.com

Abstract

Soil is one of the Earth's most precious resources and is essential to sustaining life on our planet. However, soils are increasingly subject to degradation due to intensive agricultural practices, deforestation, pollution and climate change. Conserving soil and preventing soil degradation has become imperative in our efforts to ensure food security, protect biodiversity and maintain healthy ecosystems. Impact strategies are essential to maintain soil fertility, prevent soil erosion and degradation, conserve water and help reduce greenhouse gas emissions. In this context, the aim of the research is to explore the impact of key conservation strategies and practices that can be adopted to protect soils and ensure their long-term sustainability. Data were collected from public institutions, from the official National Institute of Statistics, NIS, website Tempo-Online and the National Land Improvement Administration. Implementing soil conservation strategies is essential to protect the environment, ensure the sustainability of the food system and maintain the ecological balance of our planet. Soil conservation is a vital component of sustainable development and environmental protection in Romania. Through effective implementation of conservation strategies and stakeholder involvement, the country can protect the essential resource of soil with a positive impact for future generations. The strategic elements and techniques discussed in this article contribute to maintaining ecological balance and conserving natural resources for future generations.

Key words: *soil fertility, degradation, strategies, key practices, Romania*

INTRODUCTION

The impact of soil conservation and soil degradation prevention strategies is crucial for several reasons:

Soil is the foundation of our food system. Most crops grow in soil and depend on their fertility. By conserving soils, we ensure that we have healthy and productive soils to support the food production needed for a growing population.

Agriculture is an important economic sector contributing to GDP [12].

Soils are home to much of the Earth's biodiversity, from small organisms such as bacteria and worms to larger organisms such as insects and mammals. Soil degradation can lead to habitat loss and species decline, affecting the whole food chain.

Healthy soil can play a significant role in absorbing carbon from the atmosphere and reducing greenhouse gas emissions.

By adopting practices that increase soil organic matter content and improve soil quality, we contribute to the fight against climate change [9].

Healthy soils help retain and filter water, maintaining the water table and preventing run-off, thus reducing the risk of flooding and ensuring the availability of water for irrigation and domestic use.

Soil erosion is a major problem that can affect agricultural land and natural ecosystems. By applying conservation practices such as conservation agriculture and planting vegetation, we can prevent soil loss due to erosion.

Ecological restoration with biological material is extremely efficient when it comes from the same areas with those which need restoration. The necessity of restoration is generated by the huge damage brought by the surface and deep erosion to habitats, areas and soil [1].

Degraded soils require more inputs, such as chemical fertilizers, to maintain agricultural production. Soil conservation reduces the need for these inputs, saving resources and reducing environmental impact [6].

Climate stress factors, and especially drought, due to the lack of water in the soil reserve, correlated with the precipitation volume reduction, require new studies, highlighting the risks of reducing wheat yield, the main agricultural crop of the area and the development of new agricultural techniques, to capitalize more efficiently the reduced water resource and deal with hot summers, especially during the flowering – filling the grain – maturity periods, when the wheat is very sensitive to temperatures above 30°C [2].

After Romania's accession to the European Union, there is a significant improvement of the main technical indicators, so that the financial support provided to farmers is also reflected in the productions obtained [4].

The EU agriculture is highly developed but important differences are from a country to another In the EU the development of agriculture is based on small scale farms, the average farm size being about 12 ha, ranging between 152 ha in Czech Republic and 3 ha in Cyprus and Romania [11].

The aim of the paper is to examine and analyse strategies for soil conservation and prevention of soil degradation in Romania. Through the S.W.O.T. analysis the paper aims to provide a deeper understanding of the current state of soils and soil protection measures in the specific context of our country.

The paper should serve as a resource for policy makers, researchers, farmers and anyone interested in protecting soils and promoting sustainable agriculture in Romania.

MATERIALS AND METHODS

Data were collected from public institutions, from the official National Institute of Statistics, NIS, website Tempo-Online and the National Land Improvement Administration R.A, ZAV0232 [10] - Horizon 8 - Environment - Area of land improved with soil improvement and soil erosion control works, by land use categories.
The study was a literature search, carrying out analyses using the comparative method which led to a relevant interpretation of the statistical data.

RESULTS AND DISCUSSIONS

Soil improvement and erosion control works in Romania

Implementing soil conservation strategies is essential to protect the environment, ensure the sustainability of the food system and maintain the ecological balance of our planet. Neglecting these strategies can have serious consequences for society and our environment [5]. The area designed to combat soil erosion - is the complex of hydrotechnical works carried out to reduce or halt the degradation of the soil surface by removing its fertile layer under the action of external geographical agents and carrying out regularization works to prevent rainwater runoff from the slopes in order to avoid damage caused by floods on the land at the foot of the slope [7].

Agricultural area of Romania by category in the interval 2016-2020 is shown in Table 1.

Table 1. Romania's agricultural area by category (ha)

Agricultural area under development				
Unit of measure = Hectare				
2016	2017	2018	2019	2020
2,145,635	2,145,581	2,145,547	2,145,467	2,145,426
Arable land				
2016	2017	2018	2019	2020
1,227,584	1,227,554	1,227,521	1,227,444	1,227,407
Natural pastures				
2016	2017	2018	2019	2020
517,747	517,747	517,747	517,892	517,888
Natural meadows				
2016	2017	2018	2019	2020
200,680	200,677	200,677	200,677	200,677
Vineyards, vine nurseries and hop gardens				
2016	2017	2018	2019	2020
82,783	82,763	82,762	82,761	82,761
Orchards, nurseries, fruit bushes				
2016	2017	2018	2019	2020
116,841	116,840	116,840	116,693	116,693

Source: NIS, http://statistici.insse.ro [10].

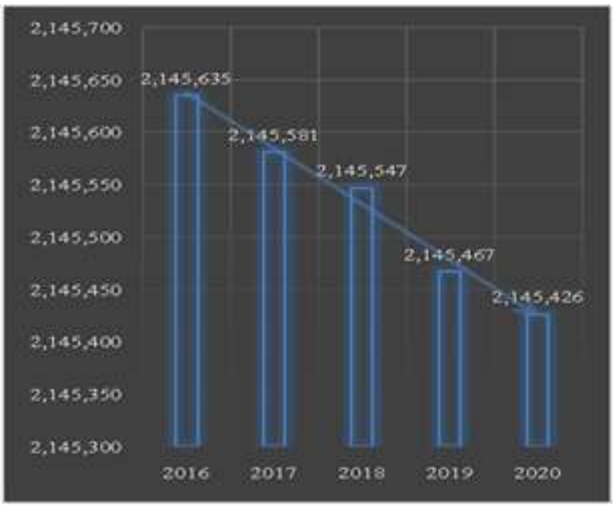

Fig. 1. Dynamics of agricultural area in Romania, 2016-2020 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [10].

As can be seen in Fig.1, the data are on an ascending scale, but the data in the 5 analyzed years are very similar because in Romania and the difference between the reference years 2016 - 2020 is not even 1 %.

The cereal market in Romania represents the total amount of grain transactions that have at its center the farm and the farmer. Both the farmer, exporters, port operators, lawyers, local and regional authorities, transporters, livestock consumers, and processing industries are meeting on this market [5].

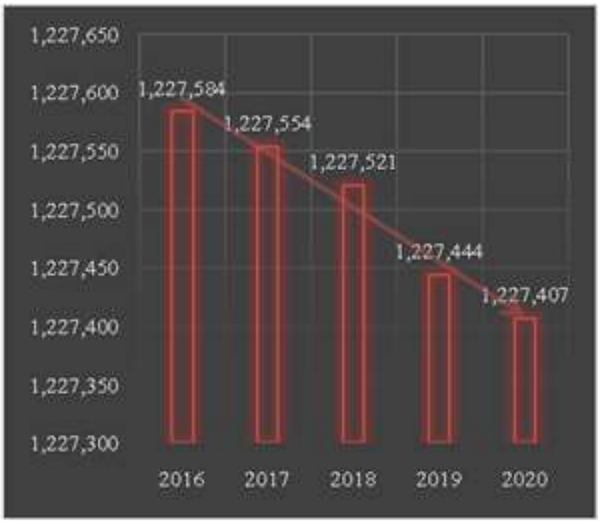

Fig. 2. Dynamics of arable land in Romania, 2016-2020 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [10].

Arable land in Romania is subject to a variety of protective measures and regulations to preserve soil fertility and prevent erosion and degradation. These measures include: Agricultural policies; Monitoring and evaluation; Use restrictions; Rural development programs; Education and awareness.

Fig. 3. Dynamics of the areas covered by natural pastures in Romania, 2016-2020 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [10].

Protecting and conserving Romania's natural grasslands is essential for maintaining biodiversity, natural resources and promoting sustainable agricultural practices.

Here are some ways in which Romania is helping natural grasslands:

-Compliance with land use regulations;
-Avoiding overcrowding;
-Application of rotational grazing;
-Avoiding the use of pesticides and chemical fertilizers;
-Preserving native vegetation;
-Participating in conservation programs;
-Supporting research and education;
-Respecting protected areas;
-Participating in voluntary actions.

Conservation of natural grasslands is essential for maintaining biodiversity and natural resources in Romania, and your contribution can make a significant difference in protecting these ecosystems.

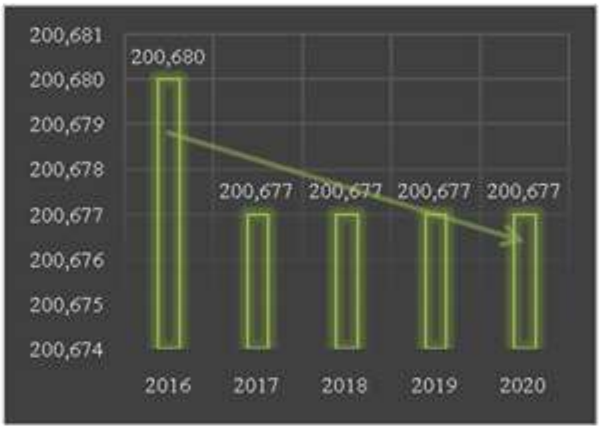

Fig. 4. Dynamics of the areas representing natural meadows in Romania, 2016-2020 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [10].

Natural meadows, like natural grasslands, play a vital role in maintaining biodiversity and natural resources in Romania.

Natural meadows are a valuable habitat for biodiversity and for the conservation of natural resources [3].

The risk of environmental degradation, depletion of resources, and impoverishment of the planet has existed and will continue to exist [8].

People's contribution to the protection and conservation of these ecosystems can have a significant impact on maintaining Romania's biodiversity and natural beauty.

Fig. 5. Dynamics of surfaces covered by vineyards, vine nurseries and hop gardens in Romania, 2016-2020 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [10].

Vineyards, vine nurseries and hop fields are important for the wine industry and beer production and can contribute to biodiversity and environmental protection in Romania.

Environment conservation could be assured by **adopting sustainable viticulture practices** as mentioned below:

-use vineyard management methods that minimize the use of pesticides and chemical fertilizers. Opt for organic and environmentally friendly solutions where possible.

-promote crop rotation and intercropping with certain related crops to prevent soil depletion.

-install efficient irrigation practices to save water and prevent run-off.

Conserve water resources:

-use irrigation systems that minimize water loss and avoid surface runoff.

-collect rainwater and use it for irrigation or other agricultural purposes.

Promote biodiversity:

-leave areas of natural vegetation around vineyards and hop fields to provide habitat for native flora and fauna.

-plant perennials, flowers and grasses to attract pollinators and increase biodiversity in the area.

Recycle and reduce waste:

-implement recycling and waste management programs to minimize environmental impact.

Participate in green certification projects:

-If possible, consider organic certification of vine or hop crops. This involves adhering to higher standards of environmental and sustainability practices.

Support research and innovation:

-get involved in research and innovation projects aimed at developing more sustainable practices in viticulture and hop growing.

Promote awareness:

-organize events or workshops for the local community to raise awareness of the importance of environmental conservation and sustainable practices in viticulture and hop production.

Work with environmental organizations:

-work with environmental organizations and local authorities to develop and implement environmental conservation strategies in your community.

By applying these practices and promoting sustainability in viticulture and hop production, you will contribute to protecting the environment and maintaining the sustainability of these important crops in Romania.

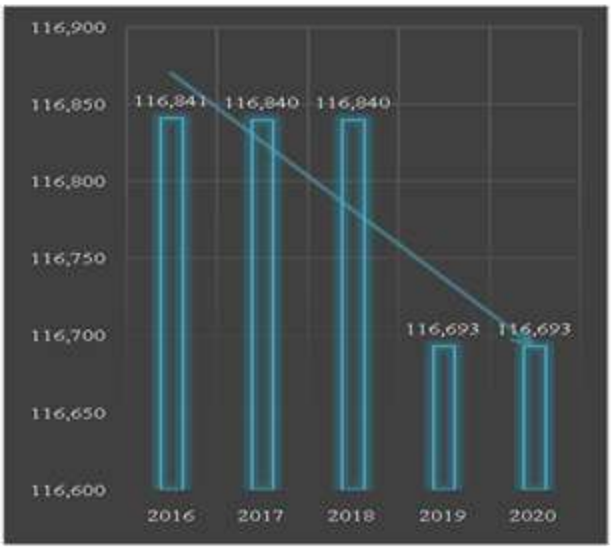

Fig. 6. Dynamics of the surfaces covered by orchards, nurseries, fruit bushes in Romania, 2016-2020 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [10].

Tree orchards, nurseries and fruit bushes are essential components of agriculture and gardens in Romania. These crops can benefit from sustainable practices and proper care to help protect the environment. Here's how you can help and make these crops more sustainable:

Use environmentally friendly management methods:

-avoid excessive use of pesticides and chemical fertilizers and opt for more environmentally friendly methods of plant protection.

-adopt weed and pest management practices that minimize environmental impact and reduce chemical use.

Efficient irrigation:

-use efficient irrigation systems that minimize water waste and help save water resources.

Respect crop rotation:

-promote crop rotation in orchards and gardens to prevent soil depletion and reduce the risk of diseases and pests.

Promote biodiversity:

-leave areas of natural vegetation or parts of the garden uncultivated to provide habitat for pollinators and other wildlife.

-plant flowers and plants that attract pollinators such as bees and butterflies.

Responsible waste management:

-implement recycling and waste management practices to minimize environmental impact.

Use organic fertilizers:

-organic fertilisers, such as compost, can improve soil quality and contribute to better soil fertility.

Restore degraded land:

-If you have degraded or eroded land in orchards or nurseries, implement restoration projects to restore them to their original condition.

Support research and education:

-get involved in research and education projects aimed at developing and promoting sustainable farming practices in your crops.

Collaborate with environmental organizations:

-collaborate with environmental and other local agricultural organizations to develop and implement conservation strategies in your garden and orchard.

By adopting sustainable practices in the management of tree orchards, nurseries and fruit bushes, you contribute to the protection of the environment and to the sustainability of these vital crops in Romania.

In order to provide an accurate picture of the application of soil conservation and soil erosion prevention measures in Romania in reality, it is important to consider the following aspects:

-*Adoption of conservation measures:* Romania has implemented a number of measures and programs for soil conservation, including subsidies for farmers who adopt conservation farming practices and for the rehabilitation of agricultural land affected by erosion.

-*Infrastructure and construction projects:* In certain areas of the country, earthworks and construction works are carried out to combat soil erosion, especially in mountainous areas.

-*Pasture and meadow management:* In mountain and rural areas, grassland and pasture management practices are applied, including rotational grazing to prevent soil compaction.

Education and awareness raising programs: The existence of education and awareness programs on soil conservation and soil erosion prevention may vary from area to area.

However, the application and effectiveness of these measures can be uneven depending on the region and socio-economic factors. There are several challenges in implementing these measures in Romania:

-*Limited resources:* Some regions and communities may have limited resources to implement soil conservation practices and address erosion.

-*Limited awareness:* In some areas, farmers and local communities may not be sufficiently aware of the importance of soil conservation and sustainable practices.

-*Climate change:* Climate change may exacerbate soil erosion problems, making them more difficult to manage.

-*Infrastructure deficit:* In some cases, lack of adequate water management infrastructure can contribute to erosion.

In general, Romania has a legislative framework and agricultural policy aimed at soil conservation and prevention of soil degradation, but uniform and effective implementation may require additional efforts and resources in some areas. Awareness, education and continued support from authorities and communities can help to better implement these measures across the country. Climate change could influence the increase of the incidence of pests and pathogenic agents attack on agricultural crops, but it is still considered to have a minor role, the main drivers in the use of pesticides being agronomic, economic, environment reasons and social reasons [13].

Fig. 7. S.W.O.T. analysis on the impact of soil conservation and soil degradation prevention strategies in Romania
Source: authors' own conception.

Strategies for soil conservation and prevention of soil degradation in Romania are essential for maintaining agricultural sustainability and protecting the environment. However, there are challenges, such as limited resources and low awareness, that need to be addressed. Technology development and application, financial support and cooperation between stakeholders can help improve soil conservation practices in Romania.

CONCLUSIONS

Soil conservation and the prevention of soil degradation are crucial issues for maintaining the fertility of agricultural land and protecting the environment in Romania.

There are effective measures and strategies that can be applied to conserve soils and prevent soil erosion and degradation in the country.

These measures include the adoption of conservation agriculture, use of cover crops and mulch, water management, use of organic fertilizers, grassland and pasture management, reforestation, education and awareness, government policies and continuous monitoring of soil condition.

Recommendations:

It is important to continue education and awareness campaigns for farmers, communities and the general public on soil conservation practices and their importance.

Conservation agriculture needs to be further promoted and supported through government programs, subsidies and technical support for farmers.

Soil condition monitoring systems, such as moisture sensors and remote sensing, would should be more widely implemented to help detect problems and assess the effectiveness of conservation strategies.

Scientific research and development of more effective soil conservation technologies and practices should continue to address new challenges and climate change.

Collaboration between environmental organizations, government and the agricultural sector is key to addressing soil issues and successfully implementing conservation strategies.

It is important that the government implements clear policies and effective laws that promote soil conservation practices and sanction harmful land use.

Romania's agricultural potential is still insufficiently exploited.

Monitoring soil condition and the results obtained by applying conservation strategies should be a continuous practice to ensure the maintenance of soil health in Romania.

Soil conservation is a vital component of sustainable development and environmental protection in Romania. Through effective implementation of conservation strategies and stakeholder involvement, the country can protect the essential resource of soil with a positive impact for future generations.

REFERENCES

[1]Berca, M., Ene, D., Sturzu, C., 2007, Model of stabilization for the soils affected by erosion and landslides using the biological material offered by sea buckthorn (*hippophaerhamnoides*) on the slopes of Brebu, Prahova Nationla Symposium with International Participation "Impact of Romania's Integration in the European Union on agriculture (Model de stabilizare a solurilor afectate de eroziune şi alunecări de teren prin folosirea materialului biologic oferit de cătină (*hippophaerhamnoides*) pe pantele din Brebu – Prahova, Simpozionul National cu Participare Internationala "Impactul integrarii Romaniei in Uniunea Europeana asupra agriculturii"), pp. 49-54; Domino Publishing House, April 2007.

[2]Berca, M., Horoias, R., NDMI use in recognition of waterstress issues, related to winter wheat yields in Southern Romania, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22(2), 105-111.

[3]Europa.eu, 2012, Report on securing our life, our natural capital: an EU biodiversity strategy to 2020, dated 3.4.2012 - (2011/2307(INI)), https://www.europarl.europa.eu/doceo/document/A-7-2012-0101_RO.html, Accessed on 20.09.2023.

[4]Gimbasanu (Dumitru), G.F., Rebega, D.E., Tudor, V.C., 2021, Comparative analysis of the main technical indicators for sunflower crop in Romania, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 21(2), 267-273.

[5]Gimbasanu, G., Tudor, V., The evolution of average prices for agricultural products in Romania during 2007-2017, Scientific Papers. Series "Management,

Economic Engineering in Agriculture and rural development", Vol. 19(2), 161-166.
[6]Green Report, 2022, What is soil pollution: causes, effects and ways to combat it, 5 August 2022, https://green-report.ro/poluarea-solului-cauze-efecte-si-modalitati-de-combatere/, Accessed on 06.09.2023.
[7]Institute of Pedology, Agrochemistry and Soil Protection "Nicolae Dimo", 2015, Guide on conservation and rational use of soil moisture, year 2015, https://www.gwp.org/globalassets/global/gwp-cee_files/regional/idmp-guide-moldova-ro.pdf, Accessed on 14.09.2023.
[8]Marcuta, L., Popescu, A., Marcuta, A., 2021, The need to monitor the water footprint under the conditions of smart development application, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 21(3), 549-554.
[9]Mureșean, P., 2023, Innovations in recycling: a look at a sustainable future, https://republica.ro/inovatii-in-reciclare-o-privire-asupra-unui-viitor-sustenabil, Accessed on 02.09.2023.
[10]NIS, Tempo online, Statistical data, http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table, Accessed on 11.09.2023.
[11]Popescu, A., 2013, Considerations on utilized agricultural land and farm structure in the European Union, Scientific Papers Series Management Economic Engineering in Agriculture and Rural development, Vol.13(4), 221-225.
[12]Popescu, A., Dinu, T.A, Stoian, E, 2019, Efficiency of theagricultural land use in the European Union, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.19(3), 475-486.
[13]Popescu, A., Tindeche, C., Marcuta, A., Marcuta, L., Hontus, A., 2021, Pesticides - a problem in Romania's agriculture?, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 21(4), 477-486.

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EDUCATION, AWARENESS AND CONSERVATION OF ROMANIA'S BIODIVERSITY

Cristiana Silvia BUZATU, Iulian Virgil GHIULEANU, Valentina Constanța TUDOR, Răzvan PANAIT

University of Agronomic Sciences and Veterinary Medicine Bucharest, 59 Mărăști Blvd., District 1, 011464, Bucharest, Romania, E-mails: buzatu.cristiana@managusamv.ro, vghiuleanu@yahoo.com, tudor.valentina@managusamv.ro, panait.razvan@managusamv.ro.

Corresponding author: vghiuleanu@yahoo.com

Abstract

Romania's biodiversity is a natural treasure, offering a vast array of species and ecosystems, but faces increasing threats from human activities and climate change. Education, awareness and conservation of biodiversity are key to protecting this priceless biological diversity. In this article, through statistical methods of analysis, we aim to explore the role of education and awareness in the conservation of Romania's biodiversity, highlighting initiatives and efforts to promote public understanding and commitment to protecting the environment and unique species. This analysis allowed us to identify relevant patterns, trends and conclusions related to biodiversity education, awareness and conservation in Romania. Protecting Romania's biodiversity is therefore not only a necessity for the environment, but also for society, the economy and human well-being. Biodiversity conservation is essential for our well-being and the health of the planet, and it is our responsibility to act on it. We will explore the importance of education in schools and universities, the role of NGOs and government actions, and their impact on biodiversity conservation in the country.

Key words**:** *biodiversity, vast nature, continuous process, essential practices, oxygen*

INTRODUCTION

Global environmental problems have begun to become prevalent and have created the need for additional actions to raise public awareness, leading the international community to take timely and functional action, both internationally and nationally. Assessing the effects of these "new" environmental issues has led to the recognition that too little progress has been made in integrating environmental protection into development policies and activities [2].

Soil, water, air, biodiversity and all together form the areas - ecosystems - the biosphere [4].

Romania's biodiversity is a priceless natural treasure, with a heritage of extremely varied species and ecosystems. From the Carpathian Mountains and their impressive forests to the Danube Delta and its rich habitats, Romania is home to an impressive range of life forms. However, this exceptional biological diversity is increasingly threatened by pressures from human activities such as rapid urban development, extensive deforestation and climate change. In this context, education, awareness and conservation of biodiversity become imperative to protect and prolong the existence of this natural wealth for future generations.

Biodiversity conservation, even in small areas, can lead to the reconstruction of ecosystems and agro-ecosystems in the event of major man-made or natural disasters [4].

The favourable conditions of the environment and of the climatic factors have influenced the inhabitation since ancient times [9].

This paper is intended as an exploration of the complex relationship between education, awareness and biodiversity conservation in Romania. The purpose of this paper is to highlight the fundamental importance of education and awareness in biodiversity conservation efforts, and to examine how these aspects interact and support each other in the specific context of our country.

Education is the backbone of any informed society committed to environmental conservation. However, in Romania and other countries, biodiversity education has not always received the attention it deserves. This paper will explore how education in schools and universities can promote a deeper understanding of biodiversity, cultivate a love of nature and shape future generations as responsible citizens of the planet.

In addition, we will examine the active role of non-governmental organisations (NGOs) and government institutions in promoting public awareness and citizen involvement in concrete conservation actions. We will also examine how local communities can play a vital role in protecting biodiversity in rural and urban areas.

Rural space plays an important role in preserving the landscapes which are a treasure of the splendours of nature. Also, in the rural areas, the environmental factors: air, water, soil are much better conserved than in the cities.

The large range of plant species either belonging to the wild flora or to the cultivated crops, and the great number of animal species from the wild fauna and farms which emphasize the key role of the rural areas in preserving biodiversity [11].

This paper is intended to be a journey through Romania's efforts, achievements and challenges in biodiversity education, awareness and conservation. By bringing these issues to the fore, we aim to highlight the urgent importance of protecting this biological diversity and ensuring that future generations will continue to enjoy Romania's natural wealth.

This goal involves:

Education - the provision of relevant and accessible knowledge and information related to biodiversity within the education system and in communities, with the aim of developing a deeper understanding of the importance of environmental conservation and awareness of the impact of human actions on the environment.

Awareness raising - raising awareness of biodiversity and conservation issues through awareness campaigns, events and effective communication.

Promoting nature tourism - exploiting the tourism potential of biodiversity-rich areas to financially support conservation and develop the local economy.

One of the great current challenges at the global level is represented by finding sustainable production systems that ensure both social, economic and environmental sustainability, while at the same time pursuing the optimal provision of production, trade or consumption indicators [6].

In this context, the goal of the paper is emphasizing the role of education and awareness in the conservation of Romania's biodiversity, pointing out initiatives and efforts to promote public understanding and commitment to protecting the environment and unique species.

The study is destined to create a Romania where biological diversity is protected, valued and properly integrated into people's lives, thus ensuring a sustainable future for the environment and Romanian society. It is a vision that involves the collaboration and commitment of all stakeholders to preserve and promote this priceless natural heritage.

MATERIALS AND METHODS

The study is based on a literature search on the topic, carrying out analyses using the comparative method which led to a relevant interpretation of the statistical data.

The statistical data are collected from the official National Institute of Statistics, NIS, website Tempo-Online, the account of the environmental goods and services sector, forestry planning, studies provided for by Order no. 2.525 of 30 December 2016 on the establishment of the National Catalogue of virgin and quasi-virgin forests in Romania (studies carried out on the basis of a public tender), the codes being:

-TQY1552 - Target 5 - Environment - Area of land on which regeneration has been carried out by regeneration category;

-TQY1521 - Target 4 - Environment - Production value of environmental goods and services for biodiversity and landscape protection;

-TQQ1533 - Target 3 - Environment - Area of virgin and quasi-virgin forests.

The research was based on statistical methods and qualitative analyses depending of their type and proposed objectives.

This analysis allowed us to identify the patterns and trends to formulate relevant conclusions in relation to education, awareness and conservation of biodiversity in Romania.

RESULTS AND DISCUSSIONS

Protecting Romania's biodiversity is of fundamental importance for many reasons, from preserving our natural heritage to ensuring a healthy environment for current and future generations. Identifying some key reasons to protect Romania's biodiversity, we can say that:

-**Romania is a country of remarkable biological diversity, home to many rare or endemic plant and animal species**. Protecting these species and their unique ecosystems is essential to preserve the country's natural heritage.

-Each species and ecosystem have a unique role in maintaining ecological balance. Reducing biodiversity can disrupt this balance and lead to negative consequences for ecosystems and ultimately for humans.

-Biodiversity provides a range of essential ecosystem services for humans, such as plant pollination, water purification and climate regulation.

-Conserving biodiversity contributes to maintaining human health and well-being.

-Romania's biological diversity is a valuable resource for nature tourism and for the development of a green economy. Wild ecosystems and protected areas attract tourists, generating income and jobs.

-Healthy ecosystems can play a key role in adapting to climate change. Well-managed forests and wetland habitats can help reduce the effects of climate change, such as floods or droughts.

Mountain areas are of a special beauty and greatness, grace to their peaks, valleys and depressions, fairy tale landscapes, virgin forests of a large tree and shrub diversity, wild flora and animals, water sources, lakes and glaciers, fantastic rainfalls, fascinating caves [10].

Recent research made in the area show the need for detailed study regarding the modelling of local ecosystems functioning, including the grasslands, as database for environmental reconstruction projects and for the increase of ecosystems value and the sustainability of local communities [3].

-Romania is home to many threatened or endemic species, and biodiversity conservation contributes to their survival and to preventing their extinction.

The study of biodiversity provides opportunities for discovering new species and understanding ecological processes. This research can have applications in medicine, agriculture and other fields.

We have a moral responsibility to protect and pass on this priceless natural heritage to future generations [7].

Rural space plays an important role in preserving the landscapes which are a treasure of the splendours of nature. Also, in the rural areas, the environmental factors: air, water, soil are much better conserved than in the cities. The large range of plant species either belonging to the wild flora or to the cultivated crops, and also the great number of animal species from the wild fauna and farms which emphasize the key role of the rural areas in preserving biodiversity [12].

Analysing the data collected from National Institute of Statistics regarding the situation in Romania, in terms of regenerations by land type, an increase in the total area is observed starting from 2022, after a decreasing trend in the period 2019-2021.

The area of land on which regeneration was carried out by regeneration category in the period 2018-2022 is shown in Table 1.

For a good understanding of the analysed phenomenon, we define the main analysed terms:

Regeneration is the process by which a new generation of forest trees is established and can be achieved through natural regeneration and artificial regeneration (afforestation) [8].

Natural regeneration is the process of transition to a new generation of trees, which is achieved naturally from shoots or by germinating seeds that have naturally arrived on the ground.

Artificial regeneration (afforestation) is the process of planting or seeding an area of land with the aim of creating new stands, both on logged forest land and on land with no forest vegetation.

Table 1. The area of land on which regeneration was carried out by regeneration category (ha)

Regeneration by land type	Types of regenerations	2018	2019	2020	2021	2022
Unit of measurement: Hectare						
Regenerations - Overall	Overall	27,043	24,459	25,189	23,981	27,981
	Natural regeneration	17,972	16,016	17,162	15,904	19,781
	Artificial regeneration	9,071	8,443	8,027	8,077	8,200
In forester fund - Overall	Overall	26,971	24,258	25,083	23,748	27,765
	Natural regeneration	17,970	16,016	17,162	15,898	19,781
	Artificial regeneration	9,001	8,242	7,921	7,850	7,984
On areas covered by regeneration cuts - Overall	Overall	24,764	22,352	23,065	20,748	24,344
	Natural regeneration	17,789	15,882	16,746	15,458	19,129
	Artificial regeneration	6,975	6,470	6,319	5,290	5,215
of which: On areas covered with cuttings breeds of forest trees	Overall	5,655	4,494	4,464	3,434	3,652
	Natural regeneration	1,681	812	1,107	779	910
	Artificial regeneration	3974	3682	3357	2655	2742
Replacement and replanting of poorly productive stands	Overall	940	981	1288	685	703
	Natural regeneration	50	41	320	55	29
	Artificial regeneration	890	940	968	630	674
Unregenerated ponds and hollows	Overall	1,258	911	723	587	590
	Natural regeneration	131	92	94	133	186
	Artificial regeneration	1,127	819	629	454	404

Source: NIS, http://statistici.insse.ro [7].

Analysing the statistical data, we observed a variation regarding the surface with regenerations (Fig. 1).

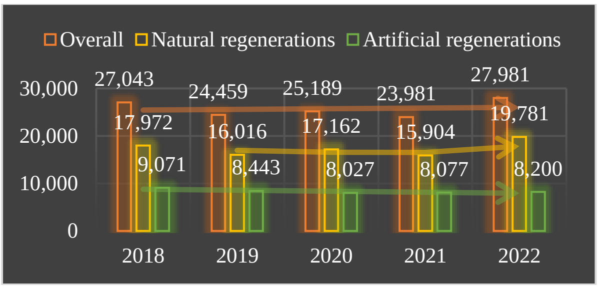

Fig. 1. Dynamics of regenerations in Romania, 2018-2022 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [7].

As can be seen from Fig. 1, the statistics vary from a year to another.
The total number between the years 2018 - 2020 undergoes a decrease (-6.86%) but increases between the years 2020 - 2022 (+ 9.98%).
In the case of natural regeneration, the imaginary line looks like Gauss's Bell, the data is on an ascending scale between the years 2018 - 2022 (+9.15 %).
Artificial regeneration on the other hand, suffers decreases in percentage (the scale being a descending one), this being -9.6 % between the reference years 2018 – 2022.

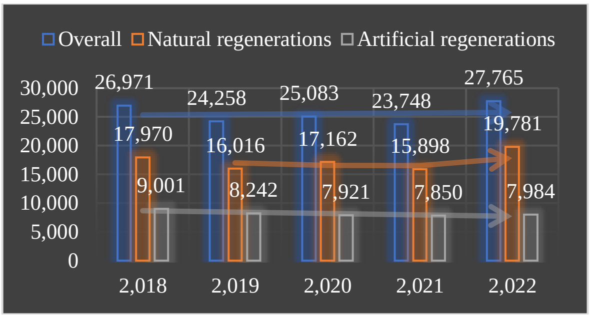

Fig. 2. Dynamics in Romania of the forest fund, 2018-2022 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [7].

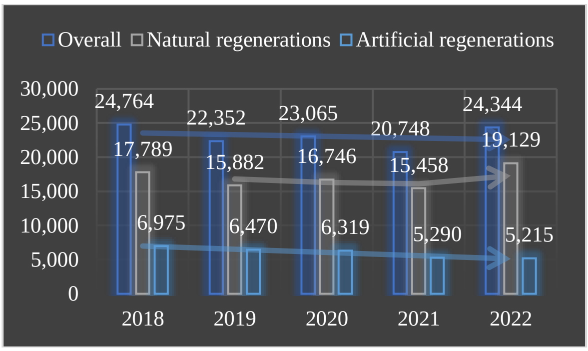

Fig. 3. Dynamics of the areas covered by regeneration cuts in Romania, 2018-2022 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [7].

From Fig. 2 it can be seen that the forest fund, the total number (+2.86 % between 2018 - 2022) and the number of natural regenerations (+9.16 % between 2018 - 2022) are on an ascending scale, but the artificial ones are on a descending scale (-11.3 % between 2018 - 2022). From the data shown in Fig. 3, we may identify that the total number with areas destined for regeneration cuttings are on a decreasing scale (-1.7 % between the years 2018 - 2022 and the lowest number being in the reference year 2021), but in the case of natural regeneration the percentage is increasing (+7.01 % between the years 2018 - 2022) and as in the previous graphs, the number of artificial regeneration decreases in percentage (- 25.23 % between the years 2018 - 2022).

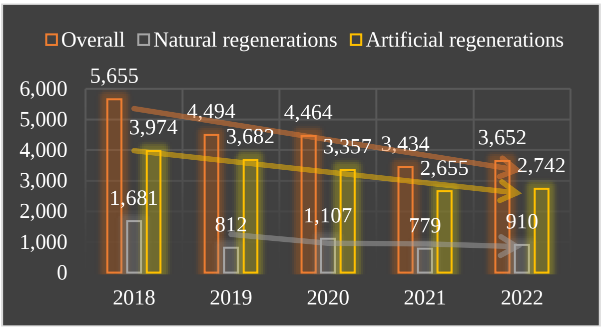

Fig. 4. Dynamics of areas covered with cuttings breeds of forest trees, 2018-2022 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [7].

From Fig. 4, the statistical information presents the areas devoted to forest trees, and we may notice that the number of hectares decreases in all respects, and between the reference years 2018 - 2022 they are:

⇨ 35.42 % overall.
⇨ 45.87 % natural regeneration.
⇨ 31 % artificial regeneration.

The forest is of vital importance for Romania for several major reasons:
Biodiversity conservation - Romanian forests are home to a wide range of plant and animal species, many of them rare and endemic.
Ecological role - forests play an essential role in maintaining ecological balance and natural cycles.
Natural resources - Romanian forests provide important resources such as timber, mushrooms, berries and medicinal herbs.
Tourism and recreation - forests are a major attraction for nature tourism and recreation in Romania.
Soil protection and flood control - forests act as a natural shield against soil erosion and help to prevent floods due to their ability to absorb and retain water.
Protection of agricultural crops and sustaining productivity, as it was proved that the crops cultivated on surfaces protected by agro-forestry curtains produce yields by 30-40% higher than the crops which are not protected.
Protection of the ways of communications (roads etc) is assured by forest curtains.
Protection of the localities and agricultural fields against winter storms, favoring the formation of an uniform snow layer benefic for protecting the cultivated crops.
Cultural and historical aspect - forests have a deep significance in Romanian culture and history.
Ecological connectivity - forests provide crucial habitat for wildlife species and play an important role in maintaining ecological connections between different habitats and protected areas.
Carbon sequestration - forests have the capacity to store carbon in the atmosphere, helping to combat climate change.
Education and research: Forests provide excellent opportunities for scientific research and education in ecology and conservation.

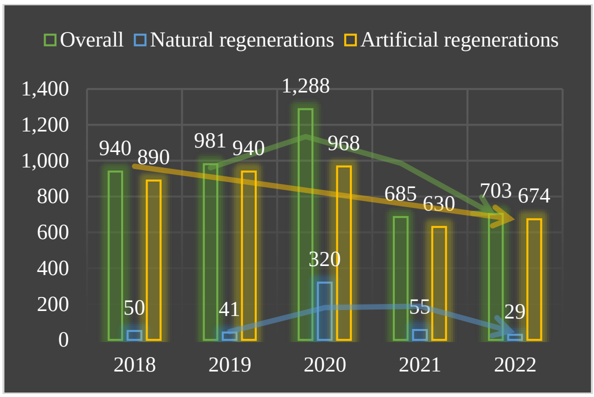

Fig. 5. Dynamics of replacement and replanting of poorly productive stands in Romania, 2018-2022 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [7].

Analyzing the information from Fig. 5, poorly productive stand replacement and restocking is significant in reference year 2020 for all categories, but between reference years 2020 - 2022 the percentages decrease significantly in percentages (-45.42 % total, -90.94 % natural, -30.37 % artificial).

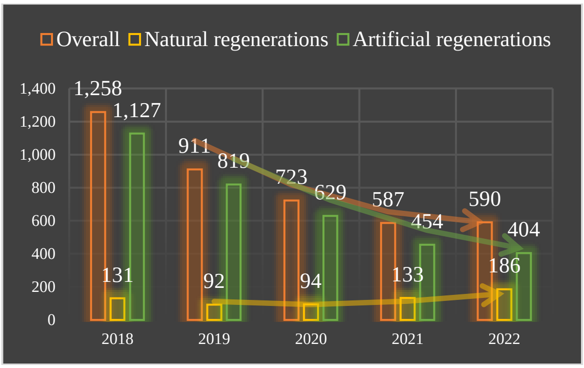

Fig. 6. Dynamics of unregenerated ponds and hollows in Romania, 2018-2022 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [7].

From Fig. 6, it results that the number of hectares of total and artificial unregenerated fallows and hollows decreases in percentages but in the case of natural ones they increase as follows (between the reference years 2018 - 2022):

⇨ - 53.1 % overall.
⇨ + 29.57 % natural regeneration
⇨ - 64.15 % artificial regeneration.

The area of land on which regeneration was carried out by regeneration category in the period 2018-2022 was shown in Table 1.

The value of producing environmental goods and services for biodiversity and landscape protection in the period 2016 – 2020 is shown in Table 2.

Biodiversity and landscape protection refers to measures and activities aimed at the protection and restoration of fauna and floraspecies, ecosystems and habitats, as well as the protection and restoration of natural and semi-natural landscapes.

Table 2. The value of production of environmental goods and services for the protection of biodiversity and the Romanian landscape (million lei).

2016	2017	2018	2019	2020
Unit of measurement: million lei				
65.53	92.57	96.09	95.43	170.18

Source: NIS, http://statistici.insse.ro [7].

Also, the maintenance or establishment of certain landscape types, biotopes, ecological zones and related issues (fences, tree lines to restore "natural corridors") have a clear link with biodiversity conservation [13].

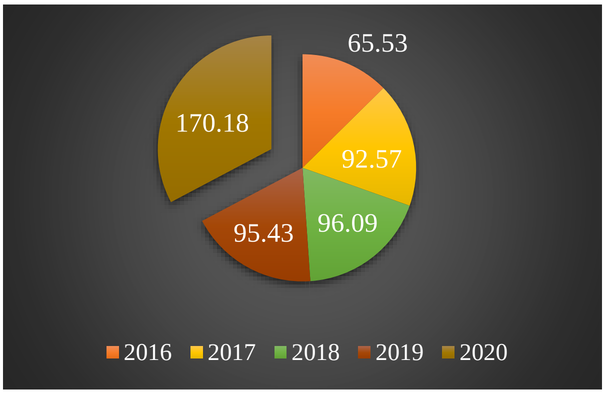

Fig. 7. Dynamics of the value of producing environmental goods and services in Romania, 2016-2020 (million lei)
Source: Own design based on the data from NIS, http://statistici.insse.ro [7].

From existing data in Fig. 7, it appears that services dealing with biodiversity protection are increasingly expensive (due to new trends and technologies), with an increase of +61.49% between the reference years 2016 - 2020. Area of virgin and quasi-virgin forests in 2018-2022 is shown in Table 3.

Table 3. Area of virgin and quasi-virgin forests in Romania, 2018-2022 (ha)

Surface of forests	2018	2019	2020	2021	2022
Overall	21,091.52	30,147.43	43,823.36	70,069.03	71,077.44
Virgin forests	5,898.92	6,665.46	7,401.98	8,579.8	8,579.8
Quasi-virgin Forests	15,192.6	23,481.97	36,421.38	61,489.23	62,497.64

Source: NIS, http://statistici.insse.ro [7].

The virgin and quasi-virgin forests are those forests formed and developed exclusively under the action of natural factors and in which ecosystem processes in their dynamics occur without any direct or indirect anthropogenic influence and past virgin forests, which, in the meantime, have undergone observable, insignificant anthropogenic changes on ecosystem structure, stature and processes [1].

The area covered by virgin and quasi-virgin forests increased from 21,091.52 ha in 2018 to 71,077.44 ha in 2022, meaning a gain of +236.9 % gain. In the same interval, the area with virgin forests increased by +45.4 %, while the surface with quasi-virgin forests became +4.11 % larger in 2022 versus 2018.

The quasi-virgin forest are dominant in overall forest surface, having a share of 87.92% (Table 3, Fig. 8).

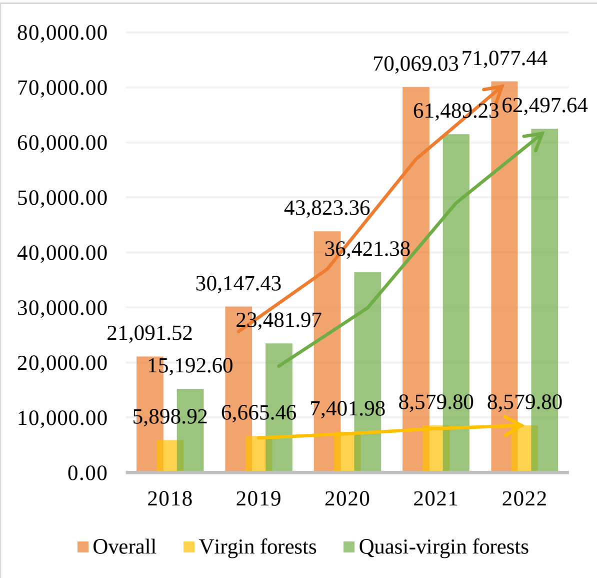

Fig. 8. Dynamics in Romania of the area of virgin and quasi-virgin forests in 2018-2022 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [7].

From the data shown in Fig. 8, it appears that the area of virgin and quasi-virgin forests has increased, a good sign for Romania, the increases expressed in percentages being:

⇨ 236.99 % total;
⇨ 45.44 % virgin forests;
⇨ 311.36 % quasi-virgin forests.

There are several non-governmental organisations (NGOs) actively involved in protecting Romania's biodiversity and promoting conservation practices of which we mention:

MaiMultVerde Association - This organization focuses on environmental protection and biodiversity conservation in Romania through various projects and campaigns. They are involved in planting trees, preserving wetlands and promoting a sustainable lifestyle.

Carpathia Conservation Foundation - This organisation focuses on protecting biodiversity in the Romanian Carpathians, with a focus on the conservation of mountain ecosystems and wild species. They work closely with local communities to develop sustainable practices.

Natural and Human Environment (ADEPT) - ADEPT focuses on biodiversity conservation in the Transylvania region, with a focus on promoting sustainable development and traditional agriculture.

Foundation for Partnership - This organisation engages in biodiversity conservation projects and local community development. They work to protect natural areas and fragile ecosystems.

Association for the Conservation of Biological Diversity (ACDB) - ACDB focuses on biodiversity conservation through research, education and the development of conservation projects in various areas of Romania.

Emperor Bird Study Group (GSPI) - This organisation focuses on the conservation and study of the Emperor Bird (Pyrrhula pyrrhula) and its habitats in Romania.

Save the Zălanului Plains - This organisation fights to protect the Plain Valleys, an area of rich biodiversity threatened by development projects.

These are just a few examples of organisations working to protect biodiversity in Romania. They carry out various projects, campaigns and actions to conserve ecosystems, protect wild species and educate the public about the importance of biodiversity. This collective effort is crucial to maintaining the country's natural wealth and ensuring a sustainable future for the environment.

Protecting and sustainably managing forests is essential for Romania's sustainable future, helping to conserve biodiversity, combat climate change and ensure human well-being.

Protecting Romania's biodiversity is therefore not only a necessity for the environment, but also for society, the economy and human well-being. It is a commitment to a healthier and more sustainable future for the country and the planet.

S.W.O.T. Analysis

S.W.O.T. analysis is an effective method of assessing the situation for a particular problem or area.

In this case, S.W.O.T. analysis for this diversified issue is presented below:

Strengths:

Rich biological diversity - Romania has a diverse natural environment with many species of plants and animals, which provides a solid basis for conservation.

Local community engagement - There are many local communities that are actively involved in environmental conservation and promoting sustainable practices.

Active NGOs and environmental organisations - There is a significant presence of NGOs and environmental organisations in Romania, which carry out various conservation projects and educational programmes.

Weaknesses:

Environmental education deficit - Biodiversity education is not always properly integrated into education systems and public awareness.

Pressure on ecosystems - Urban development, deforestation and industrialisation can have a negative impact on natural habitats.

Limited financial resources - Limited availability of financial resources can make it difficult to implement conservation projects or awareness campaigns.

Opportunities:

Increased education and awareness - There is an opportunity to develop and implement broader education and awareness programmes to increase public engagement in biodiversity conservation.

Development of ecotourism - The tourism potential of Romania's natural areas can be exploited for the benefit of conservation and local economic development.

International cooperation - Romania can collaborate with other countries and international organisations to benefit from additional expertise and resources in the field of biodiversity conservation.

Threats:

Climate change - Climate change may affect ecosystems and species in Romania, putting additional pressure on biodiversity conservation.

Over-exploitation of natural resources - Over-exploitation of natural resources such as timber or minerals can have a negative impact on natural habitats.

Unregulated urbanisation - Rapidly increasing urbanisation can lead to loss of natural habitats and destruction of ecological areas [5].

S.W.O.T. analysis reveals that there are many important opportunities and resources for biodiversity conservation in Romania, but continued efforts are needed to overcome challenges and to harness the potential for environmental protection and promotion of biodiversity education [1].

CONCLUSIONS

Education and awareness are fundamental pillars for biodiversity conservation in Romania. Although the country has significant biological diversity, the current level of awareness and education in this area needs to be improved.

Non-governmental organisations, government institutions and local communities play a vital role in biodiversity conservation efforts. Collaboration and coordination between these entities is essential to achieve conservation goals.

Promoting nature tourism and sustainable economic development in biodiversity-rich areas provides opportunities for conservation and awareness raising.

Recommendations:

-Develop and implement education programs that cover the importance of biodiversity and promote awareness among students.

-Provide resources and technical assistance to NGOs and local communities involved in biodiversity conservation.

-Implement sound laws and regulations to protect the environment and fragile ecosystems and ensure proper enforcement.

-Continue scientific research to assess the state of biodiversity, identify threats and adapt conservation strategies.

-Organise awareness-raising campaigns and events to encourage the public to become actively involved in environmental and biodiversity conservation.

-Collaborate with foreign organisations and countries to share knowledge and resources on biodiversity conservation.

-Addressing climate change and its impact on biodiversity by developing adaptation strategies.

-Education and awareness-raising campaigns should emphasise the link between lifestyle, consumption and biodiversity conservation.

-Environmental professionals and researchers should play a significant role in developing and implementing conservation strategies.

-Implement monitoring systems to track progress towards conservation goals and adapt strategies to current developments.

By implementing these recommendations and involving all stakeholders, Romania can take important steps towards protecting its unique biodiversity and ensuring a sustainable future for the environment.

Biodiversity conservation is essential for our well-being and the health of the planet, and it is our responsibility to act on it.

REFERENCES

[1]Antena Satelor, 2 April. 2021, Biodiversity enhancement and conservation in Romania on an upward trend, https://www.antenasatelor.ro/vrem-sa-stii/vss3/natura/sporirea-si-conservarea-biodiversitatii-in-romania-in-trend-ascendent-id27431.html, Accessed on 25.09.2023.

[2]Bejan M., Rusu T., 2007, Exploitation of natural resources and the concept of sustainable development, Bulletin of AGIR, no. 1/2007.

[3]Berca, M., Robescu, O.V., Buzatu, C.S., 2009, The Natural Model of Biomass Growth and Biomass Quality in Agroecosystems of Meadows from Northen Part of Dambovita County, Romania; Proceedings of 7th WSEAS International Conference on Environment, Ecosystems and Development, December 2009, pp.186-190.

[4]Berca, M., Robescu, O. V, Buzatu, C.S., 2012, Environmental management, Ceres Publishing House, Bucharest, pp. 41 and 209.

[5]Ciur, M., 29 Jun. 2023, Assessment of ecopedological conditions and anthropogenic impact on the perimeter of the Satchinez locality, https://www.scribd.com/document/656192480/referat-satchinez, Accessed on 18.09.2023

[6]Marcuta, L., Popescu, A., Tindeche, C., Fintineru, A., Smedescu, D., Marcuta, A., 2023, Study on the evolution of fair trade and its role in sustainable development, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 23(2), 427-436.

[7]NIS, Tempo online, Statistical data, http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table, Accessed on 10.09.2023.

[8]NIS, Sustainable Romania, Project coordinated by the Department for Sustainable Development, 2014-2020, https://insse.ro/cms/files/POCA/ro-durabil/ro/15-obiectiv-viata-terestra/tinta-5/PC-TQY1552-Suprafata-terenurilor-pe-care-s-au-executat-regenerari-pe-categorii-de-regenerari.pdf, Accessed on 10.09.2023.

[9]Plesoianu, D.M., Popescu, A., 2021, The influence of climatic conditions on tourism in Sinaia resort, Prahova valley, Romania, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 21(4), 423-436.

[10]Popescu, A., Dinu, T.A., Stoian, E., Șerban, V., Ciocan, H.N., 2022, Romania's mountain areas - present and future in their way to a sustainable development, Scientific Papers Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22(4), 549-563.

[11]Popescu, A., Tindeche, C., Mărcuță, A., Mărcuță, L., 2022, Rural areas in Romania - Discrepancies versus urban areas and European Union, Scientific Papers Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22(1), 515-532.

[12]Simina, A. E., Tudor, V. C., Necula (Rădoi), R. A., 2022, Study on the management of the agritourism pensions promotion in the Apuseni mountains area, Scientific Papers Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22(1), 595-602.

[13]Vasiliu, A.E., 27.04.2022, Green Page. State spending on biodiversity conservation has been increasing since 2016 and is approaching 100 million lei annually, https://www.zf.ro/companii/pagina-verde-cheltuielile-statului-pentru-conservarea-20778200, Accessed on 13.09.2023

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TECHNIQUES BASED ON UAV IMAGES FOR WHEAT PRODUCTION ESTIMATION

Ciprian BUZNA[1], Marinel Nicolae HORABLAGA[1,2], Florin SALA[1,2]

[1]Agricultural Research and Development Station (ARSD) Lovrin, Lovrin, 307250, Romania, E-mails: buznac@yahoo.com; hnm75@yahoo.com; florin_sala@usvt.ro
[2]University of Life Sciences "King Michael I" from Timisoara, Timișoara, 300645, Romania Emails: hnm75@yahoo.com; florin_sala@usvt.ro

Corresponding author: florin_sala@usvt.ro

Abstract

The aim of the study was to use a technique based on aerial images (UAV) to wheat production estimation. The images were taken with the drone (UAV, DJI Phantom 4) at different image capture heights (ICH), in the range of 1.5 - 50 m from the ground level, and resulted in 18 sets of images (trials, T). The resized images (crop image, 1,000 x 2,000 pixels) were analyzed and the information for RGB color parameters was obtained. Very strong correlations were recorded between color parameters R and G (r=0.993), as well as between these two color parameters and ICH (r=0.940 in the case of R, respectively r=0.918 in the case of G). Based on the trials distribution in the PCA diagram and in the CA dendrogram, 14 trials (T1, T3-T6, T8-T10, T12-T14, T16-T18) were selected for Training & model construction (Tmc), and four trials (T2 , T7, T11 and T15) for were used for Testing & model validation (Tmv). Through the regression analysis, a wheat production estimation model was obtained based on RGB parameters under statistical safety conditions (R^2=0.999, p<0.001). Flowchart diagram of process was proposed for the present study, and the work process, respectively the obtained models can be adapted for various other agricultural crops.

Key words: *Flowchart diagram, model, UAV image, wheat crop, yield prediction*

INTRODUCTION

Techniques based on imaging analysis have penetrated more and more into agricultural practices, and the facilities offered by these techniques are successfully used for the management of the farm, land and agricultural crops [2, 14, 21, 24].
Unmanned aerial vehicles (UAVs) have already been used for more than a decade in different approaches of general or specific aspects in agriculture, and facilitate studies and decisions in the optimization of technologies and productions for different crops [22, 27].
UAV-based techniques have been used in the study of land surfaces and modeling of different land categories [7], land administration [28], classification and phenotyping of agricultural crops [4, 29].
In the case of cereal crops, drones were used for observations, collecting images and data for the purpose of evaluating the state of the crops, characterizing different genotypes, and substantiating decisions to optimize yields [5, 20].
In the case of wheat crops, UAVs were used to evaluate some growth parameters and the status of wheat plants [9, 32], the evaluation of some foliar and physiological indices in wheat plants [34], plants nutritional status assessment [11], plants relationship with the water regime and the diagnosis of water stress in wheat [11, 37], wheat lodging [35], wheat biomass [15], wheat yield prediction [36], prediction of production variability and some wheat quality indices [38]. The use of UAVs in the study of crops presents a series of advantages, such as affordable costs, high image resolution, ease of use and flexibility of movement, which has made their popularity grow in agricultural practice [1, 19].
The present study used imaging analysis techniques, based on aerial images (UAV) in order to formulate a process flowchart diagram and production prediction models for the wheat crop, based on the spectral information from the captured digital images.

MATERIALS AND METHODS

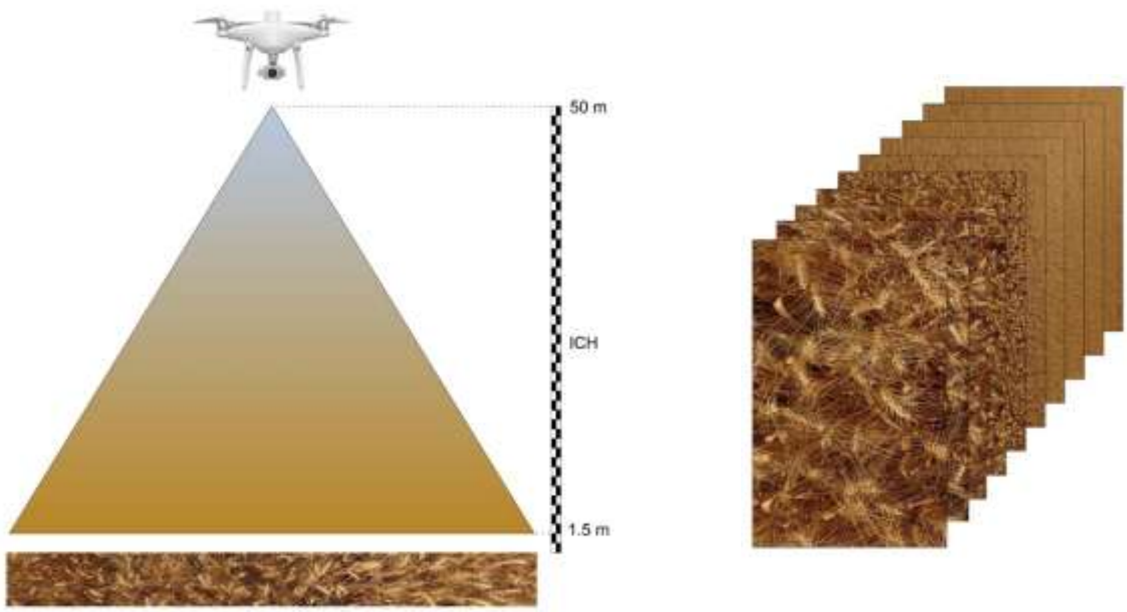
The study was carried out at the Agricultural Research and Development Station Lovrin (ARSD), Timis County, Romania. The wheat crop, 'Dacic' cultivar, was taken into account in the present study.

Wheat crop was carried out on plot 4-7 Lovrin, on a chernozem type soil, in non-irrigated conditions, agricultural year 2021-2022.

The crop technology ensured disking soil tillage, sowing at the optimal time (Dacic wheat cultivar, seed of the superior biological category), mineral fertilization before sowing and in vegetation (NPK complex fertilizers, ammonium nitrate), foliar fertilization in vegetation (Naturamin), post-emergence weed control (Sekator, Falcon Pro), phytosanitary treatments.

A DJI Phantom 4 drone was used to take the images. The images were captured at different heights (ICH), from 1.5 m to 50 m above ground level.

Identical camera settings (FC330 camera model) were used for image acquisition. The images were taken at physiological maturity, BBCH code 9, Senescence [17]. Digital images were taken at 18 different heights in the specified range (1.5 to 50 m), Figure 1.



(a) (b)

Fig. 1. Aspects of image capture in wheat culture; (a) DJI Phantom 4 drone and image capture height (ICH); (b) selective presentation from the set of 18 images, relative to ICH
Source: Original figure, photos and concept of the authors.

The crop was mechanically harvesting, and the average production recorded, under the conditions of the 2021-2022 agricultural years, was 5,026 kg ha^{-1}. The images were processed by resizing (crop size, central area) in order to select a unitary area for analysis, with 1,000 x 2,000 pixels dimensions. The images were analyzed to obtain the spectral data, the RGB color system [23].

The data recorded by the study were analyzed by the ANOVA test, as well as by other appropriate statistical methods to quantify the relationship between the spectral values obtained from the aerial images (UAV), the images capture height, and production.

Based on PCA (Principal Component Analysis) and CA (Cluster Analysis), a number of 14 variants (T1, T3-T6, T8-T10, T12-T14, T16-T18) were selected for Training & model construction (Tmc) , and 4 other variants (T2, T7, T11 and T15) that were used for Testing & model validation (Tmv). Flowchart diagram concept of process used for this study is presented in Figure 2.

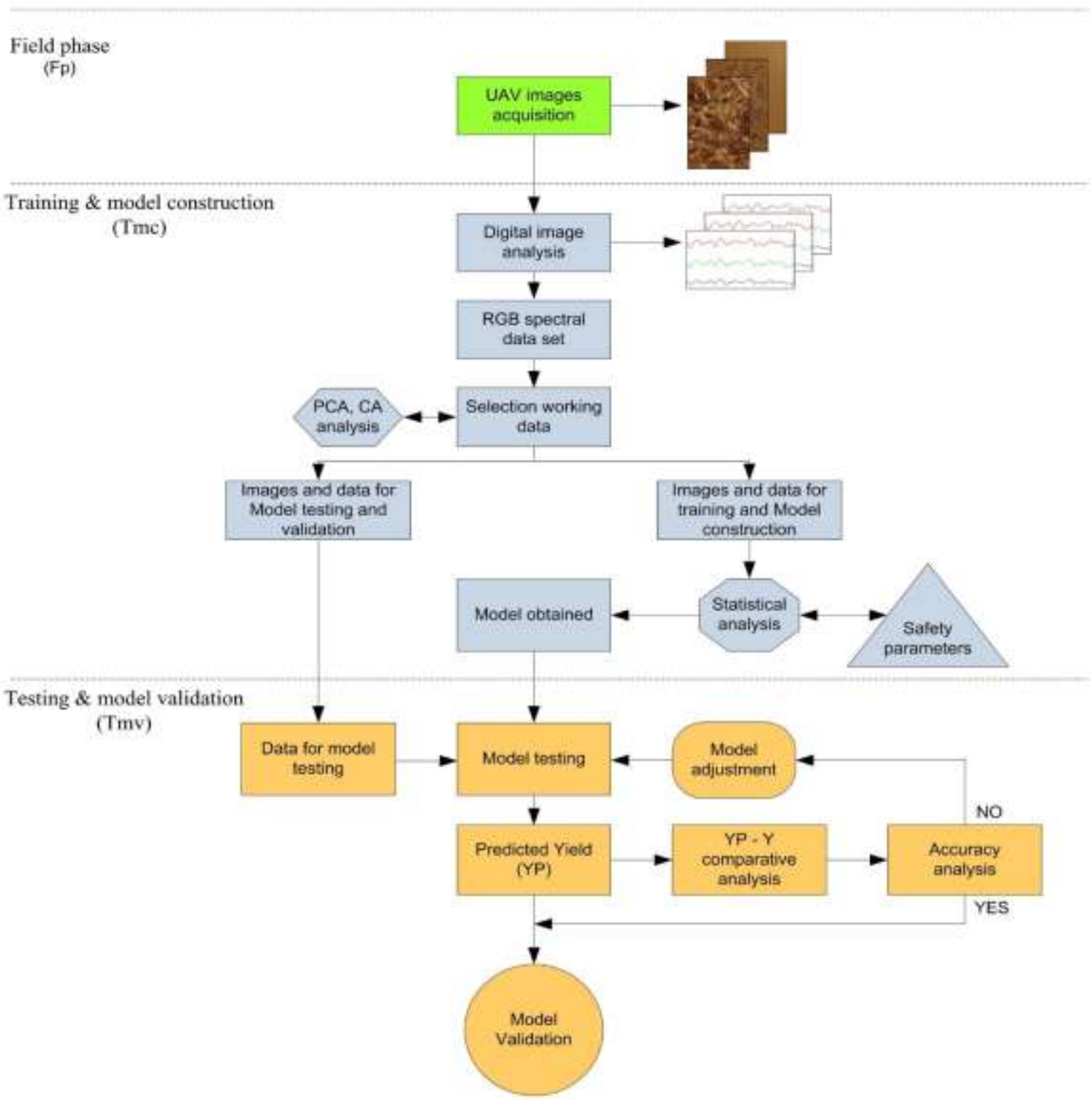


Fig. 2. Flowchart diagram of process used for this study
Source: Original figure, concept of the authors.

To confirm the safety of the data analysis and the results obtained, various appropriate statistical parameters were used; correlation and regression coefficients r, R^2; p parameter; RMSEP, equation (1), REP; and the Cophenetic coefficient.

$$RMSEP = \sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(y_j - \hat{y}_j\right)^2} \qquad (1)$$

Data analysis and processing was done with the EXCEL calculation module, Microsoft Office, and PAST [8, 10, 33].

RESULTS AND DISCUSSIONS

From the analysis of the digital images captured on the 18 height positions, relative to the ground level, the RGB spectral values were obtained. From the set of retrieved images, in the range of 1.5 - 50 m height (ICH), two categories of images use were established, respectively 14 images were used for Training & model construction (Tmc), and 4 images were used for Testing and model validation (Tmv).

Table 1 shows the variants (T1 to T18) in relation to the image capture height (ICH, m), the categories of images use (Tmc, Tmv), the RGB spectral values, and the calculated values for the standard error (SE).

Table 1. The RGB spectral values for the wheat crop, in relation to the images capture height, 'Dacic' cultivar

Trial	Images usage category	ICH (m)	Spectral data		
			R	G	B
T1	Tmc	1.5	132.4	87.68	48.13
T2	Tmv	2	127.29	80.83	42.94
T3	Tmc	3	123.25	77.11	40.2
T4	Tmc	4	124.6	78.9	41.04
T5	Tmc	5	123.74	78.53	39.94
T6	Tmc	6	126.04	81.14	41.56
T7	Tmv	7	125.13	80.67	41.42
T8	Tmc	8	127.62	82.85	42.32
T9	Tmc	9	126.86	79.19	36.33
T10	Tmc	10	128.19	80.32	36.56
T11	Tmv	15	133.79	88.94	45.36
T12	Tmc	20	136.53	91.96	47.18
T13	Tmc	25	141.09	95.7	47.86
T14	Tmc	30	144.15	98.88	50.08
T15	Tmv	35	144.56	98.65	48.19
T16	Tmc	40	145.38	99.21	47.81
T17	Tmc	45	145.88	99.26	47.1
T18	Tmc	50	146.59	99.95	47.45
SE			±2.08	±2.06	±0.99

Note: Tmc - Training & model construction; Tmv - Testing & model validation
Source: Original data from images analysis.

The ANOVA test, single factor, was used to analyze and evaluate the recorded data, under the aspect of statistical safety and the presence of the variance, and the results obtained are presented in Table 2 ($p<0.001$, $F=435.2939$, Alpha=0.001).

Table 2. ANOVA test

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	139993.7	3	46664.58	435.293	2.67E-44	6.0766
Within Groups	7289.768	68	107.203			
Total	147283.5	71				

Source: Original data, obtained by calculation.

Based on the coefficient of variation (CV), it was assessed that high variability was recorded in the case of the G color parameter ($CV_G=9.9960$), intermediate values were recorded in the case of the B color parameter ($CV_B=9.6311$), and low variability of recorded in the case of the R color parameter ($CV_R=6.6009$).

The correlation analysis highlighted very strong and strong, positive correlations between the values of the color parameters (RGB) and in relation to the image capture height (ICH), under statistical safety conditions ($^{**}p < 0.01$, $^{***}p < 0.001$), Table 3.

Table 3. Correlation table

Variable		ICH	R	G	B
1. ICH	Pearson's r	—			
	p-value	—			
2. R	Pearson's r	0.940^{***}	—		
	p-value	< .001	—		
3. G	Pearson's r	0.918^{***}	0.993^{***}	—	
	p-value	< .001	< .001	—	
4. B	Pearson's r	0.654^{**}	0.830^{***}	0.879^{***}	—
	p-value	0.003	< .001	< .001	—

Source: Original data, obtained by calculation.

The regression analysis described the variation of the color parameters G in relation to R, equation (2), under statistical safety conditions ($R^2=0.989$, $p<0.001$), Figure 3.

$$G = -0.001622\,x^3 + 0.6483\,x^2 - 85.19\,x + 3{,}767 \qquad (2)$$

where:
x – R, the values of the R color parameter

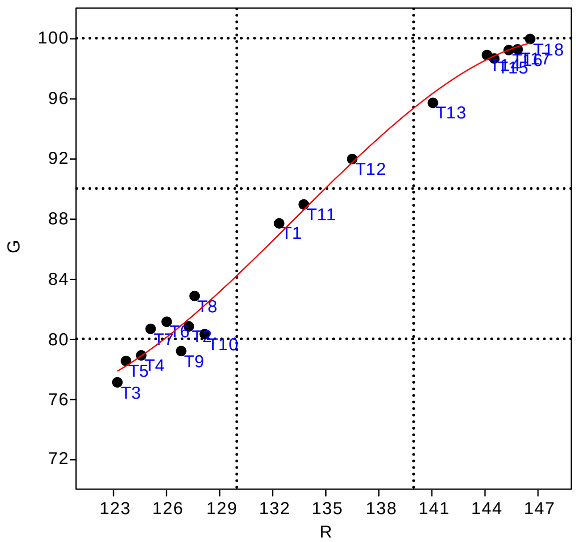


Fig. 3. Graphical distribution of G values in relation to R
Source: Original figure, based on data obtained.

The variation of the R and G color parameters in relation to the image capture height (ICH) was described by degree 2 polynomial equations, equations (3) and (4), under statistical safety conditions (R^2=0.900, p<0.001, F=67.878 for R color parameter; R^2=0.867, p<0.001, F=49.18 for G color parameter). In the case of B color parameter, the statistical safety was low, R^2=0.445, p<0.05, F=6.0215.

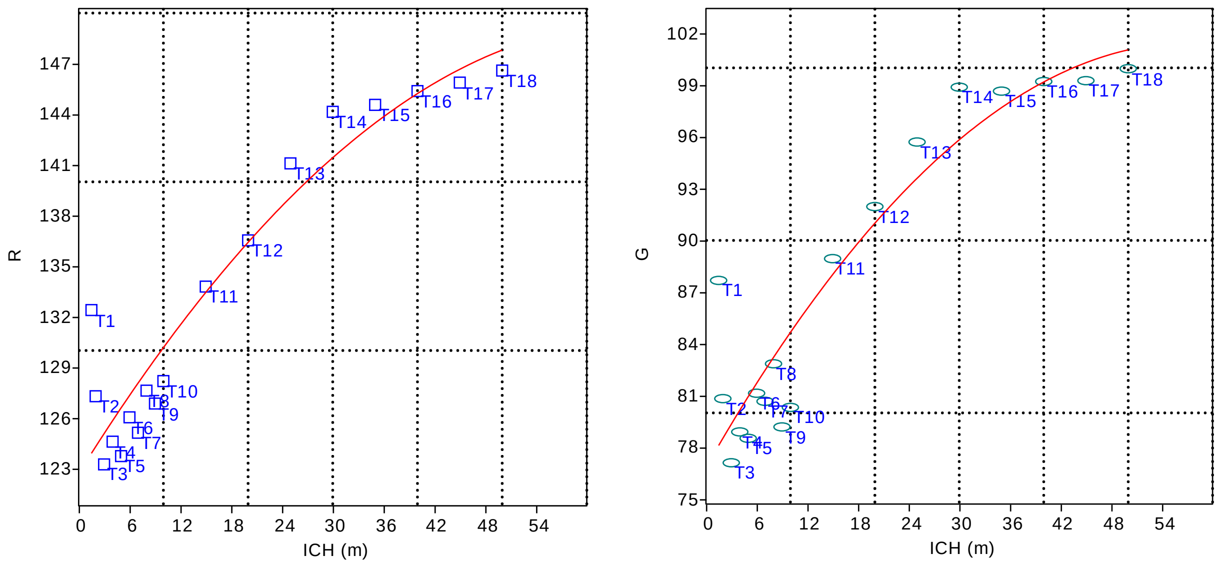
The graphic models of the R and G parameters variation in relation to ICH are shown in Figure 4 (a) and (b).

$$R = -0.006101\,x^2 + 0.807\,x + 122.7 \qquad (3)$$

$$G = -0.007447\,x^2 + 0.8563\,x + 76.85 \qquad (4)$$

where:

x – ICH, image capture images (m)



(a) (b)

Fig. 4. The graphic distribution of R (a) and G (b) values in relation to the image capture height (ICH) in the wheat crop, 'Dacic' cultivar
Source: Original figures based on recorded data

According to PCA, correlation, the diagram presented in Figure 5 was obtained. The distribution of the trials (T1 to T18) was found in relation to the affinity to the RGB color parameter, as biplot. PC1 confirmed 93.431% of variance, and PC2 confirmed 6.4967% of variance.

The trials distribution was the basis for selecting some variants for Training & model construction (Tmc) and other variants for Testing & model validation (Tmv).

Cluster analysis (CA) was used to find out the grouping of the trials, based on Euclidean distances, according to the degree of similarity in relation to the RGB values obtained at the 18 cases of images capture heights.

The dendrogram from Figure 6 was obtained, under statistical safety conditions (Coph corr. = 0.865).

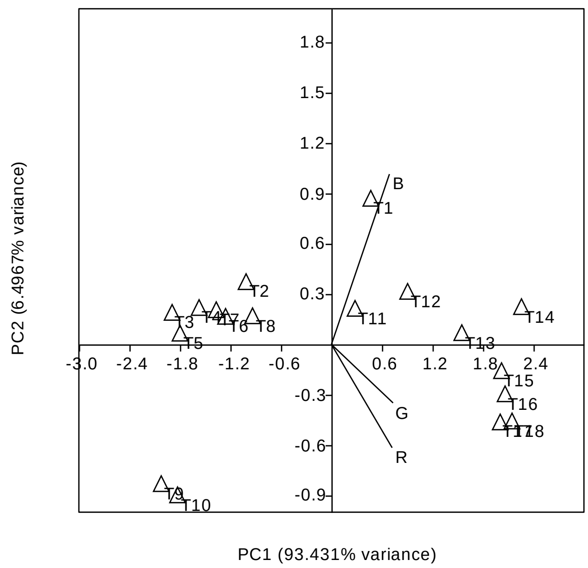


Fig. 5. PCA, correlation diagram
Source: Original figure based on recorded data.

The formation of two distinct clusters (C1 and C2) was found, and within each cluster there are several sub-clusters. The grouping of the trials based on similarity, in relation to the RGB color parameter, was the basis for selecting some trials for Training & model construction (Tmc) and other trials for Testing & model validation (Tmv).

To confirm the level of similarity, the SDI values were calculated, in relation to which the highest level of similarity was found between T16 and T17 trials (SDI=0.870), followed by trials T6 and T7 (SDI=1.034), trials T17 and T18 (SDI=1.050) respectively for the T15 and T16 trials (SDI=1.063). The set of SDI values for all studied variants (T1 to T18) is presented in Table 4.

The regression analysis facilitated the obtaining of some equations that described the production in relation to the spectral values resulting from the analysis of the digital images, captured at different heights (ICH).

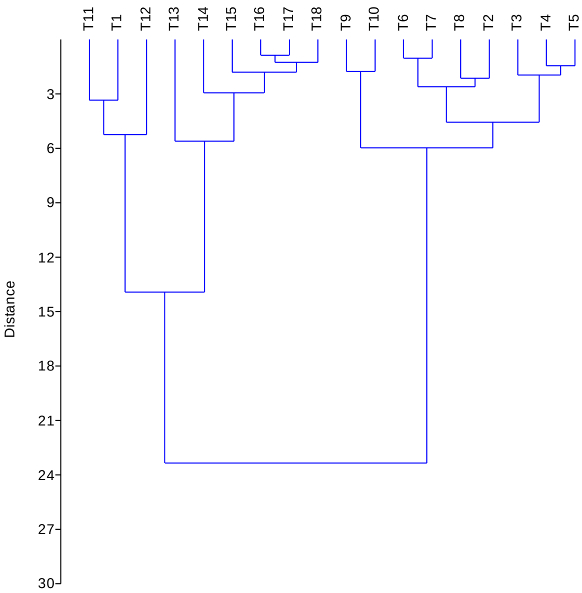


Fig. 6. Dendrogram of trials grouping based on Euclidean distances, in relation to RGB parameter values, 'Dacic' wheat cultivar
Source: Original figure based on recorded data.

Table 4. SDI values in the case of trials in relation to ICH, and RGB color parameters, UAV images, 'Dacic' wheat cultivar

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18
T1		9.999	16.073	13.718	15.02	11.24	12.12	8.941	15.55	14.34	3.346	6.023	11.82	16.34	16.37	17.36	17.80	18.77
T2	9.999		6.137	3.817	5.186	1.888	2.646	2.139	6.824	6.463	10.67	15.07	20.87	25.71	25.36	26.24	26.50	27.53
T3	16.073	6.137		2.394	1.525	5.087	4.207	7.519	5.686	6.925	16.66	21.10	26.88	31.75	31.33	32.18	32.40	33.45
T4	13.718	3.817	2.394		1.445	2.713	1.886	5.134	5.232	5.914	14.28	18.72	24.50	29.37	28.97	29.83	30.06	31.10
T5	15.026	5.186	1.525	1.445		3.838	2.950	6.275	4.817	5.868	15.45	19.90	25.66	30.55	30.10	30.95	31.16	32.20
T6	11.242	1.888	5.087	2.713	3.838		1.034	2.449	5.642	5.504	11.63	16.08	21.86	26.74	26.33	27.19	27.43	28.47
T7	12.125	2.646	4.207	1.886	2.950	1.034		3.430	5.576	5.754	12.60	17.04	22.84	27.71	27.32	28.18	28.43	29.47
T8	8.941	2.139	7.519	5.134	6.275	2.449	3.430		7.061	6.317	9.187	13.63	19.42	24.29	23.89	24.76	25.01	26.05
T9	15.557	6.824	5.686	5.232	4.817	5.642	5.576	7.061		1.760	14.98	19.34	24.65	29.59	28.85	29.59	29.67	30.72
T10	14.344	6.463	6.925	5.914	5.868	5.504	5.754	6.317	1.760		13.53	17.82	23.03	27.96	27.18	27.90	27.97	29.02
T11	3.346	10.671	16.663	14.280	15.45	11.63	12.60	9.187	14.98	13.53		4.466	10.25	15.11	14.77	15.67	15.99	17.01
T12	6.023	15.074	21.109	18.724	19.90	16.08	17.04	13.63	19.34	17.82	4.466		5.937	10.69	10.50	11.45	11.86	12.85
T13	11.828	20.875	26.880	24.509	25.66	21.86	22.84	19.42	24.65	23.03	10.25	5.937		4.940	4.566	5.543	6.016	6.963
T14	16.349	25.711	31.755	29.379	30.55	26.74	27.71	24.29	29.59	27.96	15.11	10.69	4.940		1.948	2.603	3.467	3.744
T15	16.377	25.365	31.336	28.976	30.10	26.33	27.32	23.89	28.85	27.18	14.77	10.50	4.566	1.948		1.063	1.817	2.522
T16	17.364	26.245	32.188	29.835	30.95	27.19	28.18	24.76	29.59	27.90	15.67	11.45	5.543	2.603	1.063		0.870	1.463
T17	17.801	26.506	32.409	30.068	31.16	27.43	28.43	25.01	29.67	27.97	15.99	11.86	6.016	3.467	1.817	0.870		1.050
T18	18.772	27.539	33.451	31.109	32.20	28.47	29.47	26.05	30.72	29.02	17.01	12.85	6.963	3.744	2.522	1.463	1.050	

Source: Original data, obtained by calculation.

Thus, Y production was described in relation to R and G values based on equation (5) under general statistical safety conditions, R^2=0.999, p<0.001, RMSEP=1.5526, REP=0.03. Based on the ANOVA test, the level of statistical confidence was found for all the coefficients of equation (5), p<0.001. Based on equation (5), a 3D model of production expression (Y) in relation to R and G was obtained, Figure 7, and a model in the form of isoquants, Figure

8. For high precision, up to 16 decimals for the equation (5) coefficients were used.

$$Y_{(R,G)} = ax^2 + by^2 + cx + dy + exy + f \qquad (5)$$

where:

$Y_{(R,G)}$– wheat production in relation to R and G; x – R spectral values; y – G spectral values; a, b, c, d, e, f – coefficients of the equation (5); a = -2.09485773; b = -2.04843713; c = 200.37349341; d = -191.04807646; e = 4.11077817; f = 0

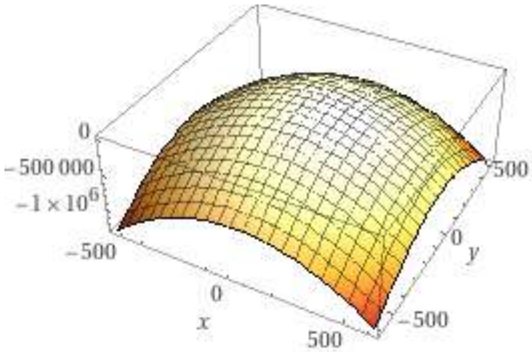


Fig. 7. The 3D graphic distribution of production (Y) in relation to the spectral values R (x-axis) and G (y-axis), Dacic cultivar
Source: Original graph based on recorded and calculated data.

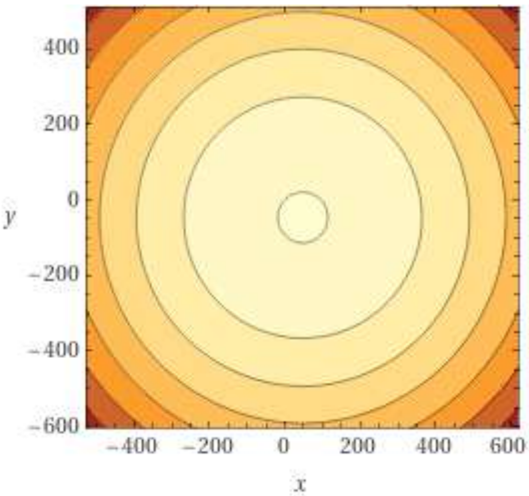


Fig. 8. The graphical distribution in the form of isoquants of the production (Y) in relation to the spectral values R (x-axis) and G (y-axis), Dacic cultivar
Source: Original graph based on recorded and calculated data.

Equation (6) described the Y production in relation to the R and B values in general statistical safety conditions, R^2=0.999, p<0.001, RMSEP=9.6026, REP=0.19. Based on the ANOVA test, the level of statistical safety for the coefficients x and x^2 of the equation (6) was found, p<0.001. Based on equation (6), a 3D model of production expression (Y) in relation to R and B was obtained, Figure 9, and a model in the form of isoquants, Figure 10.

$$Y_{(R,B)} = ax^2 + by^2 + cx + dy + exy + f \qquad (6)$$

where:

$Y_{(R,B)}$– wheat production in relation to R and B; x – R spectral values; y – B spectral values; a, b, c, d, e, f – coefficients of the equation (6); a = -0.15562396; b = -0.17124354; c = 56.95051393; d = 54.21621582; e = -0.31153661; f = 0

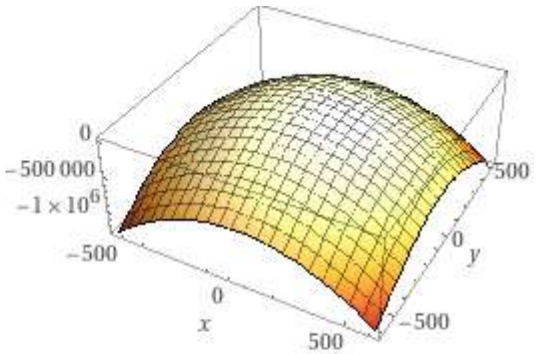


Fig. 9. The 3D graphic distribution of production (Y) in relation to the spectral values R (x-axis) and B (y-axis), Dacic cultivar
Source: Original graph based on recorded and calculated data.

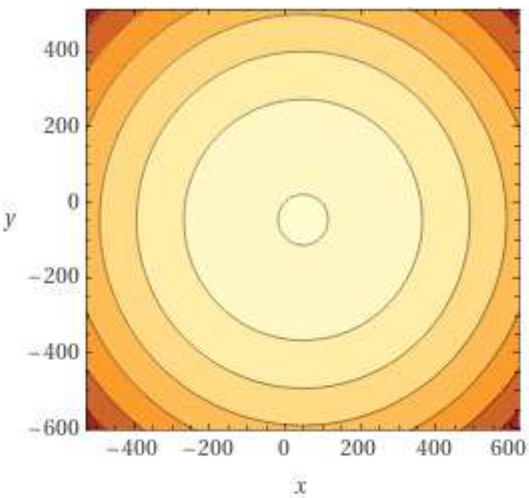


Fig. 10. The graphical distribution in the form of isoquants of the production (Y) in relation to the spectral values R (x-axis) and B (y-axis), Dacic cultivar
Source: Original graph based on recorded and calculated data.

For high precision, up to 16 decimals for the equation (6) coefficients were used.

Based on the trials distribution in the PCA diagram and in the CA dendrogram, 14 trials were selected for Training & model construction (Tmc), and four trials were used for Testing & model validation (Tmv), Table 1. For Testing and model validation (Tmv), trials T2 and T7 were used, with a distinct / independent position in relation to RGB as biplot color parameters, respectively which were integrated into the C1 cluster, and trials T11 and T15, which were positioned in the PCA diagram associated with RGB parameters, and in the CA dendrogram they were included in the C2 cluster.

The regression analysis was used to obtain the wheat production prediction model based on the spectral values of the RGB parameters (Y_{RGB}), obtained from the analysis of aerial images (UAV). Equation (7) was obtained, under statistical safety conditions, according to R2=0.999, $p<0.001$. For high precision, up to 12 decimal were used in the calculation for the coefficients of equation (7). According to the ANOVA test, the values of the coefficients of equation (7) showed statistical safety, $p<0.001$ for each equation coefficient (R, G, B).

$$Y_{RGB} = 102.5317R - 122.6898G + 48.0574B \qquad (7)$$

where:

Y_{RGB} – Model of production estimation based on RGB values; R, G, B – spectral values

For the testing and validation of the obtained model, the values of the T2, T7, T11 and T15 trials were used, in order to predict wheat production. The estimated production values and the error values compared to the measured production were obtained, Table 4.

Table 4. Values of production predicted based on equation (7), Dacic wheat cultivar

Trial	Trial category	ICH (m)	YP (kg ha^{-1})	Error (kg ha^{-1})
T2	Tmv	2	5,197.829	168.829
T7	Tmv	7	4,922.943	-106.057
T11	Tmv	15	4,985.569	-43.431
T15	Tmv	35	5,034.520	5.520

Source: Original data, obtained by calculation.

Different methods, techniques and models have been developed and used for wheat crop analysis [26] and for agricultural production estimation, in relation to plant species, crop conditions, category of agricultural products, harvest destination, development of agricultural policies, food safety and security [12, 13, 18, 31].

Along with the optimization of agricultural technologies [16, 25], production prediction is useful at the farm level from a logistical perspective, for organizing the process harvesting of agricultural crops, organization and dimensioning of transport, storage spaces, honoring commercial contracts, industrialization etc. [30].

Based on UAV techniques, high levels of prediction in the wheat crop (expressed on the basis of R^2, RMSE, average error) were communicated by different authors in various studies conditions [3, 6, 36].

In the context of the present study, high precision was obtained in the prediction of wheat production based on UAV images, respectively of the RGB color parameters, in relation to the images capture hight (ICH), the absolute error being between 5.520 - 168.829 kg ha^{-1}. The obtained model showed high statistical safety ($p<0.001$), and the Flowchart diagram of process used can be adapted to different agricultural crops.

CONCLUSIONS

Based on the UAV images taken at different heights (ICH) of the wheat crop, the Dacic cultivar, it was possible to create a flowchart diagram of the process and obtain production prediction models in relation to the values of the RGB color parameters.

Models of the type of polynomial equations were obtained through regression analysis, which described with statistical certainty the variation of RGB color parameters in relation to ICH.

In relation to the PCA and CA analysis, ICH trials were selected for Training & model construction (Tmc), respectively for Testing & model validation (Tmv), and the obtained model facilitated the prediction of production under conditions of statistical safety under conditions of maximum errors of up to to 168.829 kg ha^{-1}.

Flowchart diagram of process and production prediction models can be adapted for different agricultural crops, in relation to the time and images capture height.

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REFERENCES

[1]Aslan, M.F., Durdu, A., Sabanci, K., Ropelewska, E., Gültekin, S.S., 2022, A comprehensive survey of the recent studies with UAV for precision agriculture in open fields and greenhouses, Appl. Sci., 12(3):1047.

[2]Benami, E., Jin, Z., Carter, M.R., Ghosh, A., Hijmans, R.J., Hobbs, A., Kenduiywo, B., Lobell, D.B., 2021, Uniting remote sensing, crop modelling and economics for agricultural risk management, Nat. Rev. Earth Environ, 2:140-159.

[3]Bian, C., Shi, H., Wu, S., Zhang, K., Wei, M., Zhao, Y., Sun, Y., Zhuang, H., Zhang, X., Chen, S., 2022, Prediction of field-scale wheat yield using machine learning method and multi-spectral UAV data, Remote Sens, 14:1474.

[4]Bouguettaya, A., Zarzour, H., Kechida, A., Taberkit, A.M., 2022, Deep learning techniques to classify agricultural crops through UAV imagery: A review, Neural Comput. Appl., 34:9511-9536.

[5]Constantinescu, C., Herbei, M., Rujescu, C., Sala, F., 2018, Model prediction of chlorophyll and fresh biomass in cereal grasses based on aerial images, AIP Conf. Proc., 1978(1):390003.

[6]Costa, L., McBreen, J., Ampatzidis, Y., Guo, J., Gahrooei, M.R., Babar, M.A., 2022, Using UAV-based hyperspectral imaging and functional regression to assist in predicting grain yield and related traits in wheat under heat-related stress environments for the purpose of stable yielding genotypes, Prec. Agric., 23:622-642.

[7]Czapiewski, S., 2022, Assessment of the applicability of UAV for the creation of digital surface model of a small peatland, Front. Earth Sci., 10:834923.

[8]Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001, PAST: Paleontological statistics software package for education and data analysis, Palaeontol. Electron., 4(1):1-9.

[9]Han, X., Wei, Z., Chen, H., Zhang, B., Li, Y., Du, T., 2021, Inversion of winter wheat growth parameters and yield under different water treatments based on UAV multispectral remote sensing, Front. Plant Sci., 12:609876.

[10]JASP Team, 2022, JASP (Version 0.16.2) [Computer software].

[11]Jiang, J., Atkinson, P.M., Zhang, J., Lu, R., Zhou, Y., Cao, Q., Tian, Y., Zhu, Y., Cao, W., Liu, X., 2022, Combining fixed-wing UAV multispectral imagery and machine learning to diagnose winter wheat nitrogen status at the farm scale, Eur. J. Agron., 138:126537.

[12]Kheir, A.M.S., Alkharabsheh, H.M., Seleiman, M.F., Al-Saif, A.M., Ammar, K.A., Attia, A., Zoghdan, M.G., Shabana, M.M.A., Aboelsoud, H., Schillaci, C., 2021, Calibration and validation of AQUACROP and APSIM models to optimize wheat yield and water saving in Arid regions, Land, 10:1375.

[13]Kuehne, G., Llewellyn, R., Pannell, D.J., Wilkinson, R., Dolling, P., Ouzman, J., Ewing, M., 2017, Predicting farmer uptake of new agricultural practices: A tool for research, extension and policy, Agric. Syst., 156:115-125.

[14]López, A., Jurado, J.M., Ogayar, C.J., Feito, F.R., 2021, A framework for registering UAV-based imagery for crop-tracking in Precision Agriculture, Int. J. Appl. Earth Obs. Geoinf., 97:102274.

[15]Lu, N., Zhou, J., Han, Z., Li, D., Cao, Q., Yao, X., Tian, Y., Zhu, Y., Cao, W., Cheng, T., 2019, Improved estimation of aboveground biomass in wheat from RGB imagery and point cloud data acquired with a low-cost unmanned aerial vehicle system, Plant Methods, 15:17.

[16]Manos, B., Chatzinikolaou, P., Kiomourtzi, F., 2013, Sustainable optimization of agricultural production, APCBEE Proceedia, 5:410-415.

[17]Meier, U., 2001, Growth stages of mono-and dicotyledonous plants e BBCH monograph, Federal Biological Research Centre for Agriculture and Forestry, 158 pp.

[18]Muruganantham, P., Wibowo, S., Grandhi, S., Samrat, N.H., Islam, N., 2022, A systematic literature review on crop yield prediction with deep learning and remote sensing, Remote Sens., 14:1990.

[19]Noor, N.M., Abdullah, A., Hashim, M., 2018, Remote sensing UAV/Drones and its applications for urban areas: A review, IOP Conf. Ser. Earth Environ. Sci., 169:012003.

[20]Pandey, U.S., Pratihast, A.K., Aryal, J., Kayastha, R.B., 2020, A review on drone-based data solutions for cereal crops, Drones, 4(3):41.

[21]Peprah, C.O., Yamashita, M., Yamaguchi, T., Sekino, R., Takano, K., Katsura, K., 2021, Spatio-temporal estimation of biomass growth in rice using canopy surface model from Unmanned Aerial Vehicle images, Remote Sens., 13:2388.

[22]Rahman, M.F.F., Fan, S., Zhang, Y., Chen, L., 2021, A comparative study on application of Unmanned Aerial Vehicle systems in agriculture, Agriculture, 11(1):22.

[23]Rasband, W.S., 1997, Image J. U. S. National Institutes of Health, Bethesda, Maryland, USA, pp. 1997-2014.

[24]Rejeb, A., Abdollahi, A., Rejeb, K., Treiblmaier, H., 2022, Drones in agriculture: A review and bibliometric analysis, Comput. Electron. Agric., 198:107017.

[25]Roy, P.C., Guber, A., Abouali, M., Nejadhashemi, A.P., Deb, K., Smucker, A.J.M., 2019, Crop yield simulation optimization using precision irrigation and subsurface water retention technology, Environ. Model. Soft., 119:433-444.

[26]Sala, F., Popescu, C.A., Herbei, M.V., Rujescu, C., 2020, Model of color parameters variation and correction in relation to "Time-View" image acquisition effects in wheat crop, Sustainability, 12(6):2470.

[27]Singh, A.P., Yerudkar, A., Mariani, V., Iannelli, L., Glielmo, L., 2022, A bibliometric review of the use of Unmanned Aerial Vehicles in precision agriculture and precision viticulture for sensing applications, Remote Sens., 14:1604.

[28]Stöcker, C., Bennett, R., Koeva, M., Nex, F., Zevenbergen, J., 2022, Scaling up UAVs for land administration: Towards the plateau of productivity, Land Use Policy, 114:105930.

[29]Sweet, D.D., Tirado, S.B., Springer, N.M., Hirsch, C.N., Hirsch, C.D., 2022, Opportunities and challanges in phenotyping row crops using drone-based RGB imaging, Plant Phenome J., 5:e20044.

[30]Taşkıner, T., Bilgen, B., 2021, Optimization models for harvest and production planning in agri-food supply chain: A systematic review, Logistics, 5(3):52.

[31]Van Klompenburg, T., Kassahun, A., Catal, C., 2020, Crop yield prediction using machine learning: A systematic literature review, Comput. Electron. Agric., 177:105709.

[32]Villareal, M., Tongco, A., Maja, J., 2020, Winter wheat crop height estimation using small Unmanned Aerial System (sUAS), Agric. Sci., 11:355-368.

[33]Wolfram Research, Inc., Mathematica, Version 12.1, Champaign, IL (2020).

[34]Wu, S., Deng, L., Guo, L., Wu, Y., 2022, Wheat leaf area index prediction using data fusion based on high-resolution unmanned aerial vehicle imagery, Plant Methods, 18:68.

[35]Yang, B., Zhu, Y., Zhou, S., 2021, Accurate wheat lodging extraction from multi-channel UAV images using a Lightweight Network Model, Sensors, 21(20):6826.

[36]Zeng, L., Peng, G., Meng, R., Man, J., Li, W., Xu, B., Lv, Z., Sun, R., 2021, Wheat yield prediction based on Unmanned Aerial Vehicles-collected Red–Green–Blue imagery, Remote Sens., 13(15):2937.

[37]Zhou, Y., Lao, C., Yang, Y., Zhang, Z., Chen, H., Chen, Y., Chen, J., Ning, J., Yang, N., 2021a, Diagnosis of winter-wheat water stress based on UAV-borne multispectral image texture and vegetation indices, Agric. Water Manag., 256:107076.

[38]Zhou, X., Kono, Y., Win, A., Matsui, T., Tanaka, T.S.T., 2021b, Predicting within-field variability in grain yield and protein content of winter wheat using UAV-based multispectral imagery and machine learning approaches, Plant Prod. Sci., 24(2):137-151.

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ANALYZING THE INFLUENCE OF FARMER FIELD SCHOOL (FFS) ON THE INCOME OF RICE FARMERS USING QUANTILE REGRESSION

Leomarich F. CASINILLO

Visayas State University, Department of Mathematics, Visca, Baybay City, Leyte, Philippines, E-mail: leomarichcasinillo02011990@gmail.com

Corresponding author: leomarichcasinillo02011990@gmail.com

Abstract

This study looks into the influence of Farmer Field School (FFS) in enhancing rice farmers' income in Babatngon, Leyte, Philippines. The article also aimed to determine the significant factors that affect the rice income in the aspect of the rice production process under the FFS program. Secondary data were considered from the existing current study in the literature that dealt with rice farmers who finished their training in FFS. This study used some standard statistical measures to summarize and describe the data collected and employed quantile regression to capture the significant factors affecting the income of rice farming as influenced by FFS. The results of the survey depicted that the farmers who graduated with FFS training have high knowledge, positive attitude, and very great extent in their practices on what they have learned from crop management and the PalayCheck system. Based on the quantile regression models, the level of income in rice farming is influenced by a lower number of years in farming. This implies that younger farmers are more productive and efficient in enhancing their economic income since they are more competitive than traditional farmers. In addition, the regression models revealed that knowledge and attitude toward FFS do not influence their rice income unless it is implemented and adopted. Moreover, it is depicted that the practices of FFS farmers significantly influenced their level of income at a 10% level. Hence, FFS training has improved the productivity of farmers, and positively impacted their economic income and decision-making process. Furthermore, the study suggested that the FFS program must continually reach out to more small-scale farmers, especially in rural areas to attain sustainability in the country.

Key words**:** *rice farmers, farmer field school, PalayCheck system, profitability, quantile regression analysis*

INTRODUCTION

Rice (*Oryza sativa* L.) is a vital source of carbohydrates, essential fiber, and other nutrients. Apparently, rice farming in the Philippines is a source of staple food and income for many small-scale farmers especially in rural areas in the country [6], [7], [8]. In fact, rice production in the country has a huge contribution to the gross domestic product (GDP) and it is considered one of the sustainable crops in the agricultural sector [3]. In that case, the Philippine government aims to improve and enhance rice production in the country by supporting the farmers and giving them agricultural training and workshops. One of the implemented programs by the government is the Farmer Field School (FFS) which provides training programs for innovative technologies that enhance rice productivity in the country [21], [23].

The goal of the FFS organization is to improve the lives of farmers and move toward sustainable production methods and practices. This is done by educating the farmers to have a better knowledge of complex agricultural phenomena and enhancing the ecosystem services concerning farming [20], [27]. Moreover, the FFS objective is to provide hands-on learning that improves the skills and knowledge of farmers to sustainable management and improve their livelihoods which leads to better economic profitability [23] [28]. FFS also trains the farmers in decision-making and complex problem-solving in the farming system [26]. Plus, FFS is also promoting some environmental-friendly technologies that minimize the economic cost and resources [5]. In particular, the FFS training in rice farming introduces the various crop management areas from planting to harvesting [23]. FFS assess the rice farmers' progress concerning their practices in crop management and they provide new innovative techniques and technologies that enhance their production in season or out of season. Moreover, FFS has helped farmers in pest control and management by adopting new integrated technologies through collective and experiential acquisition [14], [21]. In fact, FFS has an impact on the Philippine economy since farmers have learned the techniques in effective farming management that enhance their production and income [24]. On the face of it, it is vital to elucidate and provide a piece of the necessary information about the progress of farmers under the FFS training to improve the current policies. Additionally, an investigation of the FFS programs for farmers may give details on the effectiveness and constraints that can be used for policy formulation.

Although FFS in rice farming is well-research, research on the effectiveness of the rice farmers' income is relatively scarce. In addition, correlating the income of rice farmers to the knowledge, attitude, and practices that were influenced by FFS training using the quantile regression has never been done before. Hence, this article's research was realized to fill in the said gap. In general, the study elucidates the effect of FFS training on rice income through the knowledge, attitude, and practices of the farmers. Specifically, the article aims to provide an answer with the following agenda: (1) to summarize the farming profile of the FFS farmers; (2) to estimate the farmers' knowledge, attitude, and practices as influenced by FFS training; (3) to model the impact of FFS to the farmers' income via knowledge, attitude, and practices. The purpose of this article is to provide an understanding of the income level of farmers under the FFS training. Results may supply information on how to improve the farmers' income and productivity as well as well-being. Moreover, the findings may provide an argument that can be used to improve the weaknesses (if there are any) of FFS training and enhance the program that leads to sustainability and improving the skills and practices of farmers.

MATERIALS AND METHODS

The article's purpose is to create a statistical model that predicts the factors affecting the income level of rice farmers in the aspect of their farming profile, knowledge, attitude, and practices as influenced by FFS training. Hence, the study utilized a complex-correlational research design. Cross-sectional and secondary data were employed and analyzed through standard statistical measures and inferential statistics namely regression modeling analysis.

This article considered secondary and cross-sectional data from the current study by Red et al. [23] entitled “Effect of Farmer Field School (FFS) on the Knowledge, Attitude, Practices, and Profitability of Rice Farmers" which was published in the journal "Philippines Social Science Journal." The study dealt with a comparison test between FFS farmers and non-FFS farmers concerning their knowledge, attitude, practices, and profitability. However, the study does not develop a statistical model that determines the correlates of income incorporating the farming profile, knowledge, attitude, and practices as independent variables which were influenced by FFS training. The study was conducted at selected barangays in Babatngon, Leyte, Philippines namely Bagong Silang and Governor E. Jaro. Map 1 presents the location of Babatngon, Leyte.

Map 1. Location of Babatngon Leyte, Philippines
Source: [10].

These two barangays have a wide area for rice farming and they are beneficiaries of Farmer Field School (FFS) implemented by the

Department of Agriculture in the country. Hence, this study only dealt with farmers who already finish the FFS training. In that case, 47 FFS farmers were selected at random and considered as a participant in this research study. As for the data, the farming profile such as tenurial status (0 - non-owner, 1 - owner), number of years in farming, net income during the wet and dry seasons, and annual income (income during wet plus dry season) were employed. Note that these FFS farmers are cultivating a wide paddy farm of approximately 1.1 hectares for rice farming alone [23]. Plus, the knowledge, attitude, and practices towards the various crop management areas (PalayCheck System introduced by FFS). The PalayCheck System is a rice crop management that introduces innovative technology and practices in the different stages of rice farming that promote improvement in production, environmental safety, and economic profitability [9]. The PalayCheck system has the following 7 stages: (1) seed quality, (2) land preparation, (3) crop establishment, (4) nutrient management, (5) water management, (6) pest management, and (7) harvest management [23]. Note that in estimating the knowledge, attitude, and practices of rice farmers in the different crop management, a Likert scale was employed. Hence, Table 1 and 2 depicts the guidelines for possible perception scores for the knowledge, attitude, and practices of rice farmers and their linguistic interpretation.

Table 1. Knowledge and Practices level guidelines

Perception Score	Knowledge	Practices
1.00 – 1.80	Very low	Small extent
1.81 – 2.60	Low	Some extent
2.61 – 3.40	Moderate	Moderate extent
3.41 – 4.20	High	Great extent
4.21 – 5.00	Very High	Very great extent

Source: Author's guidelines (2023).

Table 2. Attitude level guidelines

Perception Score	Response	Attitude
1.00 – 1.83	Strongly disagree	Very negative
1.84 – 2.67	Disagree	Negative
2.68 – 3.50	Somewhat disagree	Somewhat negative
3.51 – 4.33	Somewhat agree	Somewhat positive
4.34 – 5.16	Agree	Positive
5.17 – 6.00	Strongly agree	Very positive

Source: Author's guidelines (2023).

After the data selection and clearing, the Microsoft excel form of the data was manipulated to fit it into STATA version 14.0 for statistical computation. In summarizing the selected data, frequency distribution, and percentages, mean (M), standard deviation (SD), minimum (min), and maximum (max) values were computed and interpreted. In addition, the computed descriptive measures were presented in tabular form. As for the determination of the significant factors (FFS influence) of the income level of rice farmers, a multiple linear regression was used as a piece of baseline information, and quantile regression was employed to analyze the predictors of the different levels of income. Multiple linear regression is a statistical modeling that deals with the relationship between a continuous dependent variable and continuous (or categorical) independent variables. In addition, linear regression uses the method of ordinary least squares (OLS) wherein it approximates the conditional mean average of the dependent variable [17]. Meanwhile, quantile regression approximates the conditional median (quantiles) of the dependent variable with respect to independent variables and it is often used when some assumptions of OLS are not being met. In [29], it is stated that quantile regression analysis provides a more rigorous statistical model than OLS regression. Whence, this article is well-grounded on the empirical regression model (Eq. 1) as follows:

$$Income_i = a_0 + a_1 tenurial_i + a_2 yearsfarm_i + a_3 knowledge_i + a_4 attitude_i + a_5 practices_i + e_i \quad \text{(Eq. 1)}$$

where $Income_i$ refers to the net income (annual income (wet+dry season)). Under the OLS regression, the conditional mean average for income was computed and under the quantile regression, conditional 25th (low income), 50th (middle income), and 75th (high income) quantiles for income were approximated with respect to the independent variables. As for the independent variables, $tenurial_i$ refers to a dummy variable that captures a farmer who owned their cultivated rice farm, $yearsfarm_i$ refers to the number of farmers' years of experience in rice farming, $knowledge_i$ refers to the farmers' knowledge perception score in the PalayCheck system as influenced by FFS, $attitude_i$ refers to the farmers' attitude perception score in the PalayCheck system as influenced by FFS, $practices_i$ refers to the farmers' practices perception score in the PalayCheck system as influenced by FFS, and $e_i$represents to the random error in the model (Eq. 1). Moreover, the OLS regression has undergone post-estimation (diagnostic) test to ensure the validity of the estimated parameters and all statistical results were tested at standard level of significance [17]. Furthermore, all computations were aided with the software called STATA version 14.0 and were all presented in tabular form and interpreted accordingly.

RESULTS AND DISCUSSIONS

Profile of Farmers

Table 3 showed that about 36% of the FFS farmers owned their rice land and does not pay for rent or lease. About 64% of these FFS farmers are just tenants for their cultivated rice land. This implies that they have to pay for leases and other expenses for the rice field. On average, the FFS farmers' number of years of experience in rice farming is close to 24.36 years. During the wet season, the FFS farmers' approximate income is close to 37,191.12 PHP (SD=10,545.68 PHP) ranging from 9,725 PHP to 55,870 PHP.

On the other hand, the dry season income for rice farming is close to 28,707.32 PHP (SD=8,995.12 PHP) which ranges from 7,470 PHP to 47,510 PHP. It is worth noting that rice is more productive in the wet season since they are best grown in good water level with continuous water irrigation, hence, income in the wet season is expected to be high as opposed to the dry season [13]. Furthermore, the annual income of FFS rice farmers is close to 65,898.45 PHP (SD=17,755.94 PHP) which ranges from 26,325 PHP to 98,200 PHP.

Table 3. Farming and income profile

Variable	M	SD	Min	Max
Tenurial status[a]	0.36	0.49	0	1
Years in farming	24.36	12.35	4	50
Wet season (income)[b]	37191.13	10545.68	9725	55870
Dry season (income)[b]	28707.32	8995.12	7470	47510
Annual income[b]	65898.45	17755.94	26325	98200

Note: a - dummy (indicator) variable; b - one cropping season (in PHP)
Source: Author's computations(2023).

Knowledge, Attitude, and Practices

Table 4 depicts that no farmers have graduated from FFS training with very low and low knowledge about rice crop management. Only 4.26% of them say that their knowledge is just moderate which indicates that the training successfully imparted information to the rice farmers. About 53.19% of the FFS farmers have learned and said that they have a piece of high knowledge. Moreover, 42.55% of them said that they possessed a very high knowledge of rice farming right after they graduated from the FFS training. As a whole, farmers are having a high knowledge (M=4.12, SD=0.48) of the PalayCheck system after their FFS training. In [16], it is depicted that knowledge and learning about the present innovative agricultural technology are vital in improving the farmers' yield and income through the adoption of the said crop management practices.

Table 4. Knowledge of FFS farmers

Knowledge	Frequency	Percent (%)
Very low	0	0.00
Low	0	0.00
Moderate	2	4.26
High	25	53.19
Very High	20	42.55
M±SD	**4.12±0.48 (High knowledge[a])**	

Note: a - See Table 1.
Source: Author's computations (2023).

As seen in Table 5, no FFS farmers have responded as "strongly disagree", "disagree", "somewhat disagree", or "somewhat agree" on their attitude about what they have learned about crop management principles. This indicates that they found their learning vital in improving their productivity. About 29.79% of them have agreed on the different PalayCheck which implies that they have a positive perception score on crop management. Additionally, most (70.21) of them have a response of "strongly agree" on the PalayCheck system. Overall, the farmers are very positive (M=5.44, SD=0.49) to the new innovative technology in farming introduced by the FFS about crop management. The attitude and welfare of farmers towards the new agricultural technology and policies must be boosted through proper training so that they are more likely to adopt crop management programs in improving their farming techniques and efficiency [22].

Table 5. The attitude of FFS farmers

Response	Frequency	Percent (%)
Strongly disagree	0	0.00
Disagree	0	0.00
Somewhat disagree	0	0.00
Somewhat agree	0	0.00
Agree	14	29.79
Strongly agree	33	70.21
M±SD	**5.44±0.49 (Very positive[b])**	

Note: b - See Table 2.
Source: Author's computations (2023).

Table 6 presented that no farmers have small and some extent regarding their practices to the new FFS learning about rice crop management. Only 4.26% of the farmers have a moderate extent in their practices and about 38.30% of them have a great extent in practicing what they have learned in FFS training. Moreover, 57.45% of the farmers have a very great extent in their practices in which they have applied crop management to improve their production and economic income in rice farming.

Table 6. Practices of FFS farmers

Practices	Frequency	Percent (%)
Small extent	0	0.00
Some extent	0	0.00
Moderate extent	2	4.26
Great extent	18	38.30
Very great extent	27	57.45
M±SD	**4.24±0.44 (Very great extent[c])**	

Note: c - See Table 1.
Source: Author's computations (2023).

Overall, the FFS farmers' practices perception score can be interpreted as "very great extent (M=4.24, SD=0.44)." This implies that the farmers' practices are improved by FFS since the program involves long training and participatory activities [4]. In fact, if the farmers have high knowledge and a positive attitude about the newly introduce technology, they are more likely to practice it in their actual farming activities [16], [23].

Quantile Regression

Quantile regression models were presented in Table 7, consisting of the 25th (low net income), 50th (middle net income), and 75th (high net income) quantiles as dependent variables. The OLS model also was presented for comparison which dealt with average income in rice farming as the dependent variable in the regression. First, the diagnostics or post-estimation for the OLS model was bestowed to reveal if the results are valid for interpretation and forecasting. The Breusch-Pagan test showed that the OLS model is not heteroscedastic (X^2=0.29, p-value=0.59). Meaning, the model has more or less constant variances or does not vary significantly [17]. Using the concept of the Ramsey RESET test, the model was exposed that it does not possess an omitted variable bias (F=1.76, p-value=0.17), which indicates that independent variables were fitted and relevant as regressors. In addition, based on the variance inflation factor (VIF), it is shown that the OLS model does not possess a multicollinearity problem in which the mean VIF is equal to 1.39. This implies that there is no significant association between the found pairwise independent variables or predictors of the model [1].

Moreover, with the aid of the Shapiro-Wilk test, it is depicted that the OLS regression model has normally distributed residuals (W=0.98, p-value=0.90). The OLS model is significant at a 5% level (F=2.58, p-value=0.041) and has a coefficient of determination of 0.24. This indicates that there are significant predictors of net income in the model. In that case, the results of the OLS model are reliable for forecasting and interpretations as baseline information for the quantile regression models' results. Meanwhile, the quantile regression models has also significant predictors based on pseudo R^2 (25th quantile: R^2=0.179; 50th quantile: R^2=0.146; 75th quantile: R^2=0.105).

First, the quantile models and OLS model showed that income at all levels is not influenced by tenurial status. This means that being an owner of the rice field or being a tenant does not affect their economic income. This result is not parallel to [8], which stated that a farmer who owns their rice farm tends to have more income since they don't have to share or pay a lease. Secondly, the 25th quantile for the farmers' income model revealed that years in farming (a_2=-0.004, p-value<0.05) is a significant predictor of net income in rice farming.

Apparently, the negative coefficient indicates that a younger farmer tends to perform better as opposed to an older farmer concerning income generation. This result is supported by the OLS model, wherein the mean average income is significantly influenced by the number of years in farming. This means that for FFS graduates, younger farmers are more likely to learn and adopt innovative technologies nowadays compared to traditional farmers. Hence, rice production tends to be more successful for younger farmers due to the new application of agricultural technologies. In [18], it is mentioned that young farmers are more active and are more likely to diversify agricultural techniques than traditional farmers. Moreover, the 50th quantile regression model (a_2=-0.004, p-value<0.1) has revealed that income is influenced by younger farmers at a 10% level of significance. In fact, young farmers are having more opportunities to develop skills and are more competitive than old farmers [12]. Thirdly, knowledge and attitude in FFS towards cropping management do not influence their income in rice farming for both quantile models and the OLS model.

This means that farmers' learning and behavior in the FFS program do not help them in improving their production level and profitability in rice farming unless they put them into practice. Adoption of agricultural technologies can help solve the farmers' various problems in crop activities and enhance their efficiency which gives them relevant processes in effective farming principles [25]. The three quantile regression model (25th, 50th, and 75th) has revealed that their practices (coming from FFS learning) in crop management has influenced their income generation from rice production and it is significant at a 10% level. This is also true in the OLS regression model that the farmers' practices are significant causation to their economic income and similarly, it is significant at the 10% level. This implies that a farmer who implemented and adopted the teachings of FFS training has improved their level of production and efficiency in crop management regarding the PalayCheck system.

In [2], [23], and [24], it is mentioned that farmers who adopted innovative agricultural technologies have significantly increased their yield and productivity in rice farming and they tend to make better decisions in crop management activities as opposed to non-FFS farmers. Likewise, in [15], it is depicted that advanced technology in agriculture can easily progress the farmers' production in a smooth manner in which they have the motivation and a good decision-making process. Plus, the implementation and adoption of agricultural innovation technologies have a positive and significant impact on farmers' income and promote modernization in agriculture activities that is safety from the environment [11], [19].

Table 7. Quantile regression models for farmers' net income[b] and its determinants (FFS influenced).

Predictors	**Quantile Regression Model**			**OLS Regression**
	25th	***50th***	***75th***	
Constant	4.448*** (0.394)	4.274*** (0.300)	4.758*** (0.256)	4.447*** (0.236)
Tenurial status[a]	0.027[ns] (0.062)	0.031[ns] (0.060)	0.006[ns] (0.043)	0.023[ns] (0.040)
Years in farming	-0.004** (0.002)	-0.004* (0.003)	-0.001[ns] (0.002)	-0.003* (0.002)
Knowledge[c]	0.002[ns] (0.008)	0.002[ns] (0.006)	0.002[ns] (0.003)	0.006[ns] (0.005)
Attitude[c]	-0.007[ns] (0.011)	0.001[ns] (0.005)	-0.006[ns] (-0.236)	-0.003[ns] (0.006)
Practices[c]	0.018* (0.009)	0.016* (0.009)	0.011* (0.007)	0.011* (0.007)
n	47	47	47	47
F	-	-	-	2.58**
p-value	-	-	-	0.041
R^2	-	-	-	0.239
Psuedo R^2	0.179	0.146	0.105	-

Note: a - dummy (indicator) variable; b - one cropping season (in PHP); c - see Table 1 or 2; Standard errors are enclosed with parenthesis; ns - not significant; *p<10%; **p<5%; ***p<1%.
Source: Author's computations (2023).

CONCLUSIONS

The article's goal is to look into the influence of FFS training on rice farmers' income concerning knowledge, attitude, and practices. The descriptive measure results depicted that, on average, the rice farmers who finished the FFS training have high knowledge, positive attitude, and very great extent in their practices on what they have learned from crop management and the PalayCheck system. This goes to infer that FFS training has successfully educated the farmers on the new innovative technologies through actual and practical series of workshops in farm settings.

Based on the quantile regression models, the level of income in rice farming is significantly influenced by the lower number of years in rice farming. This implies that younger farmers are more productive and efficient in enhancing their profitability since they are more competitive and can easily learn than traditional or old farmers. In addition to that, the quantile regression models revealed that knowledge and attitude towards FFS do not influence their rice income unless it is being put into practice. Moreover, it is depicted that the practices of FFS farmers significantly influenced their level of income. This implies that the implementation and adoption of agricultural technologies can enhance their efficiency in farming and effectively manage their existing problems on the farm. Conclusively, the FFS training program has improved the productivity of rice farmers and positively influenced their economic income and decision-making process in the farming system. Therefore, it is highly recommended that FFS constituents must continually reach out to more small-scale or poor farmers in the country especially in rural areas to attain sustainability and productivity in rice farming. For future studies, one may consider a larger scale with a sufficient sample size of farmers to gather more sound information about the impact of FFS training on farmers' income. Furthermore, one may incorporate the subjective well-being of farmers about the FFS training as a possible factor of income level in the constructed regression model to strengthen the current results.

REFERENCES

[1]Allison, P.D., 2012, Logistic regression using SAS: Theory and application. SAS Institute. https://mycourses.aalto.fi/pluginfile.php/889996/mod_resource/content/2/Paul%20D.%20Allison%20-%20Logistic%20Regression%20Using%20SAS%20-%20Ch%202.pdf, Accessed on October 1, 2022.

[2]Anang, B.T., Bäckman, S., Sipiläinen, T. 2020, Adoption and income effects of agricultural extension in northern Ghana. Scientific African, 7: e00219. https://doi.org/10.1016/j.sciaf.2019.e00219, Accessed on October 13, 2022.

[3]Balié, J.,Valera, H.G. 2020, Domestic and international impacts of the rice trade policy reform in the Philippines. Food Policy, 92: 101876.https://doi.org/10.1016/j.foodpol.2020.101876, Accessed on June 8, 2023.

[4]Bhuiyan, M.M.R., Maharjan, K.L., 2022, Impact of farmer field school on crop income, agroecology, and Farmer's behavior in farming: A case study on Cumilla district in Bangladesh. Sustainability, 14(7): 4190.https://doi.org/10.3390/su14074190, Accessed on June 17, 2023.

[5]Cai, J., Chen, Y., Hu, R., Wu, M., Shen, Z., 2022, Discovering the impact of farmer field schools on the adoption of environmental-friendly technology. Technological Forecasting and Social Change, 182. 121782.https://doi.org/10.1016/j.techfore.2022.121782

[6]Casinillo, L.F., 2020, Econometric modelling on satisfaction in rice farming under Philippine rice tariffication law. Journal of Research and Multidisciplinary, 3(2):326-336. doi:10.5281/jrm.v3i2.38, Accessed on January 4, 2023.

[7]Casinillo, L., 2022, Modeling profitability in rice farming under Philippine rice tarrification law: An econometric approach, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(3): 123-130, https://managementjournal.usamv.ro/pdf/vol.22_3/Art13.pdf, Accessed on October 27, 2022.

[8]Casinillo, L., Seriño, M.N., 2022, Econometric evidence on happiness and its determinants among rice farmers in Leyte, Philippines. Independent Journal of Management & Production, 13(5): 1026-1044. https://doi.org/10.14807/ijmp.v13i5.1597, Accessed on October 10, 2022.

[9]Corales, A.M., Dizon, J.T., Cardenas, V.R., 2014, Assessing Palaycheck® Institutionalization in selected municipalities in Luzon, Philippines. Philippine Journal of Science, 143(2): 167-176.https://www.ukdr.uplb.edu.ph/journal-articles/1953/, Accessed on June 11, 2023.

[10]Google Map, 2023, Location of Babatngon, Leyte, Philippines.

https://www.google.com/maps/place/Babatngon,+Leyt, Accessed on May 21, 2023.
[11]Hailu, B.K., Abrha, B.K., Weldegiorgis, K.A., 2014, Adoption and impact of agricultural technologies on farm income: Evidence from Southern Tigray, Northern Ethiopia. International Journal of Food and Agricultural Economics (IJFAEC), 2(1128-2016-92058): 91-106.https://ageconsearch.umn.edu/record/190816/, Accessed on June 23, 2023.
[12]Hamilton, W., Bosworth, G., Ruto, E. 2015, Entrepreneurial younger farmers and the "young farmer problem" in England. Agriculture and Forestry, 61(4): 61-69. http://eprints.lincoln.ac.uk/id/eprint/20077/, Accessed on June 23, 2023.
[13]Kabir, M.J., Islam, M.A., Rahman, M.C., Rahaman, M.S., Kabir, M.S., Siddique, M.A.B., 2019, Diffusion of wet season (T. Aman) rice cultivars under changed environment in Northwest Bangladesh. Bangladesh Rice Journal, 23(1): 81-106.https://doi.org/10.3329/brj.v23i1.46084, Accessed on June 15, 2023.
[14]Kariyasa, K., Dewi, Y.A., 2013, Analysis of factors affecting adoption of integrated crop management farmer field school (ICM-FFS) in swampy areas. International Journal of Food and Agricultural Economics (IJFAEC), 1(1128-2016-92015): 29-38.https://ageconsearch.umn.edu/record/160092/, Accessed on June 1, 2023.
[15]Li, J., Liu, G., Chen, Y., Li, R. 2023, Study on the influence mechanism of adoption of smart agriculture technology behavior. Scientific Reports, 13(1): 8554.https://www.nature.com/articles/s41598-023-35091-x, Accessed on June 23, 2023.
[16]Mataia, A.B., Olivares, R.O., Manalili, R.G., Malasa, R.B., Litonjua, A.C., Redondo, G.O., ... Tolentino, C.M.A., 2015, Impact of farmer field school–Palaycheck® in the irrigated Rice areas in the Philippines. Philippine Journal of Crop Science, 40(3): 30-42.https://www.ukdr.uplb.edu.ph/journal-articles/4215/, Accessed on June 16, 2023.
[17]Mátyás, L., Sevestre, P., 2013, The econometrics of panel data: Handbook of theory and applications (Vol. 28). Springer Science & Business Media. https://link.springer.com/book/10.1007/978-94-009-0375-3,Accessed on February 24, 2023.
[18]Mazzocchi, C., Orsi, L., Ferrazzi, G., Corsi, S. 2020, The dimensions of agricultural diversification: A spatial analysis of Italian municipalities. Rural Sociology, 85(2): 316-345. https://doi.org/10.1111/ruso.12291, Accessed on June 23, 2023.
[19]Nakano, Y., Tsusaka, T.W., Aida, T., Pede, V.O. 2018, Is farmer-to-farmer extension effective? The impact of training on technology adoption and rice farming productivity in Tanzania. World Development, 105: 336-351. https://doi.org/10.1016/j.worlddev.2017.12.013, Accessed on June 23, 2023.
[20]Osumba, J.J., Recha, J.W., Oroma, G.W., 2021, Transforming agricultural extension service delivery through innovative bottom–up climate-resilient agribusiness farmer field schools. Sustainability, 13(7): 3938.https://doi.org/10.3390/su13073938, Accessed on June 5, 2023.
[21]Palis, F.G., 2006, The role of culture in farmer learning and technology adoption: a case study of farmer field schools among rice farmers in central Luzon, Philippines. Agriculture and Human Values, 23: 491-500. https://link.springer.com/article/10.1007/s10460-006-9012-6, Accessed on April 20, 2023.
[22]Prasetyo, H., Karmiyati, D., Setyobudi, R. H., Fauzi, A., Trias, A. P., Susanti, M. S., ... Mel, M., 2022, Local Rice Farmers Attitude and Behavior towards Agricultural Programs and Policies. Pakistan Journal of Agricultural Research, 35(4): 663.https://www.proquest.com/openview/ef981c59a769a4378dbb7c560a9849e6/1?pq-origsite=gscholar&cbl=616518, Accessed on June 17, 2023.
[23]Red, F.S., Amestoso, N.T., Casinillo, L.F., 2021, Effect of Farmer Field School (FFS) on the Knowledge, Attitude, Practices and Profitability of Rice Farmers. Philippine Social Science Journal, 4(4): 145-154. https://doi.org/10.52006/main.v4i4.420, Accessed on May 28, 2022.
[24]Sanglestsawai, S., Rejesus, R.M., Yorobe Jr, J.M. 2015, Economic impacts of integrated pest management (IPM) farmer field schools (FFS): evidence from onion farmers in the Philippines. Agricultural Economics, 46(2): 149-162.https://doi.org/10.1111/agec.12147, Accessed on May, 5, 2023.
[25]Shang, L., Heckelei, T., Gerullis, M.K., Börner, J., Rasch, S., 2021, Adoption and diffusion of digital farming technologies-integrating farm-level evidence and system interaction. Agricultural systems, 190: 103074.https://doi.org/10.1016/j.agsy.2021.103074, Accessed on June 23, 2023.
[26]van den Berg, H., Ketelaar, J.W., Dicke, M., Fredrix, M., 2020, Is the farmer field school still relevant? Case studies from Malawi and Indonesia. NJAS: Wageningen Journal of Life Sciences, 92(1): 1-13.https://doi.org/10.1016/j.njas.2020.100329, Accessed on June 20, 2023.
[27]van den Berg, H., Phillips, S., Dicke, M., Fredrix, M., 2020, Impacts of farmer field schools in the human, social, natural and financial domain: a qualitative review. Food Security, 12(6): 1443-1459.https://link.springer.com/article/10.1007/s12571-020-01046-7
[28]van den Berg, H., Phillips, S., Poisot, A.S., Dicke, M., Fredrix, M., 2021, Leading issues in implementation of farmer field schools: a global survey. The Journal of Agricultural Education and Extension, 27(3): 341-353.https://doi.org/10.1080/1389224X.2020.1858891, Accessed on June 15, 2023.
[29]Yu, K., Lu, Z., Stander, J., 2003, Quantile regression: applications and current research areas. Journal of the Royal Statistical Society: Series D (The Statistician), 52(3): 331-350. https://doi.org/10.1111/1467-9884.00363, Accessed on June 12, 2023.

CONSUMER PERCEPTION ON THE LOCAL GASTRONOMICAL POINTS

Daniel Ioan CHICIUDEAN[1], Ioan Sebastian BRUMA[2], Lucian CUIBUS[1,3], Iulia Diana ARION[1], Gabriela Ofelia CHICIUDEAN[1]

[1]University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Manastur, 400372 Cluj-Napoca, Cluj, Romania, E-mails: daniel.chiciudean@usamvcluj.ro, lucian.cuibus@usamvcluj.ro, iulia.gliga@usamvcluj.ro, gabriela.chiciudean@usamvcluj.ro
[2]Academy of Romanian Scientists, Ilfov 3, 050044 Bucharest, Romania, E-mail: sebastianbruma1978@gmail.com
[3]Romanian Academy Cluj-Napoca Branch, 9, Republicii Street, Cluj-Napoca, 400489, Cluj, Romania, E-mail: lucian.cuibus@acad-cj.ro

Corresponding author: gabriela.chiciudean@usamvcluj.ro

Abstract

The paper aimed to present the consumer perception on the local gastronomical points given their novelty on the market and their huge importance for the rural development. A study was conducted among the population of Cluj County using an online questionnaire. Results indicate that the consumers are preoccupied to consume local food and drinks when they travel to rural destinations. There is a positive attitude towards the LGPs among the respondents which find very attractive all the LGPs characteristics meaning serving traditional meals made from local raw materials within the locals kitchens. For a traditional local menu with a limited assortment the consumers are willing to pay between 31-45 lei. The respondents consider that the LGPs are important within the rural areas and their creation represents an opportunity both for tourism development and for rural resident's incomes.

Key words**:** *local gastronomic point, local food, rural development, rural destinations*

INTRODUCTION

In the recent years, there has been observed a growing interest for shorting the food supply chains and mainly for local food products and kilometre 0 products [24, 25, 27] given the fact that the consumers are more preoccupied by the sustainable consumption, environment and animal welfare and well-being [2, 14, 30].
The local products do not have an official definition [18] even if there are some generally accepted variants such as the food that is produced, processed and sold within a geographical area of maximum 30 miles" [12] or the geographical area where the distribution chain is short between the producer and consumer [23] while in 2007 it officially appeared the term "Locavores" in the New Oxford American Dictionary describing those individuals that deliberately try or seek to eat only food grown or produced within a 100 miles radius [39]. Local products are considered to be ecologically-friendly local specialities made from native or local raw materials, processed with a technology specific for a certain region, by a small scale producer [17].
There are many reasons for which the consumers choose to eat local food, but health is the more frequent one mentioned by previous researches [20, 42]. A previous study conducted in Cluj County analyzed the consumer behaviour when choosing a restaurant and results indicated that health represented for most of the respondents the most important decisional factor [10]. Yurtseven and Kaya (2011) [42] identified that besides health, the local food is appreciated also by the quality of taste (including quality, freshness, healthy, clear, good taste), being able to offer to the consumers authentic experience. Their research mentioned also the rural development and learning knowledge as motivational factors [42]. Besides many reasons for local food consumption, Sthapit

and Piramanayagam (2023) [37] mentioned that local food itself became reason for traveling. Discovering new local flavours was the main reason for traveling for the tourists from Spain and the gastronomic experience influenced a lot the consumer satisfaction towards the destination, leading also to customer loyalty [7].

In this context, the local food obtained a crucial role within the promotion of local identity of any region [27] throughout the gastronomy as a factor of tourist attraction [13, 6, 32] being able to provide a large number of advantages for tourist destinations by creating added value and consequently increase the competitiveness of a certain region [16] consolidate and strengthening its image. Previous studies highlighted the strong relationship existing between local gastronomy and tourism [9, 15, 26, 31, 35, 43].

Supporting the rural tourism is one of the objectives of the Romanian National Strategy for Tourism Development (2019-2030) so, an important measure was adopted by creating in 2018 the Local Gastronomical Points (LGPs) that are family-type public catering units which offer to those who wish food products and dishes specific to the geographical areas of Romania under the conditions of compliance to hygiene rules and regulations [3]. What makes these LGPs unique is the fact that the menu is different from that of restaurants by being allowed to have a daily menu with a limited assortment (at most 2 types of soups or soups, 2 main courses and possibly 2 types of dessert), specific to the area in which it operates [3]. The LGPs can be perceived as important factors of sustainable rural development thorough a small-scale tourism [4], an important job creator, the most effective way to preserve the gastronomical traditions and a sustainable link between agriculture and tourism [38].

Given the novelty of the LGPs concept, the purpose of the paper is to identify the consumer's perception on this new type of food unit, in order to determine whether the creation of new LGPs represents a real opportunity for the rural residents.

MATERIALS AND METHODS

The present paper is part of a research conducted among the residents of Cluj County that travelled at least once to the rural areas of Apuseni Mountains. Data was collected using an online questionnaire between February 2022-May 2022. The questionnaire had three main parts: the first section comprised questions and statements regarding the consumer behavior of food during travels in general and the consumer behavior at the destinations from Apuseni Mountains, the second part referred to the attitudes and perceptions towards LGPs in general with the aim of identify the degree of knowledge referring to this new form of business and the opportunity to create new LGP in the Apuseni Mountains in particular; while the third part comprised the main socio-demographical questions.

Cluj County has a population of 679,141 residents of which 409,924 lives in urban areas and 269,217 residents live in rural areas [29]. The rural areas of Apuseni Mountains are very accessible in terms of distance for the Cluj County inhabitants that want to travel to the mountains.

The questions referring to the Local Gastronomic Points were designed based on the official definitions offered by the ANSVSA (2017) that characterizes them as "family-type public catering units, which offer food products and preparations specific to the geographical areas of Romania to those who wish, subject to compliance with hygiene rules and conditions, so that the food is safe and the health of consumers should not suffer" [3]. A total number of 410 questionnaires were collected and only 398 were valid and therefore, used for the analysis.

The convenience sample comprises mainly female respondents, so it is not gender balanced. So, even if the internet was used to overcome the recruitment barriers, other issues uncontrollable could appear [8] such as the unbalanced sample. Another observation was made by Smith (2008) [34] that there is a relationship between gender and the response rate in the online surveys, women contributing disproportionate to surveys. From the age point of view most of the respondents are youngsters aged between 18-29 years, followed by the respondents aged between 30-39 (25.9%). The respondents aged over 50 years represent the smallest group (Table 1).

Table 1. Socio-demographical characteristics of the respondents

Characteristics	Variables	Number of responses N=136	Percent of responses (%)
Gender	Male	81	20.4
	Female	317	79.6
Age	18-29	229	57.5
	30-39	103	25.9
	40-49	45	11.3
	50-59	14	3.5
	+60	7	1.8
Education level	Primary school	7	1.8
	Highscool	115	28.9
	Post high school	30	7.5
	Professional	8	2.0
	Faculty	140	35.2
	Post-graduate	98	24.6
Occupation	Student	104	26.1
	Employee	240	60.3
	Entrepreneur	29	7.3
	Household	15	3.8
	Retiree	3	0.8
	Unemployed	2	0.5
Monthly income	<1,200 lei	46	11.6
	1,201-2,000 lei	60	15.1
	2,001-3,000 lei	82	20.6
	3,001-4,000 lei	82	20.6
	>4,001 lei	128	32.2
Residence	Urban	240	60.3
	Rural	158	39.7
Family members	1 member	13	3.3
	2 members	47	11.8
	3 members	114	28.6
	4 members	148	37.2
	5 members	46	11.6
	More than 5	30	7.5

Source: own contribution.

With regards to education it can be stated that the sample is quite educated since 28.9% graduated high school and 59.9% graduated faculty and post-graduates. The main categories of respondents are the employees (60%) and students (26.1%). The monthly income is situated between 2,001-3,000 lei for 20.6% of the respondents, while most of them have a monthly more than 4,001 lei (32.2%).The respondents with an income less than 1,200 lei hold the smaller percentage of all the categories that is 11.6%. The residence is urban for most of the respondents (60.3%) while 39.7% live in rural areas. Most of the respondents have a family of four members (37.2%) followed by the respondents with three members (28.6%). The singles and the families with more than 5 members represent the smallest percentages (Table 1).

Data were analyzed using SPSS 19.0 (SPSS Inc., Chicago, IL, USA). Descriptive analysis and means were used in order to create the socio-demographical profile for the respondents and also to determine the respondents ‘perception on the LGP.

RESULTS AND DISCUSSIONS

Respondents' preference for consuming local food during travels

Results indicate that the respondents are very attracted to local foods and drinks during their travels, facts that reinforce previous studies which showed the close connection between travels and consuming local [11, 1, 21] as part of the tourist experience [22]. So, with regards to food, 44.7% of the respondents agree that when they travel they prefer the local food instead of the international food from the restaurants and 23.4% totally agree with the statement. Similar results were obtained by Sünnetçioğlu et al. (2020) [38] who observed that the tourists which visit Turkey prefer the local food. Orea-Giner and Fusté-Forné (2023) concluded that local food is preferred by tourists because it is considered tastier than other types of food [28]. It can be noticed the very low percent of 2.5% of the respondents that they totally disagree and 4.8% that disagree with the statement (Figure 1).

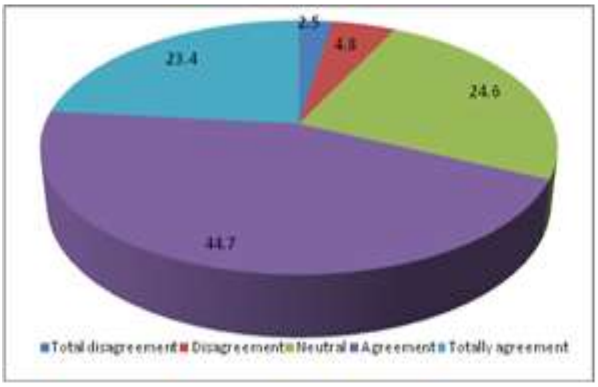

Fig. 1 When they travel, respondents prefer the local foods instead of the commercial ones
Source: own contribution.

When it comes to the type of drinks consumed during their travels, the respondents have quite the same position, meaning they prefer the local drinks instead the commercial ones, even if the percentage of the respondents that disagree with the statement is higher compared to the case of food, 7.3% totally disagree they prefer local drinks and 10.3% disagree (Figure 2). The same aspect was observed by Kline and Knollenberg (2018) [22], reporting that the tourist were divided into three types of clusters and all made special efforts at the destination to find local drinks. The same behavior, locally oriented when it comes to food and drinks at a tourist destination has been observed among both categories of travelers: youngsters [41] and also among senior travelers [5].

A special attention must be offered to the huge percentage of 35.9% of the respondents that declared themselves indifferent to the possibility to try local food or drinks. It is possible that this category not being so informed about what are the main characteristics of the local food and therefore. So, in order to attract them, special messages must be presented focusing on the local food advantages and characteristics, the health benefits and sustainable aspects.

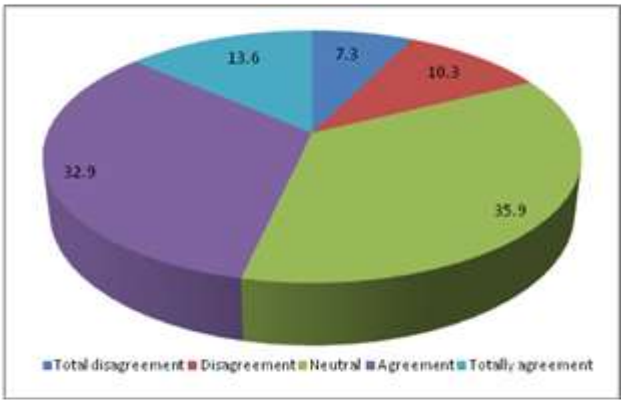

Fig. 2. When they travel, respondents prefer the local drinks instead of the commercial ones
Source: own contribution.

With regards to the sources of information that the respondents use when they intend to take lunch/dinner in a rural destination, the Internet is the most important one, 64.8% of the respondents declared that it represents the most credible source next to friends and family which represents an important source for 60.3%, while the locals are important only for 23.9% of the total sample. It can be observed that the indicatives at the destination and the points of touristic information are the least important sources of information (Figure 3).

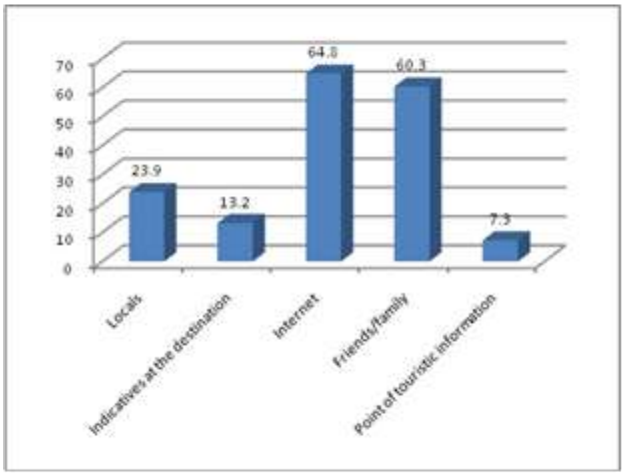

Fig. 3. Respondents' sources of information regarding the possibility to eat at the rural destination
Source: own contribution.

Respondents'' perception on the LGP's main characteristics

In order to determine whether the characteristics of the LGPs could attract tourists, the respondents were asked how attractive they consider each of the LGPs characteristic. The highest mean was obtained by the perspective of consuming dishes prepared according to traditional recipes (Mean=4.39; Std. dev=0.77) so it can be concluded that the respondents are very attracted to the traditional dishes when they choose to travel and the possibility to find a precise place when they can be sure that the food is specific for the area and also traditional, is quite attractive (Table 2). Also, attractive is considered by the respondents that the raw materials from which the dishes are prepared must come from the owners' household or from authorized/registered sanitary, veterinary and food safety units (Mean=4.35; Std. dev=0.88).

The third attractive characteristic of a LGP is the fact that the daily menu has a limited assortment (at most 2 soups, 2 main courses and possibly 2 desserts) (Mean=4.01; Std.dev=0.94). A possible explanation for the fact that this statement is considered attractive, but not as attractive as the first two statements might reside in the fact that some respondents could consider that a limited assortment could lead to situations when none of the dishes be eligible to be chosen.

The perspective to serve food in the private kitchens of rural families ((Mean=3.93; Std. dev=1.06)) and that the food to be prepared only by the PGL's owner or by its' family members (Mean=3.93; Std. dev=1.01) is almost attractive for the respondents, but not so attractive as the rest statements, being more indifferent to these aspects (Table 2).

Table 2. Means and standard deviations of characteristics referring to LGP

Characteristics of LGPs Items 1-Not attractive at all; 5-Very attractive	Mean	Std. deviation
Serving food in the private kitchens of rural families	3.93	1.06
Daily menu with a limited assortment (at most 2 soups, 2 main courses and possibly 2 desserts)	4.01	0.94
The dishes will be prepared according to traditional recipes	4.39	0.77
Food prepared only by the owner, or by family members.	3.93	1.01
The raw materials from which the dishes are prepared must come from the own household or from authorized/registered sanitary, veterinary and food safety units.	4.35	0.88

Source: own contribution.

Regarding the exact percentage of the respondents that find very attractive each of the LGP, it can be observed that the fact that the raw materials for the dishes must come from the owners' household or from authorized/registered sanitary, veterinary and food safety units is very attractive for most of the respondents (55.3%) followed by 53% of the respondents that consider the traditional recipes within the LGP very attractive.

The third most attractive aspect is the fact that the food must be prepared by the owner, a percentage of 34.4% of the respondents declared that this aspect is very attractive (Figure 4). All these findings are in line with the new trends regarding food and the consumer's preference for local dishes and traditional food especially when they travel [33].

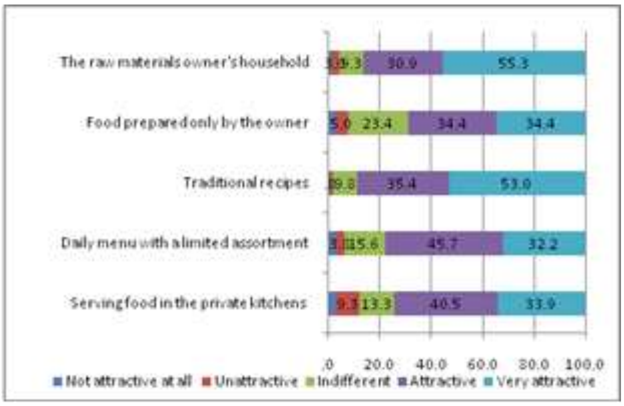

Fig. 4. Percentage in which the respondents consider attractive the LGPs' characteristics
Source: own contribution.

A correlation between the number of family members and the most sensitive characteristics of the LGP regarding serving the meals in the local's kitchen revealed that it is very attractive for 46% of the singles and also for large families with more than 5 members (47%) (Figure 5).

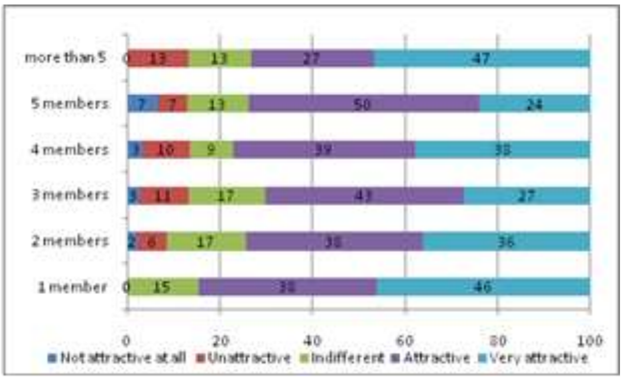

Fig. 5. Correlation between number of family members and the possibility to eat in the local's kitchens
Source: own contribution.

Respondents' preference for LGPs and the opportunity to create LGPs in the touristic rural areas

Most of the respondents totally agree (32.2%) that they would prefer to serve the food in a PGL instead of a restaurant when they travel to rural areas, while 45.2% agree with the statement.

The percentage of the indifferent respondents is quite low (18.1%) while the respondents that disagree summarize 4.5% (Figure 6).

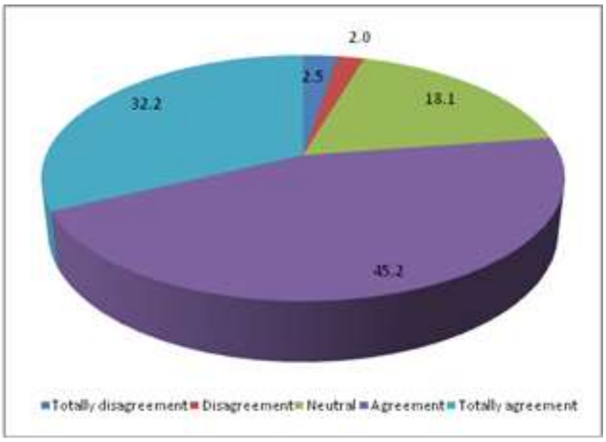

Fig. 6. Respondents would prefer to serve food in a PGL instead of a restaurant
Source: own contribution.

An important fact and very promising for the rural residents is the fact that the respondents consider that at least one LGP should exist in every touristic rural area. Only a small percentage of 1.8% of the respondents disagrees with the statement and 1.3% totally disagree (Figure 7).

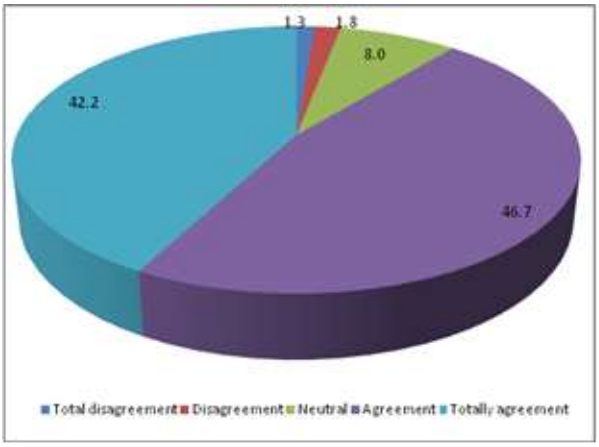

Fig. 7. LGPs should exist in every touristic rural area
Source: own contribution.

The amount of money that the respondents are willing to spend for a meal in a PGL is between 31-45 lei for the highest percentage of the respondents (37.2%) followed by 35.4% of the respondents that are willing to offer more, meaning 46-60 lei. Only 8.3% appreciate that such a menu worth 15-30 lei, while 19.1% would offer 61-80 lei (Figure 8).
Next, a correlation between the amount of money willing to spend for a menu in LGP and the respondents' income revealed as expected that as higher is the income the much money people are willing to spend.

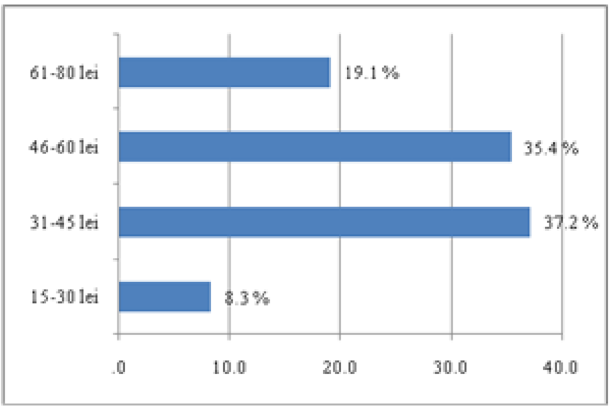

Fig. 8. Amount of money that respondents are willing to spend for a meal in a LGP
Source: own contribution.

A percentage of 33% of respondents with an income less than 1,200 lei are willing to pay maximum 30 lei for a menu and 35% maximum 45 lei, while the smallest percent of 7% are willing to pay 61-80 lei. Most of the respondents that are willing to pay more than 61 lei for a menu have an income over 4,000 lei. Only 2% of this category would pay less than 30 lei for such a menu (Figure 9).

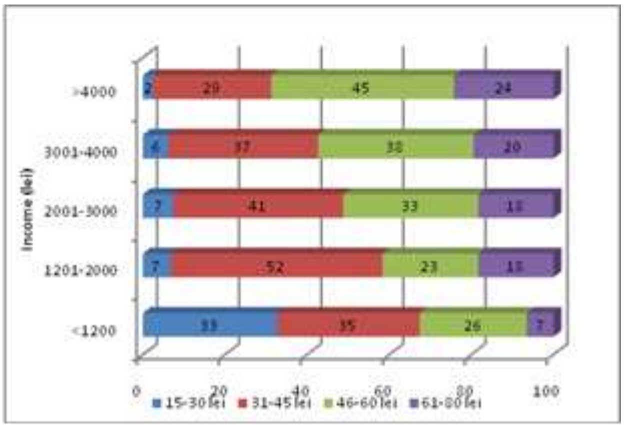

Fig. 9. Correlation between the amount of money willing to spend for a menu in LGP and income
Source: own contribution.

Consumer perception on the Local Gastronomic Points

Results indicate that the respondents generally have a positive attitude towards the LGP, an encouraging aspect for the rural residents that desire to become entrepreneurs within a small-scale business. The consumer preference for local food and drinks when they visit a tourist destination was observed by previous researches [28, 36] and confirmed by the present study. So, it is obvious how food and drinks can contribute to promote a tourist destination, by creating the "sense of place" [19] and determine the visitors to associate different types of dishes to the destination itself. It is an efficient way to create a gastronomical local culture with positive consequences for the local residents, by increasing their incomes and contribute to activities diversification.

The main characteristics of a LGP, a food unit very new on the Romanian market could have represented barriers for some tourists (e.g. serving food in the owners' kitchen, limited assortment), but the findings suggest quite the opposite. In fact the respondents find all these aspects very attractive and the explanation could be related to the fact that if they choose to visit rural areas, their profile is different to the standard tourists, by their desire to connect to the rural traditions including food and drinks. So the LGP represents a condensed symbol of the rural local cuisine from a certain area which the tourists are eager to try as part of their experience. Results indicate that most of the respondents are willing to pay between 31-45 lei for a complete menu offered by a LGP, an amount of money comparable to a common menu from a city restaurant. Besides the respondents' desire to consume local dishes when they travel to rural areas, the LGP respond to the necessity to increase the touristic infrastructure in the rural areas, where the possibilities for the tourists to serve lunch or dinner are very limited or even inexistent. So the respondents' opinion related to the LGP is that they should be encountered in every touristic rural area. First, the implementation of Local Gastronomic Points could have positive effects for many stakeholders: the tourists will have a safe place to serve local dishes, while the inhabitants of rural areas besides the supplementary incomes obtained will also have the opportunity to show to others their interest and skills in traditional cuisine, revealing to tourists the local specialties and therefore, increasing their self-esteem by becoming famous for their food and being associated to their geographical area. Secondly, the development of Local Gastronomic Points helps the horizontal development of the region where this activity will be carried out, by creating new jobs, by supporting small producers who will help supply the raw materials necessary for the preparation of traditional products and last but not least, it helps to develop national tourism and attract national and international tourists [40].

CONCLUSIONS

The most recent trends referring to consumer behavior indicate that the individuals are more and more attracted to consume local food and drinks especially when they choose to travel. So, the creation of the Local Gastronomic Points is perceived in a positive way because they offer the consumers the possibility to try local food made by the residents of the rural areas they are visiting making enriching their tourist experience. The Local Gastronomic Points truly represents an opportunity both for the rural areas in Romania, by giving the residents the possibility to obtain supplementary incomes, but also for the tourists which otherwise couldn't have the chance to try and taste local specialties. Besides that, the creation of the LGPs could have important consequences for the sustainable rural development contributing to an attractive image for any destination, the "sense of place" that can promote it both at a national and international level. Given the respondents' positive attitudes towards the LGPs, the rural inhabitants that have the conditions and the desire to create a LGP must take advantage of this opportunity in order to create a small business and most important, to find ways to be present it on the Internet since it became the most important source of information for the consumers.

REFERENCES

[1]Akyuz, B. G., 2019, Factors that influence local food consumption motivation and its effects on travel intentions. Psychology. Anatolia, 30(3), 358-367.
[2]Annunziata, A., Vecchio, R., 2013, Consumers' attitudes towards sustainable food: A cluster analysis of Italian university students. New Medit: Mediterranean

Journal of Economics, Agriculture and Environment= Revue Méditerranéenned′ Economie Agriculture et Environment, 12(2), 47.

[3]ANSVSA, 2017, http://www.ansvsa.ro/blog/campanie-de-informare-ansvsa-privind-punctele-gastronomice-locale/, Accessed on July 18, 2023.

[4]Badic, A. C., Ispas, A., 2021, Local Gastronomic Points-A Solution for the Development of Gastronomic Tourism. Case Study: Brașov County. Bulletin of the Transilvania University of Brasov. Series V: Economic Sciences, 39-50.

[5]Balderas-Cejudo, A., Patterson, I., Leeson, G. W., 2019, Senior Foodies: A developing niche market in gastronomic tourism. International Journal of Gastronomy and Food Science, 16, 100152.

[6]Beltrán, J.J., López-Guzmán, T., Santa-Cruz, F. G., 2016, Gastronomy and tourism: Profile and motivation of international tourism in the city of Córdoba, Spain. Journal of culinary Science & Technology, 14(4), 347-362.

[7]Berbel-Pineda, J. M., Palacios-Florencio, B., Ramírez-Hurtado, J. M., Santos-Roldán, L., 2019, Gastronomic experience as a factor of motivation in the tourist movements. International Journal of Gastronomy and Food Science, 18, 100171.

[8]Berry, K., Rana, R., Lockwood, A., Fletcher, L., Pratt, D., 2019, Factors associated with inattentive responding in online survey research. Personality and Individual Differences, 149, 157-159.

[9]Çalişkan, O., Yilmaz, G., 2016, Gastronomy and tourism. Global issues and trends in tourism, 33.

[10]Chiciudean, G. O., Harun, R., Muresan, I. C., Arion, F. H., Chiciudean, D. I., Ilies, G. L., &Dumitras, D. E., 2019, Assessing the importance of health in choosing a restaurant: An empirical study from Romania. International Journal of Environmental Research and Public Health, 16(12), 2224.

[11]Dedeoğlu, B. B., Çalışkan, C., Sabbağ, Ç., 2021, Local food consumption during travel: Interaction of ıncentive-disincentive factors, togetherness, and hedonic value. International Journal of Tourism Research, 23(2), 206-219.

[12]DEFRA (Department for Environment, Food and Rural Affairs). 2023, Local Food—A Snapshot of the Sector. Report of the Working Group on Local Food; DEFRA: London, UK.

[13]Dixit, S. K., 2021, Gastronomic tourism. The Routledge handbook of gastronomic tourism, 13-23.

[14]El Bilali, H., Strassner, C., Hassen, T., 2021, Sustainable agri-food systems: environment, economy, society, and policy. Sustainability, 13(11), 6260.

[15]Fields, K., 2002, Demand for the gastronomy tourism product: motivational factors. Tourism and gastronomy, 4(2), 36-50.

[16]Gálvez, J. C. P., Granda, M. J., López-Guzmán, T., Coronel, J. R., 2017, Local gastronomy, culture and tourism sustainable cities: The behavior of the American tourist. Sustainable Cities and Society, 32, 604-612.

[17]Gonda, T., Angler, K., 2021, The role of local products in tourism. European countryside, 13(1), 91-107.

[18]Granvik, M., Joosse, S., Hunt, A., Hallberg, I., 2017, Confusion and misunderstanding—interpretations and definitions of local food. Sustainability, 9(11), 1981.

[19]Haven-Tang, C., Jones, E., 2005, Using local food and drink to differentiate tourism destinations through a sense of place: A story from Wales-dining at Monmouthshire's great table. Journal of Culinary Science & Technology, 4(4), 69-86.

[20]Kim, Y. G., Eves, A., 2016, Measurement equivalence of an instrument measuring motivation to consume local food: A cross-cultural examination across British and Korean. Journal of Hospitality & Tourism Research, 40(5), 634-652

[21]Kim, Y. G., Eves, A., Scarles, C., 2009, Building a model of local food consumption on trips and holidays: A grounded theory approach. International journal of hospitality management, 28(3), 423-431.

[22]Kline, C., Lee, S. J., Knollenberg, W., 2018, Segmenting foodies for a foodie destination. Journal of Travel & Tourism Marketing, 35(9), 1234-1245.

[23]Kneafsey, M., Venn, L., Schmutz, U., Balázs, B., Trenchard, L., Eyden-Wood, T., Blackett, M., 2013, Short food supply chains and local food systems in the EU. A state of play of their socio-economic characteristics. JRC scientific and policy reports, 123, 129.

[24]Kovács, I., Balázsné Lendvai, M., Beke, J., 2022, The importance of food attributes and motivational factors for purchasing local food products: Segmentation of young local food consumers in Hungary. Sustainability, 14(6), 3224.

[25]Kusz, B., Kilar, J., 2020, Consumers' preferences for places to purchase local dairy products. Agrolife Scientific Journal, 9(1), 198-204.

[26]Nesterchuk, I., Balabanyts, A., Pivnova, L., Matsuka, V., Skarha, O., Kondratenko, I., 2021, Gastronomic tourism, Linguistics and Culture Review, 5(S4), 1877.

[27]Noguer-Junca, E., Crespi-Vallbona, M., Fusté-Forné, F., 2021, Sociocultural and gastronomic revaluation of local products: trumfa in the Vall de Camprodon (Catalonia, Spain). International Journal of Gastronomy and Food Science, 26, 100425.

[28]Orea-Giner, A., Fusté-Forné, F., 2023, The way we live, the way we travel: Generation Z and sustainable consumption in food tourism experiences. British Food Journal, 125(13), 330-351.

[29]Population and dwellings census (Recensamantul populatiei si locuintelor), 2021, https://www.recensamantromania.ro/, Accessed on July 10, 2023.

[30]Puntiroli, M., L.S., Bezençon, V., 2022, Are consumers consistent in their sustainable behaviours? A longitudinal study on consistency and spillover, Journal of Business Research, 144, 2022, 322-335.

[31]Richards, G., 2014, The role of gastronomy in tourism development. Presentation to the Fourth International Congress on Noble Houses: A Heritage for the Future, Arcos de Valdevez to be held on, 27-29.
[32]Seyitoğlu, F., Ivanov, S., 2020, A conceptual study of the strategic role of gastronomy in tourism destinations. International Journal of Gastronomy and Food Science, 21, 100230.
[33]Skallerud, K., Wien, A. H., 2019, Preference for local food as a matter of helping behaviour: Insights from Norway. Journal of Rural Studies, 67, 79-88.
[34]Smith, W. G., 2008, Does gender influence online survey participation? A record-linkage analysis of university faculty online survey response behavior. Online submission.
[35]Sormaz, U., Akmese, H., Gunes, E., Aras, S., 2016, Gastronomy in tourism, Procedia Economics and Finance, 39.
[36]Stanciu, M., Popescu, A., Stanciu, C., Popa, S., 2022, Local Gastronomic Points as Part of Sustainable Agritourism and Young People's Perception on It. Case Study, Sibiu County, Romania. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22, 697-705.
[37]Sthapit, E., Björk, P., Piramanayagam, S., 2023, Domestic tourists and local food consumption: motivations, positive emotions and savouring processes. Annals of leisure research, 26(2), 316-33
[38]Sünnetçioğlu, A., Çakici, A. C., Erdem, S. H., 2020, The effect of travel lifestyle, cultural sensitivity and food neophobia on local food preference. Journal of Tourism & Gastronomy Studies, 8(2), 746-761.
[39]Thilmany, D., Bond, C. A., Bond, J. K., 2008, Going local: Exploring consumer behavior and motivations for direct food purchases. American Journal of Agricultural Economics, 90(5), 1303-1309.
[40]Toader, C. S., Feher, A. A., Orboi, M. D., Crainic, D., Pirvulescu, L., 2022, Local gastronomic business-premise for the development of Romanian gastronomic tourism. Review on Agriculture and Rural Development, 11(1-2), 133-138.
[41]Yousaf, A., Amin, I., C Santos, J. A., 2018, Tourist's motivations to travel: A theoretical perspective on the existing literature. Tourism and hospitality management, 24(1), 197-211.
[42]Yurtseven, R., & Kaya, O. (2011). Local food in local menus: The case of Gokceada. Tourismos, *6*(2), 263-275
[43]Zečević-Stanojević, O., Vujko, A., Zečević L., 2021, The role and significance of gastronomic tourism for rural areas of the municipality of Apatin, Ekonomika poljoprivrede, 68(4) DOI: 10.5937/ekopolj2104043z.

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CROP PRODUCTION SUBSIDIZED RISKS INSURANCE FOR ENHANCING AGRICULTURAL RESILIENCE AND CLIMATE CHANGE MITIGATION IN MOLDOVA

Liliana CIMPOIEȘ, Maria GRUBLEAC

Academy of Economic Studies of Moldova, 61, Mitropolit Gavriil Banulescu-Bodoni Street, Chisinau, Moldova, E-mails: lcimpoies@ase.md, grubleac.maria@ase.md

Corresponding author: lcimpoies@ase.md

Abstract

The agricultural sector in Moldova is highly exposed to natural factors and hazards, resulting in uncertain incomes and high production volatility. Crop insurance plans against different risks plays a crucial role in supporting farmers' yield and revenues. The aim of this paper is to assess the development of subsidizing production risk insurance policy as a method to enhance agricultural resilience and alleviate the effects of climate change in Moldova. The analyzed data is based on the analysis of regulatory documents for policies regarding subsidizing productions risks insurance. For data analysis, secondary data provided by the National Bureau of Statistics (NBS), and Agency of Interventions and Payments in Agriculture (AIPA) was used. The data refer to the amount of subsidies applications for risks insurance, insured areas cultivated with different crops and its harvests, main risks insured by farmers, distribution of subsidies for risks insurance by development regions and the insurance companies. The subsidization of crop production risk insurance in Moldova has played a vital role in bolstering agricultural resilience and minimizing the adverse effects of climate change. By offering assistance to farmers and promoting the implementation of risk management practices, the government's objective is to stabilize income levels and promote sustainable growth in the agricultural sector. Nevertheless, it is crucial to continuously monitor and evaluate these policies to ensure their efficacy and fair distribution of subsidies across various regions and insurance providers.

Key words: *agriculture, crop production, farmers, risk insurance, subsidies*

INTRODUCTION

The agricultural sector has consistently been associated with uncertainty and risk, primarily due to its vulnerability to natural factors and various hazards.Thus, farmers' incomes are uncertain and the agricultural production presents high volatility. Climate change is causing growing uncertainty in the agricultural sector, especially in crop production, leading to concerns about agri-food production, market stability, and food security. Consequently, farmers and researchers are actively seeking innovative solutions to counter the adverse impacts of climate change and adopt cost-effective measures to enhance production efficiency [15, 16].

An important tool to support the farmers agricultural yield/revenues are crop insurance plans. Incomes related to agricultural activities are more variable than non-agricultural incomes [11]. Main economic risk for agricultural producers is related to the variation in earnings, thus insurance must be regarded as risk management strategy that allows to stabilize income and consumption for farmers [12]. Crop insurance payments has as main objective to reduce the risk by allocating payments when farmers need additional support and to reduce the negatives outcomes that they can experience under certain circumstances [19].

The U.S. federal crop insurance program is renowned for being the most substantial subsidized agricultural insurance initiative globally and is currently the most expensive agricultural policy tool in the United States [17].

The government determines the specifics of crop insurance contracts provided to farmers, establishes the premiums that they must pay for their policies, subsidizes the expenses associated with premiums and program administration, and serves as a reinsurer for crop insurance agencies that offer these contracts [19].

These programs are aimed to reduce the risks of farmers related to undesired events as drought, insect infection, lightning, wind, excessive moisture etc. According to Shaik [18], when the risk is lower, farmers are more positively regarding the implementation of innovative technology and efficiency enhancing production practices. As crop insurance is related to a high degree of risk, it may result that private insurance is costly and not available to farmers without governmental support program [4].

According to Quiggin [14], crop insurance implies certain features that causes problems, particularly for multi-peril crop insurance. This is mostly related to the absence of pooling, moral hazard and adverse selection and imperfect indemnity. Adverse selection is the most mentioned problem [2, 10, 5]. It is mainly caused by the fact that risk vary across farmers and they have more knowledge about the risks they face than the insurer.

Governmental support is needed to achieve and maintain the farm economic performance, which is on the long run is the key to its sustainable development. The governmental intervention into the crop insurance programs was highly discussed explaining/justifying such an involvement. This is caused by some forms of market failure, when private markets are not able to function to supply efficiently crop insurance [4]. The crop insurance market in the United States exhibits significant diversity, encompassing various types of insurance coverage. This diversity ranges from single-peril insurance to multi-peril insurance and index insurance. Furthermore, within the realm of multi-peril insurance, there are distinct insurance plans designed to address either crop yield or revenue protection. The index insurance is related to other types as: area insurance plans, weather event insurance or group plans [19].

The demand for crop revenue insurance is significant due to the tendency that farmers are encouraged to depend more on insurance than direct subsidies. One of the most used types of insurances for U.S. farmers is the revenue insurance plan. It allows farmers to receive a minimum level of revenues. Revenue insurance contracts covers from 50 to 75% against yield losses due to natural causes or against a change in harvest price. According to Goodwin [5] "yields and prices are likely to be negatively correlated since low yields are typically accompanied by high prices".

In Europe, both single and multiple peril insurance policies are available, with single peril insurance widely accessible in most member states [17]. Crop insurance, offered through private and public-private arrangements, aims to protect against climatic risks. Single-peril insurance, particularly for hail protection, is more prevalent than multi-peril risk insurance, which provides comprehensive coverage for various weather events. The public sector plays a significant role in supporting agricultural insurance due to challenges faced by private schemes, with national or Common Agricultural Policy (CAP) subsidies helping farmers afford insurance premiums.

In 2023 the European Commission has approved a €1.3 billion Polish scheme under EU State aid rules. This scheme supports agricultural producers by subsidizing insurance premiums for certain vegetable products and livestock species to protect against damage risks. The measure aligns with the objectives of the Common Agricultural Policy by ensuring stable incomes for agricultural producers. The Commission found that the scheme is necessary to address market failures, as high insurance prices would deter producers from purchasing insurance without subsidies. Additionally, a State reinsurance mechanism for drought risk is necessary as insurance companies would be reluctant to cover such risks. The measure is considered proportionate, with its positive effects outweighing any potential competition and trade distortion within the EU [3].

The primary objective of agricultural producers is to achieve profitability. From this standpoint, their top priority lies in the insurance mechanism that aims to minimize the likelihood of income decline or productivity loss due to natural risks [8].

It is believed that there is a positive impact between the insurance demand and improvement of farm economic performance. Insurance has positive impact on farm incomes and thus it affects its performance and sustainable development on the long run. It also allows the farmers to avoid certain risks that would turn their activity non efficient.

The purpose of this research is to examine the evolution of the policy of subsidizing risk insurance as a means to enhance agricultural resilience and alleviate the impact of climate change in Moldova.

MATERIALS AND METHODS

The objective of this research is to assess the progression of the policy on subsidizing production risk insurance as a method to enhance agricultural resilience and alleviate the effects of climate change in Moldova. The analyzed data is based on the analysisof regulatory documents for policies regarding subsidizing productions risks insurance. For data analysis, secondary data provided by the National Bureau of Statistics (NBS), and Agency of Interventions and Payments in Agriculture (AIPA) was used. The data refer to the amount of subsidies applications for risks insurance, insured areas cultivated with different crops and its harvests, main risks insured by farmers, distribution of subsidies for risks insurance by development regions and the insurance companies.

RESULTS AND DISCUSSIONS

In Moldova, the agricultural sector experienced various fluctuations within the last decades. With a decreasing share in GDP (9.8%), it continues to contribute to about half of Moldova's exports and employs a third of labor force. However, the Gross Agricultural Output (GAO), increased to 40,617 million MDL in 2022, experiencing fluctuations in the last years. About 70 percent belongs to crop production (Figure 1).

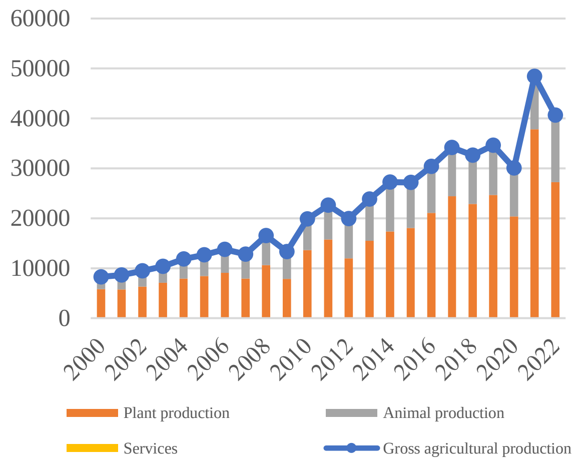

Fig. 1. Dynamics of gross agricultural output, million MDL

Source: based on data from National Bureau of Statistics [13].

Agricultural sector, particularly crop production is very sensitive to climate change. Droughts or spring and fall freeze can affect dramatically farmers harvests. The obvious decrease in GAO by 20 percent was in 2009, when one the most severe drought was recorded and caused damages of over one billion US dollars, affecting 78 percent of agricultural land. Another large drop in GAO was registered in 2020 with a decrease 26 percent of agricultural output due to severe drought caused by global warming. The adverse risks in the agricultural sector put in danger agricultural output, food security and employment.

Climate instability is one of the main causes of unstable harvests and it is a risk, particularly to crop production. The significant decrease in harvests reduces the economic efficiency and endangers the country's food security.

In Moldova, agricultural risks insurance started to be implemented with the approval of Law no. 243 from 2004 regarding subsidizing risks insurance in agriculture [9]. According to it, farmers that buy an insurance for agricultural production risks from insurance company can benefit from a subsidy between 50 and 60 percent of the paid insurance premium. Subsidizing production risks insurance in agriculture is one the subsidized measures available to farmers since 2005 when the Government approved the Regulation on subsidizing production risks insurance in agriculture [7]. The Regulation aims at compensating farmers expenses for insured crop harvests and livestock [7]. Under this regulation, farmers can avail subsidies when they enter into an insurance agreement. The subsidy is provided for the portion of the insurance premium that remains after the farmer pays their share of the premium. Moreover, the subsidy is determined based on specific criteria, including the list of insurable risks and the list of eligible agricultural crops and animal species. The subsidies are sourced from the National Fund for the Development of Agriculture and Rural Environment.

The government can offer additional support to farmers to overcome the negative consequences of adverse weather phenomena as in 2012, when by government decision was approved the Regulation no 766 to allocate financial support to overcome drought consequences in 2012 [20].

The number of payments recipients for subsidizing production risks insurance measure increased in the last years (Table 1).

Table 1. Dynamics of subsidies applications for risk insurance

Year	Subsidy applications	Approved applications	Share, %	Amount requested, thousands MDL	Amount allocated, thousands MDL	Share, %
2013	81	78	96.3	41,440.6	41,288.2	99.6
2014	122	66	54	34,487.5	22,760.5	65.9
2015	137	128	93.4	31,225	30,858	98.8
2016	118	87	73.7	11,023.6	8,875.8	80.5
2017	83	80	96.3	4,532.9	4,474.9	98.7
2018	122	119	97.5	7,533.6	7,409.5	98.3
2019	84	79	94	5,640.6	5,438.7	96.4
2020	82	81	98.8	7,640.1	7,522.4	98.4
2021	463	420	90.7	47,410.2	41,673.9	87.9
2022	527	495	93.9	65,988.7	60,873.2	92.2

Source: based on data from Agency of Interventions and Payments in Agriculture [1].

Between 2013 and 2022, over 90 percent of the applications were approved, as indicated in Table 1. The maximum subsidy amount is determined based on the insurance premiums calculated according to the rates specified in the special conditions for insuring production risks in agriculture.

During the period of 2019-2020, there was a noticeable decline in the number of farmers opting for agricultural insurance to protect against risks. This decrease can be attributed to a broader issue concerning how farmers handle their agricultural operations and the way they perceive and manage risks through insurance. Consequently, this decline has resulted in lower insurance rates within the sector and unrealistic expectations of government intervention in mitigating these risks. Additionally, the area covered by insurance policies also experienced a reduction during this same period (Figure 2).

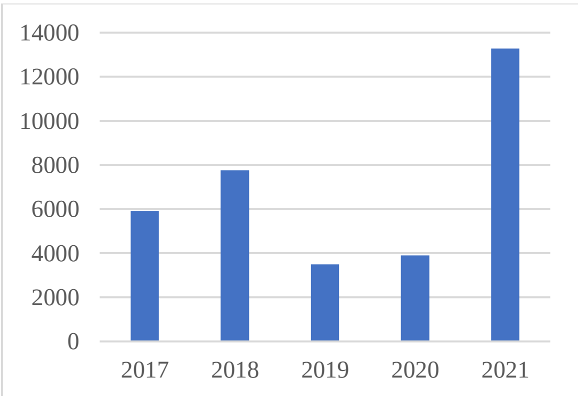

Fig. 2. Dynamics of cultivated areas under subsidizing production risks insurance
Source: based on data from Agency of Interventions and Payments in Agriculture [1].

Starting from 2021, the government provides financial coverage for up to 70 percent of the insurance premium paid to insurance companies for the assumed insurances through the National Fund for the Development of Agriculture and Rural Environment. In the same year, there was a significant increase in requests for financial support for stimulating the production risk insurance mechanism in agriculture. Insurance companies submitted 463 requests, representing a 5.6-fold rise compared to the number of requests received in 2020. Additionally, the total subsidy amount requested by insurance companies surged by approximately 8 times, reaching 47.4 million MDL, as shown in Table 1.

In 2022, the number of payments applications reached 527, with about ten percent more that the level in 2021. Also, the financial allocations increased in 2022 with 46 percent comparing its level in 2021 (60,872.2 thousand MDL). Nevertheless, the Agency of Interventions and Payments in Agriculture could not allocate 10.7 million MDL to farmers in 2022 due to lack of funds, which remains to be allocated in 2023 (Table 1). The similar increase in observed in the area of agricultural land insured which in 2021 reached 13,287.6 hectares (Figure 2).

From the insured production risks areas, over half of it belongs to wheat and barley. In 2021, about 110 hectares of sugar beet, 3,749.9 hectares of sunflower, 3,348 hectares of maize, 2,930.8 hectares of wheat, 49,3 hectares of barley, 2,380.6 hectares of perennial plantations, 276 hectares of soybean were insured (Table 2).

Table 2. Structure of crop production areas under subsidizing risks production insurance

	2017		2018		2019		2020		2021	
	Area, ha	Share, %	Area, ha	Share, %	Area, ha	Share, %	Area, ha	Share, %	Area, ha	Share, %
Sugar beet	264	4.47	130	1.68	229	6.56	80	2.05	110	0.83
Sunflower	425	7.19	731.3	9.43	213	6.10	1,179.0	30.20	3,749.8	28.22
Maize	81.5	1.38	246	3.17	110	3.15	1,669.9	42.78	3,348.0	25.20
Wheat	2,924.0	49.47	2,627.0	33.89	1,886.6	54.04	244	6.25	2,930.8	22.06
Barley	951	16.09	2,753.0	35.51	495.2	14.19	0	0	493	3.71
Perennial plantations	1,081.0	18.29	1,248.7	16.11	524.1	15.0	726	18.60	2,380.6	17.92
Soybean	160	2.71	0	0	0	0	0	0	276	2.08
Vegetables and tobacco	24	0.41	16,2	0.21	15	0.43	5	0.13	0	0.00

Source: based on data from Agency of Interventions and Payments in Agriculture [1].

Analyzing the data related to areas insured by different crops, it is obvious that after 2020 there is a change in structure of areas. Until 2020, more than half of insured area was cultivated under wheat and barley. A smaller share was maintain by sugar beet, sunflower and perennial plantations. Since 2020, area under sunflower and maize has over half of total areas subsidized under production risks insurance (Table 2).

Table 3. Main crop production insured risks in 2022

Type of risk	Area, ha	Paid insured contribution, thousands MDL	Subsidy, thousandth MDL	Amount of compensation received, thousandth MDL
Storms	84.2	60.5	0	0
Hail	2,806.4	3,071.3	3,346.6	212.5
Hail, Spring frost	1,220.2	6,279.1	3,483.4	0
Hail, Spring frost, Heavy rain	575	2,933.9	3,636.1	0
Hail, Heavy rain, Excessive drought	3,255.0	4,063.9	0	0
Hail, Excessive drought	100	53.5	0	0
Hail+Spring frost	395.6	1,657.9	3,868.4	12,174.5
Fire	198	3.2	7.4	-
Spring frost	234.7	607.3	543.6	2,125.7
Drought+Hail	6,283.7	3,649.1	8,514.4	2,163.6

Source: based on data from Agency of Interventions and Payments in Agriculture.

From the insured risks in 2022, crops were insured against one or several adverse risks as: storms, hail, spring frost, torrential rains, excessive drought, fire (Table 3).

Analyzing the types of agricultural insured risks in 2022, the largest insured area was against the risk of drought and hail - 41 percent, hail, heavy rain and excessive drought - 21 percent, followed by insurance against hail and spring frost – 8 percent.

However, the paid insured contribution is for risks against hail and spring frost – 28 percent, hail heavy rain and excessive drought – 18 percent, drought and hail – 16 percent (Table 3).

From the subsidized insured agricultural risks received in 2022, over half belongs to insured risks against drought and hail (36%) and hail and spring frost (50%). From paid compensations, 58 percents were for risks against drought and hail.

Largest insured area are in the Southern region, while the highest subsidy and compensation paid were for farmers located in the Southern region (Table 4).

Table 4. Distribution of insured risks for crop production by development regions, 2022

Region	Area, ha	insurance premium, thousands MDL		Amount of compensation paid
		Insured contribution	Subsidy	
North	4,747.65	8,082.4	3,853.7	842.7
Center	3,492.9	5,358.5	7,018.1	21,185.1
South	5,788.2	5,990.8	6,332.4	0
UTA Gagauzia	1,114.3	433.7	1,012.1	0

Source: based on data from Agency of Interventions and Payments in Agriculture [1].

Analyzing the distribution of insured risks by development regions, the largest insured area is for agricultural producers located in the Northern and Southern region, which account together 70 percent of total insured area (Table 4).

The insured contribution from the insurance premium also have the largest share for Northern and Southern region (70 percent), followed by Center region with a share of 38 percent.

However from compensations had benefit only mostly farmers from Center region (96%), while farmers from Southern region or UTA Gagauzia had not benefit at all.

According to the regulation regarding subsidizing risks production insurance in agriculture [8], the annual amount of subsidies allocated by government is set yearly based on agricultural goods and risks eligible under this measure.

The Ministry of Agriculture and Food Industry, yearly proposes the list of crops and animals for subsidized insurance, the risks and financial amount proposed for the next year. The insurance company that is eligible to provide production risks insurance in agriculture will receive from farmers the insurance premium (difference between the insurance premium and the subsidy), and the subsidy which is transferred from the Agency of Intervention and Payment in Agriculture after all required documents verification and validation.

The insurance companies that were providing production risk insurances in agriculture received from AIPA 29302150 MDL in 2022, with 40 percent less than in 2021 (Table 5).

Between 2020-2022, only four insurance companies received subsidies for risk insurance. Moreover, only “General Asigurari” SA and “SA Intact Asigurari Generale” companies received together over 80 percent of total subsidies during 2019-2022 (Table 5).

A similar trend in the whole analyzed period is observed where, mostly two insurance companies concentrate the majority of insurance subsidies allocations.

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Table 5. Amount of subsidies allocated for risk insurance to insurance companies

Insurance company	Amount of authorized subsidy, thousands MDL									
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CA Asterra Grup SA		306.9	3,965.7	9,867.4	319.9	747.2	357.9	400.8	2,785.2	1,697.1
CA General Asigurari SA					407.8	2,477.7	1,927.3	2,679.1	17,652.1	20,744.1
CA Moldasig SA	3,218.4		13,933.1	216.5	211.7	685.7	160.3	269.5	1,974.6	3,043.8
SA Intact Asigurari Generale				4,724.5	632.4	563.8	2,245.5	4,173.1	24,047.8	3,507.9
CA Garantie SA	3,789.5	2,243.1	1,519.7	732.5	413.9	234.5	341.5		0	309.3
Moldcargo	5,043.6	4,887.6	1,679.1	7,375.4	58.6					
Klassika Asigurari	270.8	196.8	1,109.9	15,558.3	1,975.4	2,664.4				
CA Acord Grup SA		146.2	1,674.4	124.5			106.3			
Galas		146.1								
CA Alliance Insurance Grup SA			7,085.5	4,986.5						

Source: based on data from Agency of Interventions and Payments in Agriculture [1].

CONCLUSIONS

The agricultural sector in Moldova is highly exposed to natural factors and hazards, resulting in uncertain incomes and high production volatility. Crop insurance plans play a crucial role in supporting farmers' agricultural yield and revenues. By providing risk management strategies, crop insurance helps stabilize farmers' income and consumption, allowing them to cope with adverse events such as droughts, pests, and extreme weather conditions, which are exacerbated by climate change.

Crop insurance programs are essential components of agricultural policies, especially in the case of Moldova, where climate instability poses significant risks to crop production. Due to market failures and the high degree of risk involved, private insurance can be costly and not readily available to farmers without government support. Thus, the Moldovan government intervenes by subsidizing crop production risks insurance to enhance the resilience of the agricultural sector and mitigate the impact of climate change.

The number of subsidies applications for risk insurance has been increasing in recent years, indicating a growing awareness among farmers about the importance of crop insurance. The insured area has also seen fluctuations, with sunflower and maize becoming dominant crops insured against risks since 2020.

The main insured risks in 2022 were related to hail, spring frost, heavy rain, drought, and storms. Southern and Northern regions had the largest insured areas, with Center region dominating in terms of paid compensations.

Over the years, a few major insurance companies have received the majority of subsidies, concentrating the market for crop insurance.

Subsidizing crop production risks insurance in Moldova has been a crucial tool in enhancing agricultural resilience and mitigating the impacts of climate change. By providing support to farmers and encouraging the adoption of risk management strategies, the government aims to stabilize income and foster sustainable development in the agricultural sector. However, continuous monitoring and evaluation of these policies are essential to ensure their effectiveness and equitable distribution of subsidies across different regions and insurance providers.

REFERENCES

[1]Agency of Intervention and Payments in Agriculture, https://aipa.gov.md/en/press-releases, Accessed on July 20, 2023.
[2]Chambers, R. G., 1989, Insurability and Moral Hazard in Agricultural Insurance Markets. American Journal of Agricultural Economics, 71(3), 604–616. https://doi.org/10.2307/1242016
[3]European Commission, 2023, https://ec.europa.eu/commission/presscorner/detail/en/ip_23_2727, Accessed on June20, 2023
[4]Goodwin, B. K., 2001, Problems with Market Insurance in Agriculture. American Journal of Agricultural Economics, 83(3), 643–649. http://www.jstor.org/stable/1245093, Accessed on July20, 2023.
[5]Goodwin, B.K., 2015, Challenges in the design of crop revenue insurance, Agricultural Finance Review, Vol. 75 (1), 19-30. https://doi.org/10.1108/AFR-03-2015-0015, Accessed on July 20, 2023.
[6]Dragos, C.M., Dragos, S.L., Mare, C., Muresan, G.M., Purcel, A.A., 2023, Does risk assessment and specific knowledge impact crop insurance underwriting? Evidence from Romanian farmers, Economic Analysis and Policy,Volume 79:343-358, https://www.sciencedirect.com/science/article/pii/S0313592623001376, Accessed on July25, 2023.
[7] Government Decision No. 217 din 24.02.2005 for approval of Regulation regarding subsidizing production risks insurance in agriculture https://www.legis.md/cautare/getResults?doc_id=128698&lang=ro, Accessed on July20, 2023.
[8]Huseynov, M., Salahov, E., Jafarov, J., 2022, Current Situation, Problems And Diversification Of Insurance Model In The Sphere Of Crop Production In Azerbaijan. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22 (3):299-312, https://managementjournal.usamv.ro/index.php/scientific-papers/95-vol-22-issue-3/2949-current-situation-problems-and-diversification-of-insurance-model-in-the-sphere-of-crop-production-in-azerbaijan, Accessed on July20, 2023.
[9]Law No. 243 from 08-07-2004 regarding subsidizing production risks insurance in agriculture https://www.legis.md/cautare/getResults?doc_id=107559&lang=ro, Accessed on July20, 2023.
[10]Miranda, M. J., 1991, Area-Yield Crop Insurance Reconsidered. American Journal of Agricultural Economics, 73(2), 233–242. https://doi.org/10.2307/1242708, Accessed on July20, 2023.
[11]Mishra, A.K., El-Osta, H.S., 2002, Managing risk in agriculture through hedging and crop insurance: what does a national survey reveal?, Agricultural Finance Review, Vol. 62(2), 135-148. https://doi.org/10.1108/00214930280001134, Accessed on July20, 2023.
[12]Mishra, A.K., Goodwin, B.K., 2006, Revenue insurance purchase decisions of farmers, Applied Economics, 38(2),149-159, DOI: 10.1080/00036840500367724, Accessed on July20, 2023.
[13]National Bureau of Statistics of the Republic of Moldova, https://statistica.gov.md/en, Accessed on July20, 2023.
[14]Quiggin, J., 1994, The Optimal Design of Crop Insurance. In: Hueth, D.L., Furtan, W.H. (eds) Economics of Agricultural Crop Insurance: Theory and Evidence. Natural Resource Management and Policy, Vol 4. Springer, Dordrecht. https://doi.org/10.1007/978-94-011-1386-1_5, Accessed on July20, 2023.
[15]Popescu, A., Tindeche, C., Marcuta, A., Marcuta, L., Hontus, A., 2022, Cereals production between climate change and price boom in Romania. Scientific Papers Series Management, Economic Engineering in Agriculture and rural development, Vol. 22(4), 579-594,https://managementjournal.usamv.ro/index.php/scientific-papers/96-vol-22-issue-4/3071-cereals-production-between-climate-change-and-price-boom-in-romania, Accessed on July 20, 2023.
[16]Popescu, A., Dinu, T.A., Stoian, E., Serban, V., 2023, Climate change and its impact on wheat, maize and sunflower yield in Romania in the period 2017-2021. Scientific Papers Series Management, Economic Engineering in Agriculture and rural development, Vol. 23(1), 587-602, https://managementjournal.usamv.ro/index.php/scientific-papers/96-vol-22-issue-4/3238-climate-change-and-its-impact-on-wheat-maize-and-sunflower-yield-in-romania-in-the-period-2017-2021, Accessed on July 20, 2023.
[17]Ramsey, A.F., Santeramo, F.G., 2017, Crop Insurance in the European Union: Lessons and Caution from the United States. Forthcoming in: EuroChoiceshttps://mpra.ub.uni-muenchen.de/79164/, Accessed on July15, 2023.
[18]Shaik, S., Coble, K., Knight, T., Baquet, A., Patrick, G., 2008, Crop Revenue and Yield Insurance Demand: A Subjective Probability Approach. Journal of Agricultural and Applied Economics,40(3), 757-766. doi:10.1017/S1074070800002303, Accessed on June20, 2023.
[19]Sherrick, B.J., Schnitkey, G.D., Woodward, J.D., 2014, Crop insurance loss experience, ratings changes, and impacts on participants, Agricultural Finance Review, Emerald Group Publishing Limited, Vol. 74(4):443-463, Accessed on June20, 2023.
[20]Regulation No. 766 din 15.10.2012 regarding the allocation of financial means to diminish drought consequences in 2012https://www.legis.md/cautare/getResults?doc_id=21570&lang=ro, Accessed on July20, 2023

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DID THE RURAL MOUNTAIN TOURISM IN ROMANIA PASS THE RESILIENCE AND SUSTAINABILITY TEST DURING THE COVID-19 PANDEMIC?

Romeo Cătălin CREȚU, Georgiana GURBAN, Ioan Iulian ALECU, Petrică ȘTEFAN

University of Agronomic Sciences and Veterinary Medicine of Bucharest, Faculty of Management and Rural Development , Department of Economics, Accounting and Agrotourism, 011464 Bucharest, Romania; E-mails: cretu.romeo@managusamv.ro, georgiana.gurban@managusamv.ro, alecu.iulian@managusamv.ro, stefanmarian2004@yahoo.com

Corresponding author: stefanmarian2004@yahoo.com

Abstract

This research focuses on two main aspects, each equally important for tourism actors. First, we analyzed the impact of the Covid-19 pandemic on the rural mountain tourism in Romania and whether the resilience and sustainability test was passed. The second aim of the research was to identify solutions for the relaunch and development of the rural mountain tourism in Romania. Several research methods have been used to meet our objectives, such as analysis, synthesis, comparison, observation or documentary research. The quantitative research methodology used is limited to the questionnaire-based survey. The questionnaire contained 16 questions and was administered by telephone, between 15-30 March 2023 was addressed to a number of 100 respondents including owners or administrators of classified accommodation units in the mountain area. The analysis of the results shows that the pandemic had a neutral to positive effect for tourism in the mountain area and that, for the most part, the resilience and sustainability test was passed. We consider that this study is very useful for tourism entrepreneurs, for local and central public authorities and the conclusions and recommendations extracted from the questionnaires can suggest valuable ideas for the relaunch and development of the rural mountain tourism in Romania.

Key words*: *Covid-19, resilience, the rural mountain tourism in Romania, sustainable management, sustainability.

INTRODUCTION

In 2019, travel and tourism were some of the most important sectors of the world economy, almost 10% of global GDP, with over 320 million jobs worldwide and a value of nine trillion dollars [12].

In Europe, the tourism sector accounts for 10% of EU GDP (up to 25% in Croatia, 22% in Cyprus and 21% in Greece, if indirect impact is included) and generates, directly and indirectly, 23 million jobs [19]. However, the COVID-19 pandemic puts the European tourism industry under unprecedented pressure: there has been a 60% to 90% drop in bookings over the same periods in previous years, leading to an estimated loss of 6%. millions of jobs [7].

2020 was an atypical, difficult and unusual year, it changed the way we live, work and many of the values we thought were important Both human health and activity in all industries were mainly negatively affected by the coronavirus pandemic [16]. The tourism industry was no exception, as it was one of the most affected by the dreaded virus and restrictions [28]. Tourism was one of the hardest hit industries in the world, and in Romania we are talking about a decrease in turnover of about 70%, going to the complete paralysis of agencies specializing in incoming or events [24].

Destinations around the world last year saw a one billion drop in the number of international visitors, compared to a decline of only 4% during the global economic crisis of 2009 [5].

The entire HoReCa industry in Romania had in 2019 revenues of 5 billion euros, and in 2020 it lost about 3 billion euros, of which 1 billion are just the losses of hoteliers. COVID-19 did not discriminate, so that all companies in the tourism sector and all travel destinations were massively affected by unprecedented travel restrictions and felt economic and social bottlenecks [9].

In Romania, the arrivals registered in the tourist reception structures in 2020 amounted to 6,335.4 thousand, decreasing by 52.3% compared to 2019. Of these, 92.8% represented the arrivals of Romanian tourists and 7.2% represented the arrivals of foreign tourists (Table 1).

Table 1. Arrivals registered in the tourist reception structures in Romania, 2019-2020

Tourist arrivals in Romania	**2020**	**2019**
Romanian tourists	5,879,251	10,597,000
Foreign tourists	456,149	2,671,000
TOTAL	6,335,400	13,268,000

Source: www.insse.ro, Accessed on Oct.5, 2023 [25].

Regarding the arrivals of foreign tourists in the tourist reception structures, the largest share was held by those from Europe - 78.4% of the total foreign tourists, and of these 74.2% were from the European Union countries [25].

The overnight stays registered in the tourist reception structures in 2020 amounted to 14,444.7 thousand, decreasing by 51.6% compared to those in 2019 (Table 2). Of these, 93.1% represented the overnight stays of Romanian tourists and 6.9% the overnight stays of foreign tourists.

Regarding the overnight stays of foreign tourists in the tourist reception structures, the largest share was held by those from Europe - 77.2% of the total foreign tourists, and 73% of them were from European Union countries.

Table 2. Overnight stays registered in the tourist reception structures in Romania 2019-2020.

Overnight stays registered in the tourist reception structures	2020	2019
Romanian tourists	13,448,015	24,612,000
Foreign tourists	996,685	5,258,000
TOTAL	14,444,700	29,870,000

Source: www.insse.ro [25].

The average length of stay in 2020 was 2.3 days for Romanian tourists and 2.2 days for foreign tourists. The index of net use of accommodation places in 2020 was 22.9% on total tourist accommodation structures,
decreasing by 11.3% compared to 2019 (Table 3). Higher indices of accommodation use in 2020 were registered at accommodation spaces on ships (29.3%), bungalows (28.9%), hotels (26.7%), campsites (24.3 %), tourist houses (22.1%), tourist villas (21.4%), tourist stops (19.4%) and agritourism pensions (16.7%).

The arrivals of foreign visitors in Romania, registered at the border points, were in 2015 of 5022.7 thousand, decreasing by 60.8% compared to last year. The means of road and air transport were the most used for the arrivals of foreign visitors in Romania, representing 82.6%, respectively 14.5% of the total number of arrivals [36].

The departures of Romanian visitors abroad, registered at the border points, were in 2020 of 9510.1 thousand, decreasing by 58.8% compared to 2019 (Table 3).

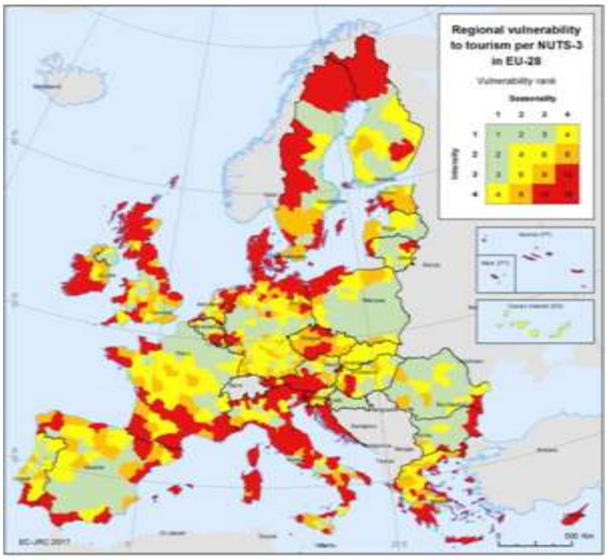
Table 3. Tourist indicators in Romania 2019-2020

Tourist indicators	**2020**	**2019**
Index of net use of accommodation	22.9%	34.2%
The departures of Romanian visitors abroad	9,510,100	23,065,000

Source: www.insse.ro [25].

The means of road and air transport were the most used for departures abroad, representing 71.0%, respectively 28.3% of the total number of departures.

The Commission's Joint Research Center, which studies the spatio-temporal patterns of tourism in Europe, has analyzed the regional vulnerability of the tourism sector (Map 1).



Map 1. Map of the regional vulnerability of the tourism sector.
Source: EU Commission Joint Research Center and [12, 17].

It points out that the region's most at risk due to the seasonal nature of activity are spread across the EU; however, the intensity is variable, for example, some islands in Greece depend 90% on tourism. Their vulnerability results from dependence on domestic or European tourism, their seasonal nature and their intensity. The trade fair and congress sector was also affected, with events being canceled or postponed in Europe [37].

Certain sectors of the tourism industry may never be able to return to pre-crisis levels, in particular due to the digital transformation that was already under way and was accelerated by the situation. An example is the MICE sector, where virtual meetings have shown that there is no need for international travel to attend conferences [30].

This research focuses on two main aspects, each equally important for tourism ac-tors. First, we analyzed the impact of the Covid-19 pandemic on the rural mountain tourism in Romania in 2020 and whether the resilience and sustainability test was passed [20].

The second aim of the research was to identify solutions for the relaunch and development of the rural mountain tourism in Romania. Several research methods have been used to meet our objectives, such as analysis, synthesis, comparison, observation or documentary research.

We consider that this study is very useful for tourism entrepreneurs, for local and central public authorities and the conclusions and recommendations extracted from the questionnaires can suggest valuable ideas for the relaunch and development of the rural mountain tourism in Romania.

Review of the scientific literature

Used in disciplines such as psychology, ecology or engineering, resilience is a term that, in recent years, is increasingly used in connection with the success of an organization. Organizational resilience can be defined as the ability to recover or adapt quickly to adverse situations or changes [33].

Whatever definition or term we adopt, after numerous corporate scandals and a financial crisis that has shaken the entire globe, it is considered that a successful organization must be able to withstand shocks, remain as strong as a result of these shocks, adapt to change and even more, take advantage of the opportunities that any change brings [13].

But how can organization gain resilience? A well-known theory published in 2011 by a well-known UK association, AIRMIC (Association of Risk and Insurance Managers in Industry and Commerce), is the theory of the 5 Rs: Risk Radar, Resources, Organization Relations, Rapid Incident Response, and Reviewing and adapting the organizational environment [11].

The risk radar is that "concern about failure", a permanent focus on detecting errors and things that need to be learned from the mistakes of the past. It seems simple, but if we look at the great scandals in the corporate world of the last 25 years, we see so many examples of organizations that have repeated the same mistakes made by other similar companies before them [26]. Resources refer to employees and the moral compass of a company. Relationships within the organization refer to both internal communication and that with external partners. If we study any organizational failure, poor communication appears to be one of the main causes in almost all cases [21].

This can mean that information does not "flow" freely within the organization, does not communicate effectively on all levels, or can define an organization that does not "listen", does not pay attention to what is happening inside and outside it [34]. Also, in the event of an incident, an organization must have a rapid response to prevent the incident from degenerating into a crisis, or even a disaster [18]. In this regard, it is essential to have an organizational culture in which risk and incident reporting is rewarded, in order to allow the organization to have an immediate response [1].

A culture that favors "shooting the messenger" can have serious consequences, eroding organizational resilience [4]. In addition, the continuous review of the organizational environment that requires changes and improvements, but also immediate adaptation, are key elements in ensuring resilience [2].

Continuing this idea, some specialists in the field of organizational resilience wonder if we are not wrong when we consider that the state of normalcy is represented by stability and maintaining the status quo [32]. If we considered that normalcy means permanent change and adaptation, and a period of stability would be just an accident, a short period of time that we must not be deceived? Perhaps this approach is indeed the secret of a resilient organization [8].

The tourism industry has evolved rapidly in recent decades [22]. In addition to the positive effects of generating growth in the destination areas, there are also negative effects with an impact on areas such as the environment, culture, politics, social and economic [35].

Prior to the Covid-19 pandemic, the growing number of tourists from some European destinations led to congestion and saturation, which risks damaging sites and making them less attractive [29]? In addition, although tourism has the potential to generate revenue and stimulate local development, tourist flows can also have an impact on the quality of life of the local population and affect local culture [28].

The new policy framework for European tourism, adopted by the Commission in 2012, includes the promotion of sustainable, responsible and quality tourism. The key issues involve limiting the environmental impact of transport related to tourism, as well as limiting the negative impact on tourist destinations [3, 23].

The growing need for sustainability is also a result of the high volume of knowledge and concern about the impact on tourism and environmental issues in general [10]. The development of tourism without sustainability can lead to serious deterioration of society, but also of the environment and the entire tourism industry. Tourism activities have repercussions on the economy, on the natural and built environment, on the local population of the destination and on the tourists themselves [14].

Tourism activities have repercussions on the economy, on the natural and built environment, on the local population of the destination and on the tourists themselves [31]. This generates multiple impacts, the range and variety of production factors needed to produce these goods and services purchased by visitors and the range of agents interested or affected by tourism, it is necessary to adopt an integrated approach to tourism development, management and control [6].

This approach is strongly recommended for the formulation and implementation of national and local tourism policies, as well as the necessary international agreements or other mechanisms on tourism [15].

MATERIALS AND METHODS

This research focuses on two main aspects, each equally important for tourism actors. First, we analyzed the impact of the Covid-19 pandemic on the rural mountain tourism in

Romania and whether the resilience and sustainability test was passed. The second aim of the research was to identify solutions for the relaunch and development of the rural mountain tourism in Romania. Several research methods have been used to meet our objectives, such as analysis, synthesis, comparison, observation or documentary research.

The quantitative research methodology used is limited to the questionnaire-based survey. The questionnaire contained 16 questions and was administered between 15-30 March 2023, by phone, because not all tourist boarding houses in the mountain area have an internet connection:

(1)What was the impact of the COVID-19 Pandemic on tourism in Romania?

(2)What was the impact of the COVID-19 Pandemic on rural mountain tourism in Romania?

(3)What was the impact of the COVID-19 Pandemic on your business?

(4)Did you have to close work points/units during this period?

(5)Did you have to lay off staff during this period?

(6)What losses did you have or estimate you will have?

(7)In this crisis, the Government's assistance was?

(8)In this crisis, the help from the local authorities was?

(9)What steps would you like the government and state institutions working in the field of tourism to take to help you overcome the pandemic crisis?

(10)What steps do you take to minimize the impact of Covid-19 on your company's business strategy, sales and cash flow?

(11)When do you expect a stabilization of the Romanian tourism industry?

(12)When do you expect a stabilization of the tourism industry in the rural mountain tourism?

(13)Did Romanian tourists choose the rural mountain tourism as a tourist destination in 2020, because they had the opportunity to use holiday vouchers?

(14)Tourists have chosen the rural mountain tourism as a tourist destination in 2020?

(15)Tourists who visited the rural mountain tourism in 2020 preferred accommodation in the reception structures?

(16)For the development the rural mountain tourism, the authorities must....?

We had a number of 100 respondents, owners or administrators of classified accommodation units in the mountain area. We analyzed 10 tourist and agritourism pensions, classified by the Romanian Ministry of Tourism from the 10 most representative mountain counties in Romania: Alba, Argeș, Brașov, Covasna, Maramureș, Neamț, Prahova, Sibiu, Suceava and Vâlcea (Map 2).

Map 2. Romania's physical map and the counties distribution on its territory
Source: Pinterest.com, https://ro.pinterest.com/pin/311241024255398778/, Accessed on Sept. 10, 2023 [27].

RESULTS AND DISCUSSIONS

From the analysis of the answers to the questionnaires, it results that the tourism actors appreciate that the impact of the COVID-19 Pandemic on tourism in Romania was devastating - negative, in proportion of 95% and neutral - 5%, Table 4.

However, at the level of pensions in the mountain area, the owners or administrators estimate that the year 2020, in terms of the number of tourists, was negative - 35%, neutral - 25% and positive - 40%. This shows that tourists chose safer, isolated and unpolluted destinations during the pandemic, Table 4.

Table 4. The impact of the COVID-19 Pandemic on tourism in Romania and on rural mountain tourism

QUESTIONNAIRE QUESTIONS	What was the impact of the COVID-19 Pandemic on tourism in Romania?	What was the impact of the COVID-19 Pandemic on rural mountain tourism in Romania?
Negative	95%	35%
Neutral	5%	25%
Positive	0%	40%

Source: own processing based on data obtained from the centralization of questionnaire responses.

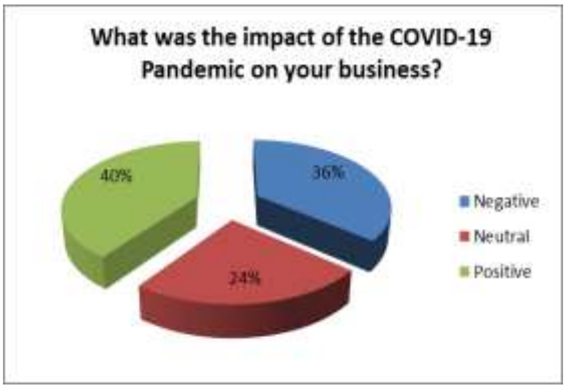


Fig. 1. The impact of the COVID-19 Pandemic on business. Source: own processing based on data obtained from the centralization of questionnaire responses

This correlates with the answers received to the question related to the impact of COVID-19 on the business of each respondent: negative - 36%, neutral - 24% and positive - 40% (Figure 1).

When asked if they had to close units or work points, tourism managers stated that: yes - 8%, temporary - 12%, no - 73% and partial - 7% (Table 5).

Regarding the dismissal of staff, the employers stated that: yes - 10%, temporary - 21%, no - 65% and partially - 4% (Table 5).

Table 5. The impact of the COVID-19 Pandemic on work points/units and on lay off staff.

QUESTIONNAIRE QUESTIONS	Did you have to close work points/units during this period?	Did you have to lay off staff during this period?
Yes	8%	10%
Temporary	12%	21%
No	73%	65%
Partial	7	4

Source: own processing based on data obtained from the centralization of questionnaire responses.

In addition to staffing issues, economic results are very important. Pension owners stated that during the pandemic, the losses were: very big - 13%, big - 17%, minimal - 25% and nothing - 45% (Figure 2).

According to the centralization of the data from the questionnaires, the 100 respondents stated that in this crisis, the Government's assistance was: big - 0%, small - 45%, medium - 8% and nothing - 47% (Table 6).

Regarding the help from the local authorities was: big - 0%, small - 5%, medium - 45% and nothing - 50% (Table 6).

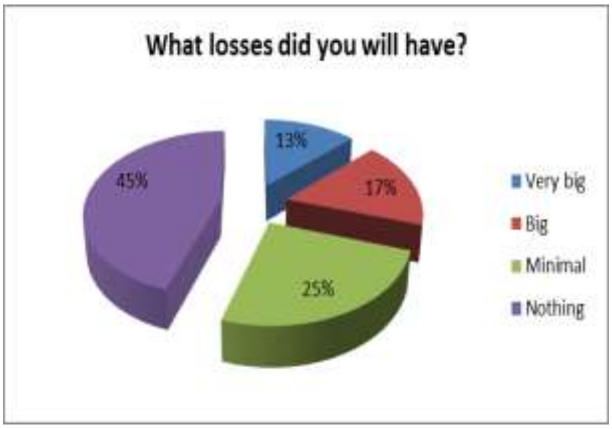


Fig. 2. The impact of the COVID-19 Pandemic on business

Source: own processing based on data obtained from the centralization of questionnaire responses.

Table 6. The Government's assistance and the help from the local authorities

QUESTIONNAIRE QUESTIONS	In this crisis, the Government's assistance was:	In this crisis, the help from the local authorities was:
Big	0%	0%
Small	45%	5%
Medium	8%	45%
Nothing	47%	50%

Source: own processing based on data obtained from the centralization of questionnaire responses.

Through this questionnaire, we wanted to find out the opinion of the owners or administrators of the pensions regarding the measures that the Government and the authorities with attributions in the field of tourism must take, in order to overcome the crisis. The answers were: state funds - 30%, guaranteed/subsidized loans - 5%, exemptions or postponements of taxes and duties - 40% and insistent promotion of rural mountain tourism - 25% (Figure 3).

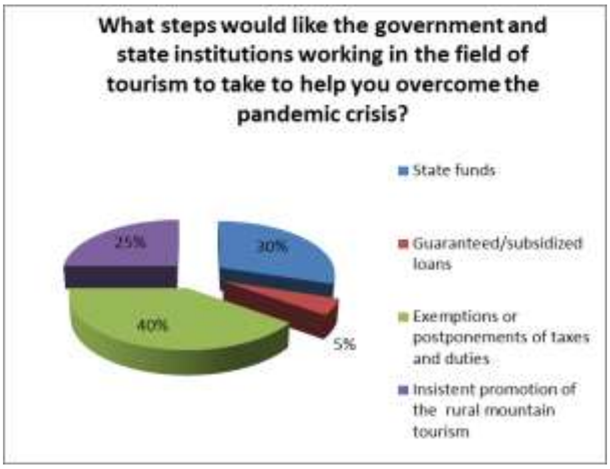


Fig. 3. Government measures to save tourism
Source: own processing based on data obtained from the centralization of questionnaire responses.

In the next questionnaire, we wanted to see what concrete measures taken by tourism entrepreneurs to minimize the effects of the pandemic. They stated that they had taken the following measures:
reduction of staff - 2%, loans - 5%, adding other services for tourists - 35%, sale of certain products obtained locally-40%, promoting offers in agencies in other countries - 8% and aggressive promotion - 10% (Figure 4).

Fig. 4. Measures of entrepreneurs to save the business
Source: own processing based on data obtained from the centralization of questionnaire responses.

We wanted to find out the opinion of the tourism actors, in connection with the moment when the tourism in Romania will return to normal (Table 7).
The answers were:
- 2021 – 8%,
- 2022 – 62%,
- 2023 – 27%
- 2024 – 3%.

Because rural tourism in the mountain area was less affected, we also wanted to see the opinion of the respondents regarding the return to normal in the areas where they live (Table 7).
The answers were:
- 2021 – 42%
- 2022 – 33%
- 2023 – 25%
- 2024 – 0%.

Table 7. The opinion of the entrepreneurs regarding the return to the normal state in tourism

QUESTIONNAIRE QUESTIONS	When do you expect a stabilization of the Romanian tourism industry?	When do you expect a stabilization of the tourism industry in the rural mountain tourism?
2021	8%	42%
2022	62%	33%
2023	27%	25%
2024	3%	0%

Source: own processing based on data obtained from the centralization of questionnaire responses.

Because the topic of holiday vouchers has been much discussed lately, we wanted to find out the opinion of entrepreneurs in the mountain area, about the number of tourists who used holiday vouchers.
The answers were: Majority - 20%, Small majority - 36%, They came anyway, even on their own money - 44% (Figure 5).

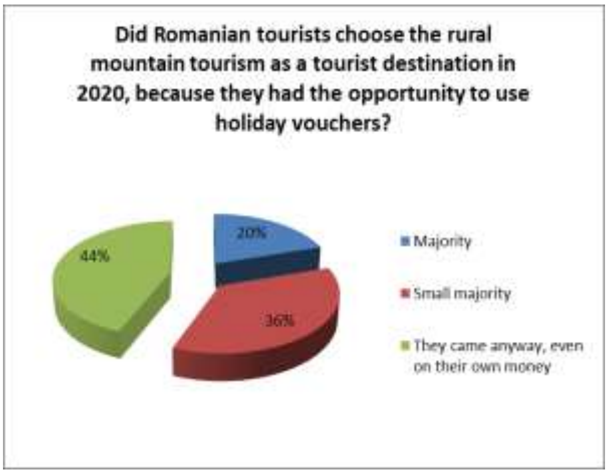


Fig. 5. Use of holiday vouchers
Source: own processing based on data obtained from the centralization of questionnaire responses.

Through this questionnaire, we wanted to identify the main motivation of tourists, who chose rural tourism in the mountain area and the connection with the restrictions during the pandemic:
Because they are passionate about the wilderness – 12%, To know the local culture and traditions – 18% , To protect yourself from Covid-19 – 51%, For the local gastronomic offer – 19% (Figure 6).
According to the respondents, the tourists who stayed in 2020 in the mountain area, preferred the pensions: Maximum 8 rooms – 65%, Between 9 and 15 rooms – 25%, Up to 15 rooms – 10% (Figure 7).

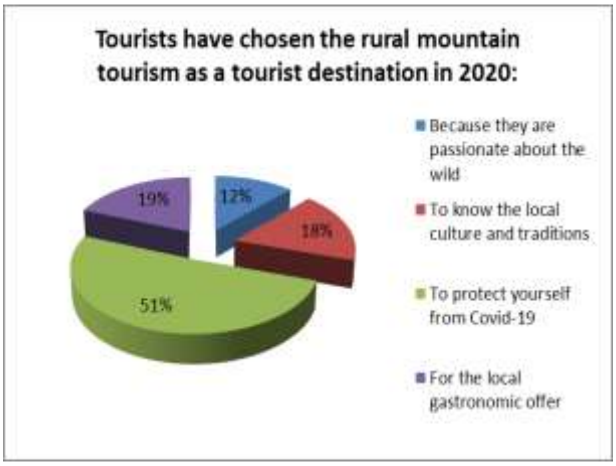


Fig. 6. The motivation for choosing rural pensions in the mountain area
Source: own processing based on data obtained from the centralization of questionnaire responses.

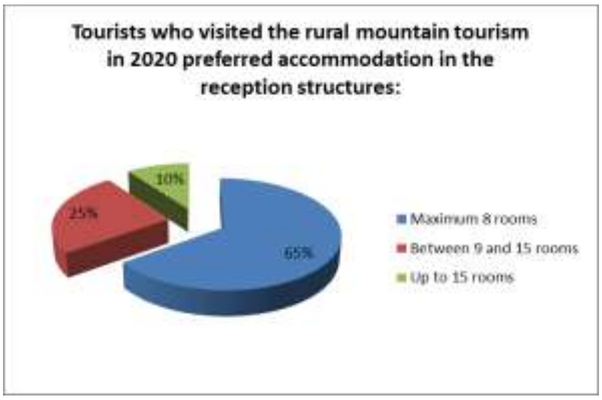


Fig. 7. The option regarding the size of the pension
Source: own processing based on data obtained from the centralization of questionnaire responses.

At the end, we asked the entrepreneurs from the rural mountain tourism about what measures the authorities must take for the future development of tourism in this area:
- Develop transport infrastructure – 25%

- Promote more aggressively the rural mountain tourism - 24%
- Organize several events – 25%
- Grants tax exemptions to classified accommodation ownners – 26% (Figure 8.

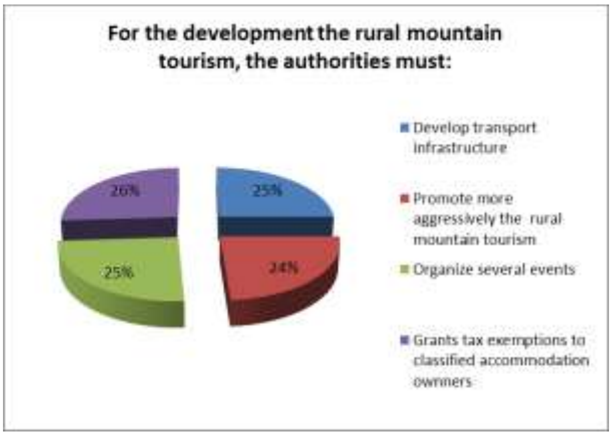


Fig. 8. What measures should the authorities take for the future development of rural mountain tourism
Source: own processing based on data obtained from the centralization of questionnaire responses.

The analysis of the results shows that the pandemic had a neutral to positive effect for tourism in the mountain area and that, for the most part, the resilience and sustainability test was passed. We consider that this study is very useful for tourism entrepreneurs, for local and central public authorities and the conclusions and recommendations extracted from the questionnaires can suggest valuable ideas for the relaunch and development of the rural mountain tourism in Romania.

From the analysis of the answers to the questionnaires, it results that the owners and administrators of the pensions estimate that the impact of the COVID-19 Pandemic on tourism in Romania was negative, in proportion of 95% and neutral - 5%. This is an x-ray of tourism in Romania from 2020 and shows the size of the tourism disaster during the pandemic.

However, at the level of pensions in the mountain area, the owners or administrators estimate that the year 2020, in terms of the number of tourists, was negative - 35%, neutral - 25% and positive - 40%.

This shows that during the pandemic, tourists chose safer, isolated and unpolluted destinations. This aspect is very important to demonstrate that the rural pensions in the mountainous area of Romania have passed the resilience and sustainability test during this period.

This correlates with the answers received to the question related to the impact of COVID-19 on the business of each respondent in the mountain area: negative - 36%, neutral - 24% and positive - 40%.

When asked if they had to close units or work points, mountain tourism managers stated that: yes - 8%, temporary - 12%, no - 73% and partially - 7%, unlike managers in mountain tourism. urban or coastal areas, which have been severely affected by the Covid-19 pandemic, with some having to close their tourism business for a long time or even permanently. We must mention the fact that many units in the urban area went bankrupt, especially those that had loans.

The same phenomenon happens regarding the dismissal of personnel, the owners from the mountain area stated that: yes - 10%, temporary - 21%, no - 65% and partially - 4%, aspects that demonstrate the successful passing of the resilience test.

In addition to the staffing issues, also related to the resilience test, the economic results are very important. Pension owners in the mountain area said that during the pandemic, the losses were: very big - 13%, big - 17%, minimal -25% and nothing - 45%, as opposed to the massive losses recorded by tourism entrepreneurs national.

A very important question referred to the size of aid coming from the state or local authorities during the pandemic.

According to the centralization of the data from the questionnaires, the 100 respondents stated that in this crisis, the Government's assistance was: big - 0%, small - 45%, medium - 8% and nothing - 47%. These answers show that the government's promises have not been honored and that employers and tourism workers have been forgotten.

Regarding the help from the local authorities was: big - 0%, small - 5%, medium - 45% and nothing - 50%. At the local level, support has come more directly, with many local governments exempting or postponing the payment of local taxes and fees for rural pensions.

Through the following questionnaire, we wanted to find out the opinion of the owners or administrators of the pensions in the mountain area, in connection with the measures that the Government and the authorities with attributions in the field of tourism must take in order to overcome the crisis. The answers were: state funds - 30%, guaranteed/subsidized loans - 5%, exemptions or postponements of taxes and duties - 40% and insistent promotion of rural mountain tourism - 25%. A very interesting aspect is the fact that tourism entrepreneurs do not want special facilities and consider that the postponement of taxes and the insistent promotion of rural tourism in the mountain area are solutions for overcoming the crisis and for the development of mountain areas.

In the next questionnaire, we wanted to see what concrete measures taken by tourism entrepreneurs to minimize the effects of the pandemic. They stated that they had taken the following measures:

- reduction of staff - 2%,
- loans - 5%,
- adding other services for tourists - 35%,
- sale of certain products obtained locally- 40%,
- promoting offers in agencies in other countries - 8%
- aggressive promotion - 10%.

These answers show that pensioners considered that solutions to the crisis should not come from the government and that by providing diversified services to tourists (leisure, local cuisine, involvement of tourists in agricultural activities, crafts and traditions, trips to nature, harvesting of berries and mushrooms, folk art) and, especially by selling traditional local products (cheese, natural juices, jam, meat products, alcoholic beverages, handicrafts), the crisis can be overcome.

Here is another proof that rural tourism in the mountain area has passed the test of resilience and sustainability. Moreover, this aspect demonstrates the capacity of the actors involved in mountain tourism to innovate.

In the next questionnaire, we wanted to find out the opinion of tourism actors, in connection with the moment when tourism in Romania will return to normal.

The answers were:

- 2021 – 8%,
- 2022 – 62%,
- 2023 – 27% and
- 2024 – 3%.

Because rural tourism in the mountain area was less affected, we also wanted to see the opinion of the respondents regarding the return to normal in the areas where they live.

The answers were:

- 2021 – 42%
- 2022 – 33%
- 2023 – 25%
- 2024 – 0%.

This shows that entrepreneurs in mountain rural tourism have been less affected by the Covid-19 pandemic and that they are more optimistic about the return to normal in national and local tourism.

Because the topic of holiday vouchers has been much discussed lately, we wanted to find out the opinion of entrepreneurs in the mountain area, about the number of tourists who used holiday vouchers.

The answers were:

- Majority – 20%
- Small majority – 36%
- They came anyway, even on their own money – 44%.

These answers are explained by the fact that rural guesthouses in the mountains do not have the logistical means to receive holiday vouchers, as well as by the fact that many tourists used holiday vouchers on the coast and went to the mountains with their own funds.

Through the following questionnaire, we wanted to identify the main motivation of tourists, who chose rural tourism in the mountain area and the connection with the restrictions during the pandemic. The answers were:

- Because they are passionate about the wild - 12%
- To know the local culture and traditions - 18%

- To protect yourself from Covid-19 - 51%
- For the local gastronomic offer - 19%.

These answers show that many tourists have chosen isolated mountain boarding houses to protect themselves from Covid-19. This aspect must be assessed in the light of the pandemic, because many traditional destinations have not been able to offer this protection. However, in previous years, many tourists opted for ecotourism, rural and sustainable tourism.

It was very interesting to see the accommodation option for tourists. According to the respondents, the tourists who stayed in 2020 in the mountain area, preferred the pensions:

- Maximum 8 rooms – 65%
- Between 9 and 15 rooms – 25%
- Up to 15 rooms – 10%.

This shows that tourists preferred accommodation with few rooms to protect themselves from Covid-19.

At the end, we asked the entrepreneurs from the rural mountain tourism about what measures the authorities must take for the future development of tourism in this area:

- Develop transport infrastructure – 25%
- Promote more aggressively the rural mountain tourism - 24%
- Organize several events – 25%
- Grants tax exemptions to classified accommodation ownners – 26%.

The answers show a balance between the desire of entrepreneurs to develop infrastructure through European funds, the promotion of mountain areas and, very interestingly, the organization of events that bring tourists. We must say that these questionnaires were addressed only to pensions classified by the Ministry of Tourism and that a quarter of those interviewed said they would like to benefit from European funds and tax facilities.

CONCLUSIONS

The analysis of the results shows that the pandemic had a neutral to positive effect for tourism in the mountain area and that, for the most part, the resilience and sustainability test was passed. We consider that this study is very useful for tourism entrepreneurs, for local and central public authorities and the conclusions and recommendations extracted from the questionnaires can suggest valuable ideas for the relaunch and development of the rural mountain tourism in Romania.

From the analysis of the answers to the questionnaires, it results that the owners and administrators of the pensions estimate that the impact of the COVID-19 Pandemic on tourism in Romania was negative, in proportion of 95% and neutral - 5%. This is an x-ray of tourism in Romania from 2020 and shows the size of the tourism disaster during the pandemic.

However, at the level of pensions in the mountain area, the owners or administrators estimate that the year 2020, in terms of the number of tourists, was negative - 35%, neutral - 25% and positive - 40%.

This shows that during the pandemic, tourists chose safer, isolated and unpolluted destinations. This aspect is very important to demonstrate that the rural pensions in the mountainous area of Romania have passed the resilience and sustainability test during this period.

Also related to the resilience test, the economic results are very important. The owners of boarding houses in the mountain area stated that, during the pandemic, the losses were minimal or not at all, unlike the massive losses registered by the national tourism entrepreneurs.

A very important question referred to the size of aid coming from the state or local authorities during the pandemic.

According to the centralization of the data from the questionnaires, the 100 respondents stated that in this crisis, the Government's assistance was very small or non-existent. These answers show that the government's promises have not been honored and that employers and tourism workers have been forgotten.

As for the help from the local authorities was average, at the local level, the support came more directly, many local administrations exempting or postponing the payment of local taxes and fees for rural pensions.

Through this study, we also wanted to find out the opinion of the owners or administrators of boarding houses in the mountain area, in connection with the measures that the Government and the authorities with attributions in the field of tourism must take in order to overcome the crisis. The answers were: state funds - 30%, guaranteed/ subsidized loans - 5%, exemptions or postponements of taxes and duties - 40% and insistent promotion of rural mountain tourism - 25%.

A very interesting aspect is the fact that tourism entrepreneurs do not want special facilities and consider that the postponement of taxes and the insistent promotion of rural tourism in the mountain area are solutions for overcoming the crisis and for the development of mountain areas.

At the end of the study, we wanted to see what concrete measures taken by tourism entrepreneurs to minimize the effects of the pandemic. They stated that they were oriented towards adding other services for tourists - 35%, and sale of certain products obtained locally-40%.

These answers show that pensioners considered that solutions to the crisis should not come from the government and that by providing diversified services to tourists (leisure, local cuisine, involvement of tourists in agricultural activities, crafts and traditions, trips to nature, harvesting of berries and mushrooms, folk art) and, especially by selling traditional local products (cheese, natural juices, jam, meat products, alcoholic beverages, handicrafts), the crisis can be overcome. Here is another proof that rural tourism in the mountain area has passed the test of resilience and sustainability. Moreover, this aspect demonstrates the capacity of the actors involved in mountain tourism to innovate.

Regarding the opinion of tourism actors, regarding the moment when tourism in Romania will return to normal, the conclusions show that most believe that 2023 will be a reasonable year to overcome the crisis.

Because rural tourism in the mountain area was less affected, we also wanted to see the opinion of the respondents regarding the return to normal in the areas where they live. The answers were more optimistic, the year 2021 being a landmark and a hope for overcoming the pandemic, especially in the context of vaccinating the population.

This shows that entrepreneurs in rural mountain tourism have been less affected by the Covid-19 pandemic and that they are more optimistic about the return to normal in national and local tourism.

The conclusions regarding the use of holiday vouchers are explained by the fact that rural guesthouses in the mountain area do not have the logistical means to receive holiday vouchers, as well as by the fact that many tourists used holiday vouchers on the seaside and went to the mountains with own funds.

Regarding the main motivation of tourists, who chose rural tourism in the mountain area and the restrictions during the pandemic, the answers show that many tourists chose isolated guesthouses in the mountain area to protect themselves from Covid-19. This aspect must be assessed in the light of the pandemic, because many traditional destinations have not been able to offer this protection. However, in previous years, many tourists opted for ecotourism, rural and sustainable tourism.

It was very interesting to see the accommodation option for tourists. According to the respondents, the tourists who stayed in 2020 in the mountain area preferred the pensions of maximum 8 rooms - 65%.

This shows that tourists preferred accommodation with few rooms to protect themselves from Covid-19.

At the end, we asked the entrepreneurs from the rural mountain tourism about what measures the authorities must take for the future development of tourism in this area:

Develop transport infrastructure - 25%

Promote more aggressively the rural mountain tourism - 24%

Organize several events - 25%

Grants tax exemptions to classified accommodation owners - 26%.

The conclusions show a balance between the desire of entrepreneurs to develop infrastructure through European funds, the promotion of mountain areas and, very interestingly, the organization of events to bring tourists. We must say that these questionnaires were addressed only to pensions classified by the Ministry of Tourism and that a quarter of those interviewed said they would like to benefit from European funds and tax facilities.

REFERENCES

[1]Avery, G.C., Bergsteiner, H., 2010, Honeybees & Locusts: The Business Case for Sustainable Leadership; Allen & Unwin: Sydney, NSW, Australia, 2010.

[2]Bran, F., Rădulescu, C. V., Bodislav, D. A., Burlacu, S., 2020, Environmental risks in the context of globalization. Economic Convergence in European Union, 350-356.

[3]Bran, F., Bodislav, D.A., Angheluță, S.P., Dobrea, R.C., 2020, Nature, ecosystems and biodiversity-ecosystem management, http://irek.ase.md:80/xmlui/handle/1234567890/950, Accessed on March 10, 2023.

[4]Brouder, P., 2020, Reset redux: possible evolutionary pathways towards the transformation of tourism in a COVID-19 world. Tourism Geographies, 22(3), pp.484-490.

[5]Chiurciu, I.-A., Soare, E., Chereji, A.I., Cofas, E., 2020, Analysis regarding the evolution of agrotourism pensions in Romania between 2010 and 2019, Conference Romanian Rural Tourism in International Context. Present and prospects. Iasi. 50.

[6]Choi, H., Ann, S., Lee, K.-W., Park, D.-B., 2018, Measuring Service Quality of Rural Accommodations. Sustainability 2018, 10, 443. https://doi.org/10.3390/su10020443

[7]Chua, B., Ansi, A., Lee, M., Han, H., 2021, Tourists' Outbound Travel Behavior in the Aftermath of COVID-19: The Role of Corporate Social Responsibility, Response Effort, and Health Prevention. Journal of Sustainable Tourism.

[8]Cretu, R.F., Cretu R.C., Voinea-Mic, C.C., Stefan, P., 2019, Circular economy, green buildings and environmental protection, Quality - Access to Success, Vol. 20 S2, March 2019 WOS:000461854800032

[9]Cretu, R.C., Cretu, R.F., Stefan, P., 2017, Analysis of the economic crisis concerning the pensions from the Danube Delta, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 17(2), 67-73.

[10]Cretu, R.C., Cretu, R.F., Stefan, P., 2013, Innovative and sustainable strategies in Romanian tourism and agritourism. Proceedings of the 7th International Management Conference "New Management for the New Economy", 7-8 November 2013, Bucharest, Romania.

[11]Cretu, R.F., Ciobotar, G.N., Cretu, R.C., 2015, Survey regarding the corporate governance implementation in Romania. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 15(4), 33-38.

[12]Cretu, R.C., Stefan, P., Alecu, I.I., 2021, Has tourism gone on holiday? Analysis of the effects of the Covid-19 pandemic on tourism and post-pandemic tourism behavior. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 21(2), 191-198.

[13]Dinulescu, R., Smeureanu, I., Dobrin, C., Popa, I., 2018, A statistical approach for improving the romanian public healthcare system using the lean six sigma methodology. Economic Computation and Economic Cybernetics Studies and Research, Vol. 52. Issue 3/2018.

[14]Dragomir, C.C., Foris, D., Ţîţu, A.M., Foris, T., 2020, The Role of Intermediaries in Supporting Collaboration for Sustainability: A Model of Commissioning Intervention in the Multi-Stakeholder Collaboration for Sustainable Territorial Development. Sustainability 2020, 12(17), 6769.

[15]Duţescu, A., Popa, A.F., Ponorîcă, A.G., 2014, Sustainability in tourism industry, based on the key performance indicators, Contemporary approaches and challenges of sustainable tourism (Sustenabilitatea în industria turismului, bazată pe indicatorii cheie de performanţă, Abordări contemporane și provocări ale turismului durabil). Amfieatru Economic, 16 (special issue 8), pp.830-831.

[16]Engelmo Moriche, Á., Nieto Masot, A., Mora Aliseda, J., 2021, Economic Sustainability of Touristic Offer Funded by Public Initiatives in Spanish Rural Areas. Sustainability 2021, 13, 4922. https://doi.org/10.3390/su13094922

[17]EU Commission Joint Research Center. Regional vulnerability of tourism.

[18]Gössling, S., Scott, D., Hall, C.M., 2020, Pandemics, tourism and global change: a rapid assessment of COVID-19. Journal of Sustainable Tourism, 29(1), pp.1-20.

[19]Hui, D.S. I Azhar, E., Madani, T.A., Ntoumi, F., Kock, R., Dar, O., Ippolito, G., Mchugh, T.D., Memish, Z.A., Drosten, C., et al. The continuing 2019-nCoV epidemic threat of novel coronaviruses to global health—The latest 2019 novel coronavirus outbreak in Wuhan, China. IJID Off. Publ. Int. Soc. Infect. Dis. 2020, 91, 264–266.

[20]Iatu, C., Munteanu, A., Boghinciuc, M., Coca, A., Ibanescu, B., 2011, Active tourism in Dornelor basin—Between possibilities and spatial manifestation. Int. J. Energy Environ. 2011, 5, 175–182.

[21]Kemp, R., Parto, S., Gibson, R., 2005, Governance for sustainable development: Moving from theory to practice. Int. J. Sustain. Dev. 2005, 8, 12–30.

[22]Marcuta, L., Marcuta, A., Popescu, A., Tindeche, C., Tudor, V., Smedescu, D., 2020, Study on the development of adventure tourism in Romania. Scientific Papers. Series "Management, Economic

Engineering in Agriculture and rural development", Vol. 20(4), 339-346.

[23]Mihalic, T., Mohamadi, S., Abbasi, A., Dávid, L.D., 2021, Mapping a Sustainable and Responsible Tourism Paradigm: A Bibliometric and Citation Network Analysis. Sustainability 2021, 13, 853. https://doi.org/10.3390/su13020853

[24]Mitrica, B., Serban, P.-R., Mocanu, I., Damian, N., Grigorescu, I., Dumitrascu, M., Dumitrica, C., 2021, Developing an Indicator-Based Framework to Measure Sustainable Tourism in Romania. A Territorial Approach. Sustainability 2021, 13, 2649. https://doi.org/10.3390/su13052649

[25]National Institute of Statistics. 2023, http://statistici.insse.ro:8077/tempo-online/, Accessed on 23 April 2023.

[26]Nguyen, T.Q.T., Young, T., Johnson, P., 2019, Wearing, S. Conceptualising networks in sustainable tourism development. Tour. Manag. Perspect. 2019, 32, 100575.

[27] Pinterest.com, Map of Romania, https://ro.pinterest.com/pin/311241024255398778/, Accessed on Sept. 10, 2023.

[28]Popescu, A., Plesoaianu, D.M., 2023, Tourist arrivals and overnight stays in Romania by tourist destination in the years 2020 and 2021 of Covid-19 pandemic compared to 2019. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 23(1), 639-648.

[29]Popescu, A., Dinu, T.A., Stoian, E., Serban, V., Ciocan, H.N., 2022, Romania's mountain areas-present and future in their way to a sustainable development. Scientific Papers Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22(4), 549-564.

[30]Popescu, A., Tindeche, C., Marcuta, A., Marcuta, L., Hontus, A., Stanciu, M., 2022, Romania's tourism offer and demand in the Covid-19 pandemic of 2020 and 2021 compared to 2019. A statistical overview. Scientific Papers Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22(2), 579-590.

[31]Radulescu, C.V., Ladaru, G.-R., Burlacu, S., Constantin, F., Ioanas, C., Petre, I.L., 2021, Impact of the COVID-19 Pandemic on the Romanian Labor Market. Sustainability 2021, 13, 271. https://doi.org/10.3390/su130102

[32]Romeiro, P., Costa, C., 2010,The potential of management networks in the innovation and competitiveness of rural tourism: A case study on the Valle del Jerte (Spain). Curr. Issues Tour. 2010, 13, 75–91.

[33]Sisneros-Kidd, A.M., Monz, C., Hausner,V., Schmidt, J., Clark, D., 2019, Nature-based tourism, resource dependence, and resilience of Arctic communities: Framing complex issues in a changing environment. J. Sustain. Tour. 2019, 27, 1259–1276.

[34]Somoza-Medina, X., Monteserín-Abella, O., 2021, The Sustainability of Industrial Heritage Tourism Far from the Axes of Economic Development in Europe: Two Case Studies. Sustainability 2021, 13, 1077. https://doi.org/10.3390/su13031077

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SELF-SUFFICIENCY OF THE TURKISH AQUACULTURE SECTOR AND FORECASTING ITS PRODUCTION WITH THE ARIMA (BOX-JENKINS) MODEL

Asli DALGIC, Deniz SARICA, Vecdi DEMIRCAN

Isparta University of Applied Sciences, Faculty of Agriculture, Department of Agricultural Economics, Isparta, Türkiye, Phone: +902462146239, Fax: +902462146399; E-mails: aslidalgic@isparta.edu.tr, denizsarica@isparta.edu.tr, vecdidemircan@isparta.edu.tr

Corresponding author: denizsarica@isparta.edu.tr

Abstract

With its seas and water resources, Türkiye's aquaculture industry plays a significant role in both the nation's economy and society's ability to eat healthily. The objectives of this study are to evaluate the level of self-sufficiency in aquaculture production, assess the developments in the aquaculture sector in Türkiye, and estimate the production amount for the next ten years employing the ARIMA (Autoregressive Integrated Moving Average) method using the aquaculture production amounts between 1950 and 2021. Making forecasts for the upcoming years is believed to be beneficial in terms of investment and production planning. The amount of aquaculture production was estimated with the Box-Jenkins ARIMA method. As a result of the analyses performed, the ARIMA (1, 2, 2) model was found to be the most suitable model for forecasting aquaculture production. According to the estimation, it is expected to increase by 17.29% between 2022 and 2031. It is believed that depending on this rise, actions should be taken to expand the aquaculture processing facilities associated with the aquaculture sector.

Key words**:** *aquaculture, self-sufficiency, time series, Box-Jenkins method, Türkiye*

INTRODUCTION

It has become vital to look for alternative protein sources because of factors such as the requirement for protein in human nutrition, the diminishing availability of terrestrial protein sources, the devastation of agricultural areas where animals are kept, and people's desire to consume more. Seafood tops the list of substitute protein sources due to its high protein concentration [8].
Animal foods are one of the most important sources of protein in human nutrition. Fish holds a prominent role among animal-derived foods in terms of nutritional value, particularly because of its high protein ratio. The protein content of fish meat ranges between 18% and 20%. Fish oil is a significant source of nutrition since it has the most omega-3 fatty acids when compared to other oils [12].
Türkiye has an essential place in aquaculture production with its seas, inland waters, lakes, and ponds. It is surrounded by water on three sides and contains 8,333 kilometres of coastline, 177,714 kilometres of rivers, and 342,377 hectares of dam lakes. The seas and inland waters have a combined surface area of 25 million hectares and are positioned near agricultural areas. In this context, active use of aquaculture resources is required. It is critical to protect these resources to get the maximum benefit from them in the future. There are 247 fish species in the Black Sea, 200 in the Marmara Sea, 300 in the Aegean Sea, and almost 500 in the Mediterranean Sea, with 100 of these species recognised as economically significant [3].
The various features of Türkiye's seas allow for both aquaculture and capture in certain waters. While the share of fisheries produced by capture has declined in recent years, the share of fisheries produced by aquaculture has increased.
Over the years, Türkiye's aquaculture industry has seen substantial growth. Estimating the amount of aquaculture production, which has a significant place in Turkish nutrition and the country's economy, for the following years is regarded as advantageous in terms of investment and production planning. The purpose of this

study is to examine the developments in Türkiye's aquaculture sector between 2000 and 2021, to evaluate the level of self-sufficiency in aquaculture production, and to forecast production amounts for the next ten years using the Autoregressive Integrated Moving Average (ARIMA) method based on aquaculture production amounts between 1950 and 2021. It is believed that the study's findings will be beneficial to aquaculture producers, entrepreneurs looking to invest in this field, legislators, and researchers seeking to work in this field.

MATERIALS AND METHODS

Data

To analyse the Self-Sufficiency Ratio (SSR), the data on aquaculture export value ($), export quantity (tonnes), import value ($), import quantity (tonnes), and production amount (tonnes) were collected for a period of 61 years from 1961 to 2021 from the Food and Agricultural Organization of the United Nations [9]. From the FAO [9] database, data on aquaculture consumption (kg/per capita/yr) was also gathered. Academic studies from national and foreign scientific journals and books were also used.

Self-sufficiency index

Self-sufficiency in food seems to be a straightforward concept. If a nation can produce enough food to satisfy its own needs, it is considered food self-sufficient. In the 1960s, food self-sufficiency gained popularity and found success, even in industrialised nations. Self-production is the key element of food self-sufficiency. On the other side, food self-sufficiency relates to both the supply and the source of food. Theoretically, a nation's capacity to produce all of its food depends on its financial, economic, and natural resources, as well as its effective governance, sophisticated infrastructure and logistics systems, technological advancement, and effective agricultural plans and initiatives [6, 19].

A nation may strive for food self-sufficiency for several reasons, such as enhancing national pride, lowering susceptibility to external markets or specific nations, generating employment, or as a result of the rise of economic nationalism and patriotic leaders in a state. As can be seen, having food self-sufficiency is significant for a variety of reasons. Therefore, it is crucial to examine in the research the level of self-sufficiency of the Turkish aquaculture sector.

The Self-Sufficiency Ratio (SSR) is determined by the following formula [10]:

$$SSR = \frac{P*100}{P+M-X} \qquad (1)$$

where:

M and X stand for imports and exports, respectively, and P stands for production.

Therefore, a country is considered self-sufficient in aquaculture production when the SSR is 100 or higher; otherwise (SSR<100), it is insufficient.

Box-Jenkins ARIMA approach

The Box-Jenkins [5] method is one of the approaches used in univariate time series to produce forward-looking estimations using statistical methods. The time series must be distinct, stationary, and evenly spaced for the method to function properly [2]. The three most frequent linear stationary Box-Jenkins models are autoregressive (AR), moving average (MA), and autoregressive moving average (ARMA), which combines AR and MA models [4]. The Box-Jenkins technique has a substantial advantage in that it can use past observation values as an explanatory variable. Box-Jenkins estimation methods are an experimental process, not a method defined by a model. They can choose the best model from a range of possibilities and track the suitability of the chosen model at each level.

An ARMA model is generally referred to as ARMA (p, q), where p and q are the autoregression and moving average orders, respectively. The time series is a linear function of actual previous values and random shocks in the ARMA model [11]. A stationary time series, ARMA (p, q), is defined by the equation:

$$Y_t = \alpha + \vartheta_1 Y_{t-1} + \vartheta_2 Y_{t-2} + \cdots + \vartheta_P Y_{t-p} + \epsilon_1 + \theta_1 \epsilon_{t-1} + \cdots + \theta_q \epsilon_{t-q} \qquad (2)$$

where:

α is a constant term that represents the mean of Y. Y_t is the dependent variable at time t, and the independent variables at lags t-1, t-2, ..., t-p are denoted by Y_{t-1}, Y_{t-2},…, Y_{t-p}.

The coefficients to be estimated are denoted by ϑ s. The error terms are uncorrelated random variables with constant variance and zero means, denoted by ϵs. θs are estimated coefficients as well.

On stationary series, the AR, MA, and ARMA methods are employed. Thus, a non-stationary process must be made stationary. In this instance, the initial series is referred to as a homogeneous non-stationary series. By taking the difference to a suitable degree, a non-stationary time series can be rendered stationary and follow the autoregressive integrated moving average [ARIMA (p, d, q)] processes. In this context, the letter d stands for integration (difference). Stationarity can be confirmed visually by inspecting the data graph, the structure of the autocorrelation, and the partial correlation coefficients. Unit root tests are another approach to assessing stationarity. If it is discovered that the model is non-stationary, differencing the series will bring it into stationarity. The unit root test Augmented Dickey-Fuller (ADF) [7] was employed in the study to attain this goal. In addition, autocorrelation function (ACF) and partial autocorrelation function (PACF) graphs were generated to visually define what type of development the series contained.

The identification procedure selects the initial values for the orders of parameters (p and q) after establishing whether the series is stationary. One or more models that appear to provide statistically adequate representations of the appropriate data are tentatively chosen during the identification step. The model's parameters are then carefully estimated using least squares.

For several AR and MA combinations, various models are run independently and simultaneously. The best model is determined by low Akaike (AIC) or Schwarz (SIC) information criteria, the absence of residual autocorrelations, and the relevance of the parameters. Akaike [1] and Schwarz [13] proposed information criteria to select between time series models. The delayed order with the lowest values is regarded as the proper delay order. Consequently, the model with the lowest value of the information criteria is selected.

RESULTS AND DISCUSSIONS

The development of Türkiye's aquaculture sector and its self-sufficiency assessment

As mentioned earlier, the different features of Türkiye's seas enable both capture and aquaculture. Table 1 shows the amounts of aquaculture products produced in Türkiye by capture and aquaculture methods between the years 2000 and 2021. While Türkiye produced 582,376 metric tonnes of aquaculture in 2000, it reached 799,844 metric tonnes in 2021, showing a 37.34% increase. During the same time span, while the amount of aquaculture produced by aquaculture increased approximately six-fold, the amount of aquaculture produced by capture methods decreased by 34.80%. The reasons for the decrease in aquaculture production via the capture method can be overfishing, improper capture, destruction of natural habitats, climate change, and pollution of waters due to chemicals and heavy metals. Among the reasons for the increase in aquaculture production via the aquaculture method can be an increase in aquaculture demand, advancements in technological tools and methods used for aquaculture, an increase in productivity, the high export potential of aquaculture, and aquaculture-friendly regulations. According to data from 2021 in Türkiye, while aquaculture production accounted for 58.97% of overall aquaculture production, capture production accounted for 41.03%. In the same year, 78.85% of the total aquaculture production was obtained from the seas and 21.15% from inland waters. Fish species constituted 95.66% of the total aquaculture production, and other aquaculture products constituted 4.34%.

Türkiye has a strong position in terms of capture, given its current water resources and potential. In this regard, the number of fish species obtained by the capture method is also quite high. Türkiye's capture potential is especially essential for aquaculture because fish meal and oil used in fish feed are derived from capture production [14]. In 2021, anchovies constituted approximately half of the overall production (328,158 metric tonnes), with a share of 46.20% of the total aquaculture production.

Table 1. Aquaculture and capture production amounts in Turkish aquaculture production

Year	Capture (tonnes)			Aquaculture (tonnes)			Overall
	Marine	Inland water	Total	Marine	Inland water	Total	Total
2000	460,521	42,824	503,345	35,646	43,385	79,031	582,376
2001	484,410	43,323	527,733	29,730	37,514	67,244	594,977
2002	522,744	43,938	566,682	26,868	34,297	61,165	627,847
2003	463,074	44,698	507,772	39,726	40,217	79,943	587,715
2004	504,897	45,585	550,482	49,895	44,115	94,010	644,492
2005	380,381	46,115	426,496	69,673	48,604	118,277	544,773
2006	488,966	44,082	533,048	72,249	56,694	128,943	661,991
2007	589,129	43,321	632,450	80,840	59,033	139,873	772,323
2008	453,113	41,011	494,124	85,629	66,557	152,186	646,310
2009	425,046	39,187	464,233	82,481	76,248	158,729	622,962
2010	445,680	40,259	485,939	88,573	78,568	167,141	653,080
2011	477,658	37,097	514,755	88,344	100,446	188,790	703,545
2012	396,322	36,120	432,442	100,853	111,557	212,410	644,852
2013	339,047	35,074	374,121	110,375	123,019	233,394	607,515
2014	266,078	36,134	302,212	126,894	108,239	235,133	537,345
2015	397,731	34,176	431,907	138,879	101,455	240,334	672,241
2016	301,464	33,856	335,320	151,794	101,601	253,395	588,715
2017	322,173	32,145	354,318	172,492	104,010	276,502	630,820
2018	283,955	30,139	314,094	209,370	105167	314,537	628,631
2019	431,572	31,596	463,168	256,930	116,426	373,356	836,524
2020	331,281	33,119	364,400	293,175	128,236	421,411	785,811
2021	295,018	33,140	328,158	335,644	136,042	471,686	799,844
2000=100	64.06	77.39	65.20	941.60	313.57	596.84	137.34

Source: Turkish Statistical Institute [15].

It is a common species in the seas off Türkiye. Anchovy populations may expand due to reproduction and rapid growth when compared to other fish. Sprat and horse mackerel accounted for 8.54% and 7.32% of the total aquaculture production, respectively (Figure 1).

Figure 2 shows the primary fish species farmed in Türkiye in 2021. The share of aquaculture products obtained through aquaculture in overall aquaculture production in Türkiye exceeded the share of aquaculture products obtained through capture.

Trout, sea bass, and sea bream took the first three places in aquaculture (471,686 metric tonnes) produced through aquaculture in Türkiye's seas and inland waters in 2021. The shares of these species were 35.47%, 32.89%, and 28.30%, respectively. The fish species in question constituted 96.66% of the total production.

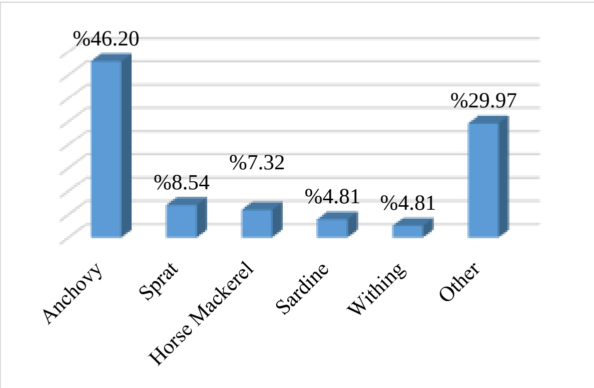

Fig. 1. The amount of capture production for the major fish species (tonnes)

Source: Graphed by the author using the data from Turkish Statistical Institute [15].

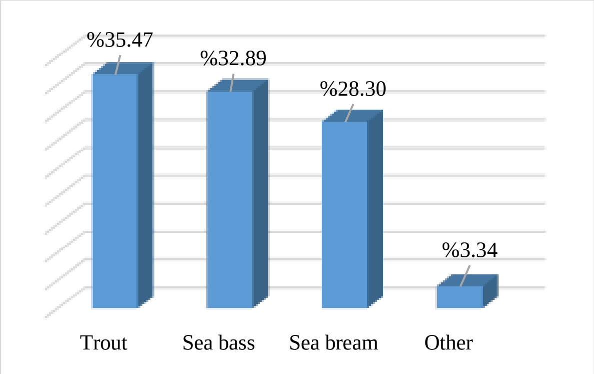

Fig. 2. The amount of aquaculture production for the major fish species (tonnes)
Source: Graphed by the author using the data from Turkish Statistical Institute [15].

The developments in Türkiye's foreign trade in aquaculture products are given in Table 2. As seen in the table, aquaculture product exports, which were 14,533 metric tonnes in 2000, increased 16.43 times and reached 238,732 metric tonnes in 2021.

The export value of aquaculture products increased 29.68 times in the same period, reaching 1.376 billion dollars.

The increase in Türkiye's aquaculture production was also reflected in exports. Incentives for exporters, in particular, were effective in increasing exports. While aquaculture product imports in Türkiye were 44,230 metric tonnes in 2000, they climbed 2.37 times to 104,708 metric tonnes in 2021. Regarding the import value of aquaculture products, it was approximately 37 million dollars in 2000 and increased by 5.93 times, reaching 217 million dollars in 2021.

Aquaculture consumption per capita and the self-sufficiency index in Türkiye are given in Table 3. While the per capita consumption of aquaculture products was 8.0 kilogrammes in 2000, it decreased by 17.75% to 6.6 kilogrammes in 2021.

Table 2. Aquaculture foreign trade in Türkiye

	Export		Import	
Year	Amount (tonnes)	Value ($)	Amount (tonnes)	Value ($)
2000	14,533	46,374,937	44,230	36,647,254
2001	18,978	54,487,312	12,971	11,295,373
2002	26,860	96,728,389	22,532	18,754,783
2003	29,937	124,842,223	45,606	32,636,120
2004	32,804	180,513,989	57,694	54,240,304
2005	37,655	206,039,936	47,676	68,558,341
2006	41,973	233,385,315	53,563	83,409,842
2007	47,214	273,077,508	58,022	96,632,063
2008	54,526	383,297,348	63,222	119,768,842
2009	54,354	318,063,028	72,686	105,822,852
2010	55,109	312,935,016	80,726	133,829,563
2011	66,738	395,306,914	65,698	173,886,517
2012	74,006	413,917,190	65,384	176,402,894
2013	101,063	568,207,316	67,530	188,068,388
2014	115,381	675,844,523	77,551	198,273,838
2015	121,053	692,220,595	110,761	250,969,660
2016	145,469	790,303,664	82,074	180,753,629
2017	156,681	854,731,829	100,444	230,111,248
2018	177,500	951,793,070	98,315	188,965,220
2019	200,226	1,025,617,723	90,684	189,438,745
2020	201,375	1,064,877,338	85,269	156,929,169
2021	238,732	1,376,291,922	104,708	217,179,174
2000=100	1642.69	2967.75	236.74	592.62

Source: Turkish Statistical Institute [16].

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Table 3. Aquaculture consumption per capita and self-sufficiency index in Türkiye

Year	Production	Consumption per capita (kg)	Import amount (tonnes)	Export amount (tonnes)	Self-sufficiency ratio
2000	582,376	8.0	44,230	14,533	95.15
2001	594,977	7.5	12,971	18,978	101.02
2002	627,847	6.7	22,532	26,860	100.69
2003	587,715	6.7	45,606	29,937	97.40
2004	644,492	7.8	57,694	32,804	96.28
2005	544,773	7.2	47,676	37,655	98.19
2006	661,991	8.2	53,563	41,973	98.28
2007	772,323	8.6	58,022	47,214	98.62
2008	646,310	7.8	63,222	54,526	98.67
2009	622,962	7.6	72,686	54,354	97.14
2010	653,080	6.9	80,726	55,109	96.23
2011	703,545	6.3	65,698	66,738	100.15
2012	644,852	7.1	65,384	74,006	101.36
2013	607,515	6.3	67,530	101,063	105.84
2014	537,345	5.5	77,551	115,381	107.64
2015	672,241	6.1	110,761	121,053	101.55
2016	588,715	5.5	82,074	145,469	112.07
2017	630,820	5.5	100,444	156,681	109.79
2018	628,631	6.1	98,315	177,500	114.41
2019	836,524	6.3	189,438	200,226	115.07
2020	785,811	6.8	156,929	201,375	117.30
2021	799,844	6.6	217,179	238,732	120.13

Source: Turkish Statistical Institute [16] and author's calculation.

A country's self-sufficiency ratio in aquaculture shows whether the amount produced in that country is sufficient to meet its needs. A self-sufficiency ratio of 100 or more indicates that the country is self-sufficient.

It is seen that Türkiye's self-sufficiency index in aquaculture products was at its lowest level at 95.15 in 2000. After 2010, a significant increase in the self-sufficiency ratio started and increased to 120.13 in 2021. This result shows that Türkiye is self-sufficient in aquaculture and has export potential in it.

Forecasting Türkiye's aquaculture production amounts with the ARIMA model

The annual time series from 1950 to 2021 was employed to forecast the amount of aquaculture production in Türkiye. While aquaculture production in Türkiye was 89,700 metric tonnes in 1950, it increased 8.92 times and reached 799,844 metric tonnes in 2021. The course of the 1950–2021 period used in estimating aquaculture production in Türkiye until 2031 with the ARIMA (Box–Jenkins) model is given in Figure 3.

Figure 3 shows how the amount of aquaculture production in Türkiye has fluctuated over time. Autocorrelation (ACF) and partial autocorrelation (PACF) graphs were used to see this more clearly and determine its stationarity.

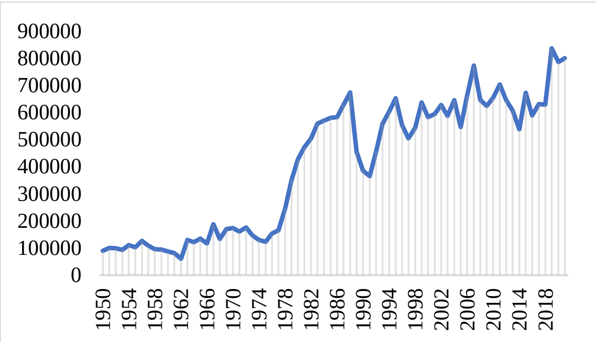

Fig. 3. Aquaculture production amount in Türkiye by years (tonnes)
Source: Food and Agricultural Organization [9] and Turkish Statistical Institute [15].

The series is not stationary in the ACF graph because several lags exceed the confidence limits. In this case, the series should be de-trended using the first- order difference to make it stationary. However, the series did not become stationary in the first-order difference process, and differentiation was repeated. The ACF and PACF graphs of the series with a second-degree difference are presented in Figure 4. In addition to visual inspection, statistical tests can be used to examine stationarity. Therefore, the Augmented Dickey-Fuller (ADF) test was used to determine if the series is stationary. The ADF test determines whether the series has a unit root. The existence of a unit root shows that the series is not stationary.

As a result of the ADF test at level, the series was not stationary. After taking the second difference, the ADF test revealed that the series was stationary; in other words, it did not contain a unit root. Thus, the degree of integration in the ARIMA (p, d, q) model was determined as I(2). When the ADF results of Türkiye's aquaculture production values were examined, it was clear that the series had a unit root since the absolute value of the test statistic (-0.897959) was less than the absolute critical values. P-value of 0.7835 in the analysis, so >0.05, indicates that the series is not stationary. For this reason, the series was made stationary by taking the differences before the estimation process. It was seen that the absolute value of the ADF test statistic (-9.093846) for the aquaculture production, which became stationary after the second-order differences were taken, was greater than the critical values. Also, a significance level (0.000) less than 0.05 indicates that the series becomes stationary and can be used for estimation with ARIMA (Table 4).

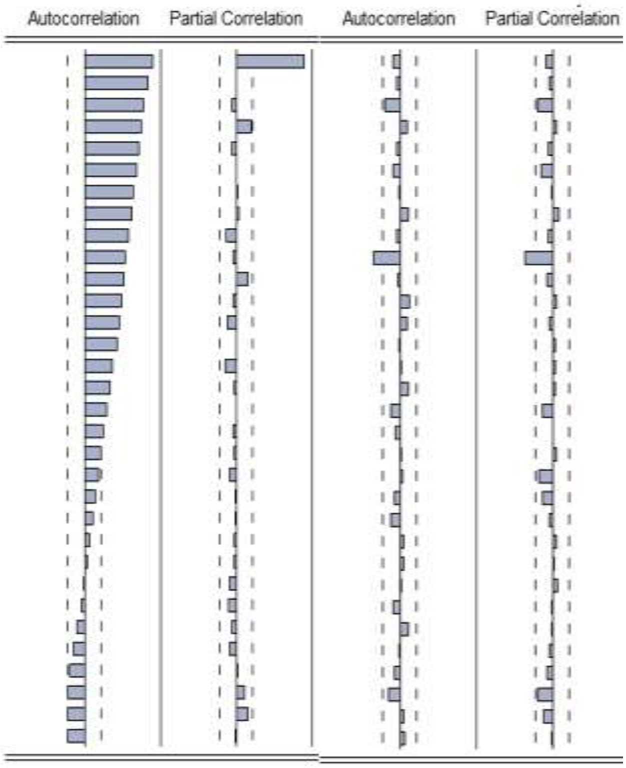

Fig. 4. ACF and PACF graphs of non-stationary and quadratic differenced series
Source: author's calculation.

Among the ARIMA models, the best statistical result was obtained with the ARIMA (1, 2, 2) model, which became stationary at the 2nd difference and showed that the 1st-order lag and 2nd-order error terms were related to their past values. Accordingly, all variables were found to be statistically significant, and the R-squared value of the model was 0.54 (Table 5).

The ADF unit root test was applied to the series of residual values to determine the accuracy of the model obtained, and the hypothesis "H0=there is a unit root" was rejected. Therefore, the model proved to be significant (Table 6).

Table 4. ADF unit root test results for aquaculture production

		t-statistic	p-value			t-statistic	p-value
I(0)		-0.897959	0.7835	I(2)		-9.093846	0.000
Critical values	1%	-3.525618		Critical values	1%	-3.531592	
	5%	-2.902953			5%	-2.905519	
	10%	-2.588902			10%	-2.590262	

Source: author's calculation.

Table 5. Results of the ARIMA (1, 2, 2) model of aquaculture production

TYPE	Coefficient	Std. error	p-value
C	95.93604	343.8059	0.7811
AR(1)	-0.999993	0.333938	0.0039*
MA(2)	-0.999272	0.016210	0.0000*
R-squared	0.543500		
F-statistics	26.19277		
AIC	25.16270		
SIC	25.29119		
HQ	25.21374		
Durbin Watson stat.	2.150504		

Source: author's calculation.

Table 6. ADF unit root tests for residuals of the aquaculture production estimation model

		t-statistic	p-value
		-8.830677	0.000
Critical values	1%	-3.528515	
	5%	-2.904198	
	10%	-2.589562	

Source: author's calculation.

The aquaculture production estimation results of the ARIMA (1, 2, 2) model are shown in Figure 5.

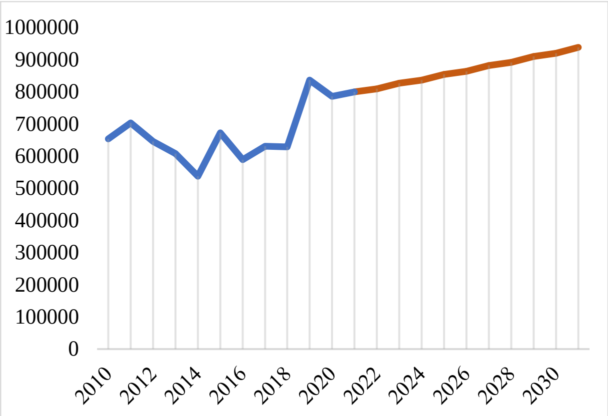

Fig. 5. Actual (1910-2021) and forecasted (2022-2031) data graphs for aquaculture production in Türkiye
Source: author's calculation.

The amount of aquaculture production in Türkiye is expected to increase between 2022 and 2031. Aquaculture production is projected to increase by 17.29% to 938,145 metric tonnes by 2031, from 799,844 metric tonnes in 2021 (Table 7).

Table 7. The aquaculture production forecast for the years 2022–2031 (tonnes)

Year	Predicted production
2022	809,124
2023	826,742
2024	836,208
2025	854,017
2026	863,674
2027	881,676
2028	891,525
2029	909,718
2030	919,760
2031	938,145

Source: author's calculation.

According to TSI's population projection research, Türkiye's population will be 88,929,672 in 2031 [17]. Because of the predicted increase in aquaculture productivity and population, it is thought that effective investment planning and production policies will be beneficial.

CONCLUSIONS

In terms of high protein and omega-3 fatty acids, aquaculture products are a significant source of nutrients in an adequate and balanced diet. Türkiye holds an important position in terms of available water resources and aquaculture production.

The total amount of aquaculture obtained through capture and aquaculture in Türkiye was 799,844 metric tonnes in 2021, of which 41.03% was obtained by capture and 58.97% by aquaculture. In the same period, 78.85% of total aquaculture production was obtained from the sea and 21.15% from inland waters. In 2021, 95.66% of the total aquaculture production in Türkiye was composed of fish species and 4.34% of other aquaculture products. The share of anchovy in the total aquaculture production (328,158 metric tonnes) in Türkiye in 2021 was 46.20%, while the shares of sprat and horse mackerel were 8.54% and 7.32%, respectively. Trout had a 35.47% share of overall aquaculture (471,686 metric tonnes), while sea bass and sea bream had 32.89% and 28.30%, respectively. Aquaculture consumption per capita in Türkiye was 6.6 kilogrammes in 2021.

After 2010, the self-sufficiency ratio of aquaculture production in Türkiye began to rise significantly, reaching 120.13 in 2021. Aquaculture production data from 1950 to 2021 was used in the ARIMA approach. Türkiye's aquaculture production has fluctuated. ACF and PACF graphs were employed to show this more clearly and determine its stationarity. The series was not stationary in the ACF graph because several lags exceeded the confidence limits. Also, the ADF unit root test indicates whether the series has a unit root. According to the ADF test results, the series contained a unit root, indicating that it was not stationary. Therefore, before the estimation phase, the aquaculture production series was converted to a stationary series using the second-order differencing approach. The ADF unit root test was employed for this, and the test statistic was -9.093846. The best statistical result was obtained with the ARIMA (1, 2, 2) model, as it remained stationary at the second difference and demonstrated that the first-order lag and second-order error terms were related to past values. All variables in the model were found to be statistically significant, and the model's R-squared value was 0.54.

According to the findings of the study, aquaculture production in Türkiye is predicted to expand during the next ten years. Aquaculture production was estimated to increase by 17.29% to 938,145 metric tonnes by 2031 from 799,844 metric tonnes in 2021. As a result of this foresight, it is thought that increasing aquaculture processing facilities and developing appropriate investment plans and production policies will be beneficial due to the expected increase in aquaculture production and Türkiye's population.

REFERENCES

[1]Akaike, H., 1974, A new look at the statistical model identification, IEEE Transactions on Automatic Control, 19(6): 716-723.
[2]Akdag, M., Yigit, V. 2016, Forecasting inflation with Box-Jenkins and artificial neural network models, Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi, 30(2): 269-283.
[3]Anonymous, 2012, Su ürünleri sektör raporu, West Mediterranean Development Agency.
[4]Ataseven, B., 2013, Forecasting by using artificial neural networks, Öneri Dergisi, 10(39): 101-115.
[5]Box, G. E. P., Jenkins, G. M., 1970, Time Series Analysis: Forecasting and Control. San Francisco, CA: Holden Day.
[6]Clapp, J., 2017, Food self-sufficiency: Making sense of it, and when it makes sense, Food Policy, 66: 88-96.
[7]Dickey, D. A., Fuller, W. A., 1979, Distribution of the estimators for autoregressive time series with a unit root, Journal of the American Statistical Association, 74: 427-431.
[8]FAO, 2016, The state of world fisheries and aquaculture 2016. Contributing to food security and nutrition for all. Rome. https://www.fao.org/3/i5555e/i5555e.pdf, Accessed on February 10, 2023.
[9]FAO, 2023, Food and Agricultural Organization of the United Nations, Statistics. https://www.fao.org/fishery/statisticsquery/en/ global_ production/global_production_quantity, Accessed on February 10, 2023.
[10]Fathelrahman, E., Davies, S., Muhammad, S., 2021, Food trade openness and enhancement of food security-partial equilibrium model simulations for selected countries, Sustainability, 13(8): 4107.
[11]Kiran, B., 2014, Time Series Analysis. Lecture Notes, Istanbul University Distance Education Application and Research Center.
[12]Ornekci, G.N., 2018, Keban baraj Gölü'ndeki su ürünleri yetiştiricilik işletmelerinin 2015 yılı yapısal ve ekonomik analizi, Master Diss., Munzur University, Science Institute, Tunceli.
[13]Schwarz, G., 1978, Estimating the dimension of a model. The Annals of Statistics, 461-464.
[14]TAGEM, 2019, Su ürünleri sektör politika belgesi 2019-2023, Republic of Türkiye Ministry of Agriculture and Forestry General Directorate of Agricultural Research and Policies, Ankara. https://www.tarimorman.gov.tr/TAGEM/Belgeler/yayin/Su%20%C3%9Cr%C3%BCnleri%20Sekt%C3%B6r%20Politika%20Belgesi%202019-2023.pdf, Accessed on March 02, 2023.

[15]TSI, 2023a, Turkish Statistical Institute, Aquaculture Statistics. https://biruni.tuik.gov.tr/medas/?kn=97&locale=tr, Accessed on February 15, 2023.
[16]TSI, 2023b, Turkish Statistical Institute, Foreign trade statistics. https://biruni.tuik.gov.tr/disticaretapp/disticaret.zul?param1=25&param2=0&sitcrev=0&isicrev=0&sayac=5802, Accessed on February 20, 2023.
[17]TSI, 2023c, Turkish Statistical Institute, Nüfus Projeksiyonları, 2013-2075. News Bulletin. https://data.tuik.gov.tr/Bulten/Index?p=Nufus-Projeksiyonlari-2013-2075-15844, Accessed on March 07, 2023.
[18]Valdesa, C., Hallahan, C., Harvey, D., 2015, Brazil’s broiler industry: Increasing efficiency and trade, International Food and Agribusiness Management Review, 18A: 263-275.
[19]Wegren, S. K., Elvestad, C., 2018, Russia’s food self-sufficiency and food security: an assessment, Post-Communist Economies, 30(5): 565-587.

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DETERMINANTS OF TECHNOLOGY ADOPTION IN CULTIVATION OF WINTER RICE IN ASSAM: AN ORDERED LOGIT ANALYSIS

Utpal Kumar DE, Ratna Kumari TAMANG

North-Eastern Hill University Shillong, Department of Economics, Shillong, India, 793022. Phones: +91-9436102066 (M), +91-9365949175, E-mails: utpalkde@gmail.com, ratnatamang670@gmail.com

Corresponding author: utpalkde@gmail.com

Abstract

The largest agrarian state in India's North-East, Assam exhibited varied growth of agrarian technology at regional level since 1950. The growth of modern technology in agriculture is expected to work as impetus to agricultural productivity and farmers' welfare. Adoption of technology such as improved seed variety and use of machine has resulted in increase in yield of winter rice. Striking difference in yield could be observed between adopters and non-adopters of technology. Ordered Logit model is applied to estimate the impacts of different factors on the adoption of agricultural technology. The result reveals that cultivated area, yield and the experience of farmers have significant positive impacts on the adoption of modern technology for the cultivation of winter rice. The findings are in support of building agrarian infrastructure and facilitation for adoption and suitable technological transformation for the enhancement of yield and sustainable agricultural progress.

Key words: *agricultural modernisation, winter rice, adoption of technology, ordered logit, yield*

INTRODUCTION

Adoption of technology in cultivation is important for increasing agricultural productivity, household income, and ultimately food security [21, 24, and 12]. Use of improved technology especially agro-implements helps completion of work at required pace, and with great precision that resulted in better output. However, application of such modern technology (seed-fertiliser-irrigation-implements) in some regions is adversely affected due to the fragmented land holdings, lack of capital and credit at the appropriate time that hinder use of tractors and other machines, lack of trained personnel, lack of cheap fuel, lack of necessary capital for investments significantly limit the use of machines [23 and 37]. Adoption of improved varieties generally has positive effects on yield and farmers' welfare. Adoption of modern technology is influenced by several other factors rather than land-labour ratio and responsible for growth of agriculture. Genesis of theories of development in agriculture both in developed and developing countries lay emphasis not only on evolution of farming system but also on other factors such as institutional, environmental, and social factors too [4]. Various institutional factors such as extension services, rental markets for farm machinery, and cooperatives play important roles in mechanisation of small-farms in South-Asian countries [7, 8 and 17].

Assam, the largest agrarian state in North-East India is blessed with various agro-climatic endowments and substantial agricultural diversities. The agroclimatic conditions of the state are very conducive for agricultural activity, mainly for the cultivation of rice. Rice is the staple food of the people of Assam and its importance is undeniable as the single most important crop. It shares 60.71 percent of gross cultivated area and 92.27 percent of the total food grown production of the state during 2020-21. Winter rice constitutes 78.96 percent of total rice production of the state. Though seed-fertiliser-irrigation technology in mainland India is over 5 decades old and that has been further modified with genetically modified seeds, organic culture in some places, its use is still at very low level in Assam and thus can be considered as modern technology in this state. The state has not yet registered noticeable growth in the use of modern technology in agriculture. Due to lack of such technological innovation, yield of crop is solely dependent upon natural fertility of soil and the toil of the farmers [36]. For the sustenance of long-term growth in agriculture reliance must be placed on the judicious use of progressive technology [11].

Green Revolution in India started in the mid-1960s when Indian agriculture was transformed into an industrial system due to gradual commercialisation process, adoption of farming technology as reflected from the increasing use of high yielding variety (HYV) seeds, tractors, irrigation facilities, pesticides, and fertilizers. Although Green Revolution led to an increase in food grain production, such development was confined only to a few states, like Punjab, Haryana. It reached Assam much later and very slowly. Comparing with other top paddy producing states of India (Punjab, Uttar Pradesh and West Bengal) in terms of area under irrigation, HYV rice, intensity of fertilizer use, availability of farm power, productivity of food grains and cropping intensity, Assam shows poor record in almost every section. In Assam HYV area of rice is about 70 percent of the total area under rice, while it is 100 percent in Punjab and about 76 percent all-India average as recorded in 2017-18.

In Assam 12.30 percent of total cropped area was under irrigation as against all India average of 51.90 percent during 2017-18 and it was the highest (99 percent) in Punjab. Per hectare consumption of fertilizer in Assam was only 73.70 kilogram as against 133.10 kilogram all India average and 224 Kg/hectare in Punjab. Availability of farm power per area (kW/ha) is also very less as compared to developed agricultural states, which is another indicator of farm modernisation having a positive relationship with productivity. Assam has 0.993 kW/ha farm power availability with yield of rice at 2,153 Kg/ha and cropping intensity of 147. While Punjab has 3,580 kW/ha farm power availability with the highest yield of rice at 4,132 Kg/ha and cropping intensity of 191. All India average farm power availability is however 2,025 kW/ha with cropping intensity being 145 and yield of rice at 2,638 Kg/ha.

Given the above scenario, productivity of rice in Assam is notably lower than that of all India average and agriculturally advanced states. Thus, it becomes pertinent to know the real status of application of modern technology in the agriculture of Assam and its effect on yield and output. Adopting newer technology, it is possible to attain sustainable yield growth and agricultural development. Application of improved varieties of seeds, synthetic fertilisers, scientific agricultural management, use of implements are essential for the continuous growth of productivity. Along with the utilisation of improved inputs, modern technology consists of integrated farm management practices such as application of organic fertiliser, intercropping, use of machine for levelling, and straight-row transplanting in case of rice. However, in Assam, modern method of cultivation has been limited to improved variety of rice and use of limited machine only. Use of agricultural technology requires capital, and not all the farmers are capable to adopt such technology. Lack of credit facility, market constraints such as information asymmetry, absence of effective agricultural extension services are reported in the study area. So, adoption of technology in this study have been contextualised with the use of HYV seeds and machinery. The objective of the paper is to analyse the factors responsible for adoption of modern farming technology in Assam.

Literature review

A brief review of literature on technology adoption, its determinants, and impacts have been emphasised in this section. However, introduction of improved variety alone does not boost yield. The core of Green Revolution was reliance on improved variety of seeds, application of fertilizer, and irrigated lands; the complete package which revolutionised the improvement of yield of crops in Asia [15]. [3] conducted study on adoption pattern of farmers in cultivation of improved variety of rice and sorghum in Burkina Faso and Guinea. Out of the various socio-economic factors, demographic and institutional factors taken under consideration, technological characteristics significantly affect the adoption decisions of improved variety of crops. Adoption of modern technology which is viewed as innovation with the introduction of new varieties of seeds, new types of fertilisers, or pesticides for adoption has brought changes in productivity and economic growth [35 and 38]. Adoption of improved varieties generally has resulted in increasing yield, and welfare of farmers by increasing household income, food security and reducing poverty [20, 21 and 44].

However, it is not that all farmers are in the position to adopt improved techniques. Determinants such as poor accessibility of information through extension services, supply side factors such as unavailability of quality seeds, fertilisers, and credit crunch are the constraints in adopting modern technology [39 and 9]. Besides risk aversion nature of farmers, inadequate farm size, insufficient human capital, inadequate incentives associated with farm tenure managements, and inappropriate infrastructure are also mentioned [14].

Adoption of improved variety does not always result in increased yield, but significant reduction in costs have increased the profitability for those who have adopted improved variety. Thus, adoption of improved variety is also done taken into consideration profitability, and efficiency aspects of farming as compared to traditional variety. Awareness of farmers with proper training facility about the improved variety, appropriate soil testing facility through extension services is the need of the hour [43]. Extension service is a critical part of decisions to adopt new agricultural practices [42]. However, such facilities are provided by the government and the public extension system is basically inefficient [40]. Satisfaction of farmers with the available extension services should be taken into consideration with the frequency of visits made by the extension agents, focused should also be placed taking into consideration not only on supply side but also demand driven approach of extension services [13].

Influence of social capital and networking of farmers is positive on the adoption of modern technology. Social capital represents the institutions, relationships, and norms that shape the quality and quantity of society's social interaction [42]. In the context of agricultural production, social capital basically represents the membership of farmers' association, the number of relatives the household can rely for support and seeking assistance which helps in adopting advanced technology and modern inputs [19].

Attainment of education helps farmers in increasing their resource base for the acquired knowledge and rising awareness about the benefits due to the adoption of modern technology. This would further encourage them to use extension services effectively [16]. Adoption affects the income of the household significantly and positively. Adoption of technology is capital intensive in nature, and thus households with higher incomes have more chances of adopting modern technology in comparison to the low-income households [41]. Accessibility to credit is also another determinant that facilitates adoption of modern technology; making use of timely inputs which they cannot afford as their resource base is small. Asset ownership such as livestock, family size, and land usually are proxies to explain wealth status which will help to increase their resource base, provide labour in times of need [6]. Besides, factors such as information asymmetry due to uncertainty of perceived benefits of adoption of such technology, environmental regulations, are some of the factors impeding the use of technology such as precision framing [46].

Access to market for input and output involves transaction costs. Transaction costs acts as negative impetus for participation in such markets and this explains the reason for market failure in developing countries [19, 20 and 5]. Agricultural intensification is typically power-intensive which helps in timely completion of agricultural operations such as land preparation, irrigation, and threshing too. Thus, mechanization helps to intensify agricultural production for agricultural development, it reduces the drudgery of farm labour, reduces cost of production, making farming attractive to the youth [10 and 31]. Small farmers have low resource base, thus availing machine on custom hiring basis will greatly be beneficial to use agricultural machinery [7 and 10].

MATERIALS AND METHODS

Data Sources

In Assam, average rainfall during the growing period of winter rice is 2,346 millimetres, and the mean temperature ranges between 21.98 ºC to 30.04 ºC. For the micro level analysis of technological adoption by farmers, primary data has been collected. Multi-stage sampling procedure is employed to select the sample units and collect data. Three districts are selected based on the intensity of HYV area of paddy, fertilizer consumption, and irrigation in terms of percentage of total area under cultivation as the best, average and worst. From each district, advanced and backward blocks are chosen by using the same method. From each chosen block, one village is selected by simple random sampling method for collecting primary information.

The following formula is used to determine the sample size for this study [18], which comes to around 384. But for the convenience and limitation of time, sample size has been kept at 300.

$$n_0 = \frac{z^2pq}{e^2} = \frac{(1.96)^2 * 0.5 * 0.5}{(0.05)^2} = 384 \dots \dots \dots (1)$$

where:

n_o is the sample size, z^2 is 95 percent confidence interval, p is the estimated proportion of an attribute that is present in the population, q is $1-p$ and e is the desired precision level.

Since the villages selected are more or less identical in size, 50 households from each village have been selected as final sample units from all the households by simple random sampling without replacement. Each selected household head is interviewed by using a schedule, which consisted of questions related to various socio-economic and demographic variables and agricultural activities e.g., age, occupation, income, educational level, land holding, ownership and tenancy, use of various agro-implements, area of crops and output.

Analytical Techniques

The model uses a set of technological attributes, farm-specific socio-economic characteristics and regional characteristics as explanatory variables which are assumed to influence farmers' level technology adoption. For each technology choice, the values are set as T_0H_0, m = 0; T_1H_0, m = 1; T_0H_1, m = 2; and T_1H_1, m = 3. Choice of the explanatory variables is based on the adoption status of modern technology. The dependent variable adoption of technology (m = 0, 1, 2, 3) is a combination of both use of tractor and HYV variety by the household. T_0H_0 – Household adopting traditional method of ploughing and traditional seed; T_1H_0 - Household adopting machine for ploughing with traditional winter paddy seed; T_0H_1 – for adopting traditional method of ploughing but HYV winter paddy seed; T_1H_1 – for adopting machine and HYV seed of winter paddy. The dependent variable in this analysis is an ordered categorical variable depicting farmers' decision-making processes to adopt technology and thus, an ordered response model is required [30]. Here, Ordered Logit model has been used to examine the impacts of adoption of various technologies, of farm-specific socio-economic and regional characteristics.

The model considered here can be written as:

$$Y_j = X_j\beta_j + u_j \dots \dots \dots\dots(2)$$

where:

$Y_j$is a $(N \times 1)$ vector of j^{th} adoption technology used by the households

α is the constant

$X_j$is a $(N \times k)$ matrix of explanatory variables

β_j is a $(k \times 1)$ vector of estimated coefficients for X_j

u_j is a $(N \times 1)$ vector of error terms $[\mu_j \sim n (0, \sigma^2{}_j)]$

The ordered logit model assumes an underlying latent (unobserved) variable Y_j*, such that:

$Y_j^* = X_j\beta_j + u_j$… … …......................... .... (3)
with $Y_j=0$ if $Y_j^* \leq 0$
$Y_j=1$ if $0<Y_j^* \leq \tau_1$
$Y_j=2$ if $\tau_1<Y_j^*< \tau_2$ and
$Y_j=3$ if $\tau_2 \leq Y_j^* < \tau_3$

where:
Y_j^* is the response variable and τ_j is the cut off-point or threshold that would indicate the level of inclination to adopt improved practices.
The probability associated with coded responses of an ordered probability model is as follows:

$Pr(Y_j=i) = Pr(\tau_{i-1} < Y_j^* \leq \tau_i) = Pr(\tau_{i-1} < X_j\beta_j + u_j \leq \tau_i)$ … … … ....(4)

where:
i represents the observation of adoption technology. The random error 'u_j' is such that:

$Pr(Y_j=i) = Pr(\tau_{i-1} < Y_j^* \leq \tau_i) = F(\tau_i - X_j\beta_j) - F(\tau_{i-1} - X_j\beta_j)$… … … ....(5)

In ordered logit, F(x) is specified as the logistic distribution function given by

$F(x) = \frac{exp(x)}{[1+exp(x)]}$ … … … ....(6)

Finally, the marginal effect of a unit increase of an independent variable for the i^{th} response can be expressed as

$\frac{\partial Pr[Y_j=i|X]}{\partial X_j} = \beta_j[F'(\tau_{i-1} - X_j\beta_j) - F'(\tau_i - X_j\beta_j)]$ ....
...(7)[26 and 45].

Explanatory Variables

The explanatory variables for this study is selected using information from the previous studies and priori expectations [3, 25, 33, 34 and 2]. The descriptions of the explanatory variables used in this model are given in Table 1. The dependent variable in this Ordered Logit model is status of adoption of technology ($ADOP_{TECH}$). The explanatory variable comprises of a set of both continuous and binary variables which represents household related, farm specific and extension related characteristics. It is hypothesised that age can positively or negatively related to adoption decision. There is no agreement in the literature regarding direction of the effect and it is purely location or technology specific [22 and 32]. Older farmers with experience in cultivation are able to assess the benefits of adoption of technology better than the younger farmers. However, older farmers are also more risk averse than the younger farmers so have lesser chance to adopt modern technology and take risk. Household specific characteristics e.g., sex of the head of household and household size would have positive or negative impact on the decision to adopt. Here sex of the head of household is considered to capture its social role.

Table 1. Description of Explanatory Variables

Description of Variables	Abbreviation	Expected Sign
Age of the household head (years)	AGE_{HH}	+/-
Sex of Household Head (Male =1)	SEX_{HH}	+/-
Education of Household head (years)	EDU_{HH}	+
Primary Occupation of head if cultivator (Yes =1)	$OCCUP_{HH}$	+
Farming Experience (Years)	*FRMEXP*	+
Training (Yes =1)	*TRAINING*	+
Yield (Kg/hectare)	*YIELD*	+
Access to Credit (Yes =1)	*CREDIT*	+
Total Livestock (Nos.)	*LVSTK*	-
Total Cultivable Land (Hectare)	*TOTLAND*	+
Total HH Income (Rs.)	INC_{HH}	+
Ownership of Land	$OWNSHP_{LAND}$	+
Proportion of Other HH Members Attended School	$EDUOTHH_{MEMBR}$	+
Distance to Input Market (Kms.)	*DIST*	-
Hired Labour Cost (Rs/hectare)	$PRICE_{WP}$	+

Note: Total Number of Observations = 300.
Source: Field survey, 2021-2022.

Generally, it is perceived that male headed farm households are often endowed with more resources than that of female headed. Education of the head of household and other members may positively influence technology adoption by the farmers as more education and experience exhibit more exposure to new ideas and help effectively making decision for adoption of technology [29].

Experience of farmers in adoption of technology is expected to be related to the ability of farmer to obtain, process and use information relevant to cultivation. Thus, it is hypothesised that a positive relationship would exist between experience and adoption of modern technology. Such positive relationship between experience and adoption of technology was also confirmed in the study of [3]. It is also hypothesised that training have positive impact in exposing farmers to new information related to technology and thus on adoption. Farmers with large farm size, higher yield and higher income are more likely to have positive significance on adoption of modern technology [27]. Of course, in return better technology used in cultivation would enhance yield, which may be suitably examined using a time series data. Livestock although is an asset for farmers but more livestock in the form of bullock, which if used in cultivation may lead to lesser adoption of mechanical devices (i.e., tractor). Access to credit is also expected to have positive influence on adoption of technology. Ownership of land and better occupation of household head are hypothesised to positively influence the decision to adopt modern farming technology. Farm owners are encouraged more than the tenants for adopting modern technology to derive own benefits. Distance to input market from home may have adverse effect on the chance of adoption of modern technology since proximity and availability of inputs in time would facilitate and thus chance of adoption of modern technology. It is also expected that cost on hired labour positively affect adoption of modern technology where normally hired labour is substituted by the machine labour.

RESULTS AND DISCUSSIONS

Descriptive Statistics

Table 2 and Table 3 display descriptive statistics of the socio-economic, farm related variables, and institutional characteristics of the respondents of the non-adopters, partial adopters, and adopters of technology. Mean age of household head is almost similar in terms of both non-adopter and adopter of technology. Mean years of schooling, farm experience, yield of winter rice, and income of the household are higher for adopter group as compared to the non-adopter and partial adopter of technology.

Table 2. Descriptive Statistics of Variables on Adoption of Technology

Variables	T_0H_0	T_1H_0	T_0H_1	T_1H_1	***All***
AGE_{HH}	44.28 (11.53)	40.27 (10.46)	47.68 (13.25)	46.92 (10.47)	46.54 (11.54)
SEX_{HH}	1 (0)	0.90 (0.29)	0.93 (0.24)	0.91 (0.27)	0.93 (0.26)
EDU_{HH}	7.35 (3.00)	8.90 (2.24)	8.62 (3.38)	9.41 (3.17)	9.04 (3.20)
$OCCUP_{HH}$	0.64 (0.49)	0.59 (0.50)	0.66 (0.47)	0.62 (0.48)	0.63 (0.48)
FRMEXP	23.57 (10.27)	20.45 (9.29)	23.43 (9.69)	24.78 (9.06)	23.99 (9.36)
TRAINING	0.14 (0.36)	0.04 (0.21)	0.10 (0.31)	0.12 (0.33)	0.11 (0.32)
YIELD	314.29 (74.49)	325 (71.96)	498.69 (176.16)	539.70 (181.07)	500.86 (183.24)
CREDIT	0 (0)	0 (0)	0.17 (0.38)	0.19 (0.39)	0.16 (0.37)
LVSTK	8 (2)	7 (2)	8 (4)	7 (3)	7 (3)
TOTLAND	5.98 (6.13)	4.43 (1.77)	10.31 (21.11)	10.25 (8.91)	9.65 (13.63)
Small	0.85 (0.36)	0.95 (0.21)	0.65 (0.47)	0.44 (0.49)	0.56 (0.49)
Large	0.14 (0.36)	0.04 (0.21)	0.35 (0.47)	0.55 (0.49)	0.43 (0.49)
INC_{HH}	16,800.5 (6,125.84)	18,396.91 (22,762.05)	37,605.24 (36,857.93)	52,072.28 (49,575.49)	43,520.18 (44,606.93)
$OWNSHP_{LAND}$	1.21 (0.42)	1.13 (0.35)	1.31 (0.57)	1.33 (0.54)	1.31 (0.53)
$EDUOTHH_{MEMBR}$	0.88 (0.14)	0.88 (0.15)	0.94 (0.11)	0.94 (0.12)	0.93 (0.12)
DIST	10 (11.65)	12.18 (12.00)	5.73 (8.30)	4.59 (7.70)	5.75 (8.69)
$HRDLABOR_{COST}$	686.35 (750.11)	682.95 (747.35)	942.56 (674.89)	962.40 (638.16)	923.25 (665.67)
No of Observation	14	22	92	172	300

Note: Figures in parentheses represent standard deviation.
Source: Field survey, 2021-2022.

Adopter group is significantly distinguishable in terms of access to credit facility, total land size, and distance to input market.

However, cost on hired labour also differs between the categories of farmers with varied adoption of modern technology. Adopters of technology have nearest distance to input market as compared to non-adopters and partial adoption of technology.

Table 3. Descriptive Statistics of the Variables

Variables	*Mean*	*Std. Dev.*	*Min*	*Max*
AGE_{HH}	46.54	11.54	22	75
SEX_{HH}	0.92	0.26	0	1
EDU_{HH}	9.04	3.20	0	17
$OCCUP_{HH}$	1.52	0.78	1	4
FRMEXP	23.99	9.36	5	50
TRAINING	0.11	0.31	0	1
YIELD	500.86	183.24	200	800
$MECH_{COST}$	229.16	177.97	0	500
CREDIT	0.16	0.37	0	1
LVSTK	7	3.09	0	20
$TOTLAND_{SIZE}$	9.64	13.63	2.25	203
Small	0.56	0.49	0	1
Large	0.43	0.49	0	1
INC_{HH}	43,520	44,605	4,291	303,758
$OWNSHP_{LAND}$	1.31	0.53	1	3
$EDUCN_{MEMBRS}$	0.93	0.12	0	1.25
$DIST_{MRKT}$	5.75	8.69	1	25
$HRDLABOR_{COST}$	923.25	665.66	0	3,250

Source: Estimated from Field Survey, 2021-2022.

Adoption status of Modern Technology and Yield

It is observed that 57.33 percent of the respondents are adopters of both machine and HYV variety of winter rice, while only 4.66 percent of the respondents are non-adopters of technology and rest are medium adopters. Yield of winter paddy is higher for adopter of technology than the non-adopter of technology by 71.72 percent. It is 58.67 percent more when the farmers adopt only improved variety of seeds, and is increased by 3.40 percent when the farmers adopt only machine (Table 2). This supports the findings of [3] who has shown that adoption of technology increases yield.

Factors Affecting Adoption

The results of ordered logit model are portrayed in Table 5. The model χ^2 is statistically significant at 1 percent level. The estimated model has a pseudo R^2 value of 0.107, which indicates that 10.70 percent of the variation in modern technology adoption is explained by the explanatory variables. Table 4 displays the bivariate correlation among the explanatory variables. Hardly any significant correlation between any two variables is revealed excepting the correlation between the age and experience. Therefore, all the explanatory variables are considered in the model for analysis.

Among the explanatory variables, three have significant positive impacts on the modern technology adoption for the cultivation of winter rice in Assam. Coefficients of land size (area under winter rice), yield of winter rice, and farmers' experience are significant positive. On the other hand, coefficient of livestock is significant negative. The other variables like education of the head of household and other family members, household income, land ownership, and cost on hired labour also positively affect the level of adoption but not significantly.

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Table 4. Correlation Matrix

Variables	AGE_{HH}	SEX_{HH}	EDU_{HH}	$OCCUP_{HH}$	FRMEXP	TRAINING	YIELD	CREDIT	LVSTK	$TOTLAND_{SIZE}$	INC_{HH}	$OWNSHP_{LAND}$	$EDUCN_{MEMBRS}$	$DIST_{MRKT}$
AGE_{HH}	1.000													
SEX_{HH}	-0.020	1.000												
EDU_{HH}	0.037	0.315	1.000											
$OCCUP_{HH}$	-0.130	-0.081	-0.195	1.000										
FRMEXP	0.802	-0.020	0.061	-0.146	1.000									
TRAINING	0.003	-0.020	0.038	0.097	0.036	1.000								
YIELD	0.103	0.025	0.153	0.161	-0.031	0.020	1.000							
CREDIT	0.122	0.022	0.058	0.006	0.125	0.122	0.243	1.000						
LVSTK	-0.067	0.103	-0.127	0.116	-0.012	-0.085	-0.015	0.034	1.000					
$TOTLAND_{SIZE}$	0.141	0.039	0.155	0.093	0.152	0.111	0.408	0.385	0.047	1.000				
INC_{HH}	0.178	0.101	0.396	-0.212	0.192	0.083	0.449	0.247	-0.180	0.355	1.000			
$OWNSHP_{LAND}$	-0.061	-0.052	-0.032	0.117	-0.094	0.028	0.182	0.125	-0.008	0.146	-0.030	1.000		
$EDUCN_{MEMBRS}$	0.027	0.063	0.181	-0.087	0.059	0.005	0.074	0.005	0.137	0.108	0.044	-0.014	1.000	
$DIST_{MRKT}$	-0.107	-0.069	-0.078	0.212	-0.038	0.220	-0.481	-0.090	-0.008	-0.219	-0.224	0.047	-0.276	1.000
$HRDLABOR_{COST}$	-0.030	-0.013	0.008	0.258	0.036	0.195	0.365	-0.045	-0.100	-0.058	0.117	0.071	-0.245	0.263

Source: Estimated from Field Survey, 2021-22.

The odds ratio of farmers experience is 1.049, which means that with a unit increase of experience of farmers, adoption of technology is increased by 1.049 times as compared to non- and partial adoption of technology, keeping all other factors constant. When the size of land is large, the odds of adoption of technology increases by 2.666 times as compared to non-adoption and partial adoption of technology keeping other variables constant. For one unit increase in yield of winter paddy, the adoption of technology increases by 1.002 times as compared to partial and non-adoption. Similarly, when livestock increases by one unit, the odds of adoption of modern technology decreases by 0.902 times as compared to non-adopters and partial adopters of technology.

Table 5. Estimates of Ordered Logit Regression

Variables	***Coefficient***	***Odds Ratio***	***Z-Score***
AGE_{HH}	-0.029 (0.179)	0.971 (0.017)	-1.62
SEX_{HH}	-0.638 (0.516)	0.527 (0.272)	-1.24
EDU_{HH}	0.045 (0.043)	1.046 (0.046)	1.03
$OCCUP_{HH}$	-0.145 (0.288)	0.864 (0.249)	-0.51
FRMEXP	0.047** (0.023)	1.049** (0.024)	2.02
TRAINING	-0.032 (0.432)	0.967 (0.418)	-0.08
YIELD	0.002* (0.001)	1.002* (0.001)	1.95
CREDIT	-0.104 (0.391)	0.900 (0.352)	-0.27
LVSTK	-0.103** (0.041)	0.902** (0.037)	-2.50
$TOTLAND_{SIZE}$ (Base -Small)			
Large	0.980*** (0.309)	2.666*** (0.824)	3.17
INC_{HH}	0.00001 (0.00004)	1.000 (0.00004)	0.44
$OWNSHP_{LAND}$	0.102 (0.236)	1.107 (0.262)	0.43
$EDUCN_{MEMBRS}$	1.384 (1.061)	3.992 (4.236)	1.30
$DIST_{MRKT}$	-0.018 (0.020)	0.981 (0.019)	-0.94
$HRDLABOR_{COST}$	0.0002 (0.0002)	1.002 (0.0002)	0.98
Threshold 1	-1.445 (1.314)		1.099
Threshold 2	-0.311 (1.309)		0.237
Threshold 3	1.674 (1.317)		1.271
LR $Chi^2(15)$	65.45		
Log likelihood	-272.08		
Pseudo R^2	0.107		
No. of Observations	300		

Notes: Figures in parentheses represent standard error; ***, **, and * indicate significance at 1%, 5% and 10% respectively.

Source: Estimated from Field Survey, 2021-2022.

Results of Ordered Logit model are further analysed to explain average marginal effects on dependent variable of non-adopter, partial adopter, and adopter of technology in cultivation of winter rice (Table 6). The average marginal effects for farmer experience indicates that a unit increase in experience of framers would decrease the likelihood of being non-adopter and partial adopter of modern technology by 0.002 and 0.004 percent respectively. Whereas, in case of adopters of modern technology, one unit increase in experience of farmers would increase the likelihood of being adopter of technology by 0.009 percent. A more experienced farmer appears to be more knowledgeable and thus likely to adopt technology.

Marginal effect of land size of large category suggests that large farm size decreases the likelihood of being a non-adopter of technology by 0.035 and partial adopter of technology by 0.005 percent for tractor and 0.118 percent for HYV variety respectively. The large size category farmers have chance of adopting modern technology significantly more than the small o marginal farmers. This finding resonates with the literature that farm size and adoption of modern technology are positively related [28 and 1].

The marginal effect of yield of winter paddy indicates that a unit increase in yield would decrease the likelihood of being non-adopter and partial adopter by 0.0001, and 0.0002 percent respectively. On the other hand, such likelihood of being an adopter of technology increases by 0.004 percent. Coefficient of yield is positive for adopter and significant, indicating that higher yield leads to better adoption of technology. As seen from the descriptive statistics (Table 2), yield of winter rice is higher for adopter so they likely use more machine, tools and improved variety of seeds to further raise yield. Use of machine helps timely tilling where farmers must complete sowing fast to avail monsoon. Hence adopting tractor/power tiller for preparing land for sowing helps timely completion of activities and raise earning through enhanced yield. The result is similar to that of findings by [3].

Table 6. Results of Marginal Effects

Variables	***Prob(Y=0/X)***	***Prob(Y=1/X)***	***Prob(Y=2/X)***	***Prob(Y=3/X)***
AGE_{HH}	0.001 (0.0008)	0.001 (0.001)	0.002 (0.001)	-0.005 (0.003)
SEX_{HH}	0.027 (0.023)	0.036 (0.029)	0.062 (0.050)	-0.126 (0.101)
EDU_{HH}	-0.001 (0.001)	-0.002 (0.002)	-0.004 (0.004)	0.008 (0.008)
$OCCUP_{HH}$	0.006 (0.124)	0.008 (0.016)	0.014 (0.028)	-0.028 (0.056)
FRMEXP	-0.002***** (0.001)	-0.002***** (0.001)	-0.004****** (0.002)	0.009****** (0.004)
TRAINING	0.001 (0.185)	0.001 (0.024)	0.003 (0.042)	-0.006 (0.085)
YIELD	-0.0001***** (0.00005)	-0.0001***** (0.00007)	-0.0002****** (0.0001)	0.0004****** (0.0002)
CREDIT	0.0044 (0.002)	0.005 (0.022)	0.010 (0.038)	-0.020 (0.077)
LVSTK	0.004****** (0.002)	0.005****** (0.002)	0.010****** (0.004)	-0.020****** (0.007)
***TOTLAND**SIZE*				
Large	-0.035******* (0.012)	-0.005******* (0.017)	-0.118******* (0.042)	0.205******* (0.064)
INC_{HH}	-0.000007 (0.000001)	-0.000001 (0.000002)	-0.000001 (0.000004)	-0.000003 (0.000008)
$OWNSHP_{LAND}$	-0.004 (0.010)	-0.005 (0.013)	-0.010 (0.023)	0.020 (0.046)
$EDUCN_{MEMBRS}$	-0.059 (0.047)	-0.078 (0.060)	-0.135 (0.105)	0.273 (0.208)
$DIST_{MRKT}$	0.0008 (0.0008)	0.001 (0.001)	0.001 (0.001)	-0.003 (0.003)
$HRDLABOR_{COST}$	-0.00001 (0.00001)	-0.00001 (0.00001)	-0.00002 (0.00002)	0.00004 (0.00005)

Notes: Figures in parentheses represent standard error; *******, ******, and ***** indicate significance at 1%, 5% and 10% respectively.
Source: Estimated from Field Survey, 2021-22.

Coefficient of marginal effect of livestock reveals an increase in likelihood of being non-adopter by 0.004 percent and partial adopter of technology by 0.005 and 0.010 percent respectively for tractor and HYV seeds. Whereas, likelihood of adopting overall technology decreases by 0.020 for adopter. The possible reason is that when farmers have livestock, they use bullocks for cultivation and use the organic manure.

CONCLUSIONS

Determinants of decision to adopt modern technology in agriculture to raise yield and revenue is influenced by several factors. The result of Ordered Logit model showed that farmers' decision of technology adoption is influenced by the level of farmers experience. The other significant factor is farm size of large category. Such results, lend support to the earlier findings of [28 and 1] on large farm size having positive impact on adoption of modern technology. Higher yield has also been found to be significant in facilitating the decision of the farmers to adopt modern technology. Also experience of farmers has significant positive impact on adoption of technology. With more experience farmers are likely to adopt technology. This finding supports the findings of [3].

Emphasis thus should be laid on the progress of modern technology in agriculture which leads to increase in yield of crops through more use of fertilizer and machine and ease up the cultivation activities through mechanization. As can be seen that those adopting technology have higher yield than that of non-adopter. Technological breakthrough is very crucial to benefit the farmers in the long run. However, risk-averse nature of farmers, meagre facility of extension services, lack of capital, ignorance, and prejudice are the possible reasons for such slow and uneven progress of modernisation of farms in Assam.

Although cultivated area has positive significant association with adoption of modern technology, in the study area majority of farmers are small and semi-medium. Further, farming is done mainly for subsistence and self-consumption. So, they mostly concern for the appropriate use of their limited resources instead of focusing on modern technology. It is thus a serious challenge to policy makers for promoting modern technology in agriculture.

REFERENCES

[1]Abara, I.O.C., Singh, S., 1993, Ethics and Biases in Technology Adoption: The Small-Firm Argument. Technological Forecasting and Social Change.Vol.43(3-4): 289-300.

[2]Addison, M., Anyomi, B. K., Acheampong, P. P., Wongnaa, C. A., Amaning, T. K., 2023, Key Drivers of Adoption Intensity of Selected Improved Rice Technologies in Rural Ghana. Scientific African.Vol.19: e01544.

[3]Adesina, A. A., Baidu-Forson, J., 1995, Farmers' Perceptions and Adoption of New Agricultural Technology: Evidence from Analysis in Burkina Faso and Guinea, West Africa. Agricultural Economics. Vol.13(1): 1-9.

[4]Adu-Baffour, F., Daum, T., Birner, R., 2019, Can Small Farms Benefit from Big Companies' Initiatives to Promote Mechanization in Africa? A Case Study from Zambia. Food Policy. Vol.84: 133-145.

[5]Addisu, S., Fissha, G., Gediff, B., Asmelash, Y., 2016, Perception and Adaptation Models of Climate Change by the Rural People of Lake Tana Sub-Basin, Ethiopia. Environmental Systems Research. Vol.5(1): 1-10.

[6]Ali, D. A., Deininger, K., 2012, Causes and Implications of Credit Rationing in Rural Ethiopia: The Importance of Spatial Variation. World Bank Policy Research Working Paper, (6096).

[7]Aryal, J. P., Mehrotra, M. B., Jat, M. L., Sidhu, H. S., 2015, Impacts of Laser Land Leveling in Rice–Wheat Systems of the North–Western Indo-Gangetic Plains of India. Food Security. Vol.7(3): 725-738.

[8]Aryal, J. P., Maharjan, S., Erenstein, O., 2019, Understanding Factors Associated with Agricultural Mechanization: A Bangladesh Case. World Development Perspectives. Vol.13: 1-9.

[9]Asfaw, S., Shiferaw, B., Simtowe, F., Lipper, L., 2012, Impact of Modern Agricultural Technologies on Smallholder Welfare: Evidence from Tanzania and Ethiopia. Food Policy. Vol.37(3): 283-295.

[10]Biggs, S., Justice, S., 2015, Rural and Agricultural Mechanization: A History of the Spread of Small Engines in Selected Asian Countries. Development Strategy and Government Decision, IFPRI Discussion Paper No. 01443. Washington D.C.: International Food Policy Research Institute (IFPRI).

[11]Bezbaruah, M. P., 1994, Technological Transformation of Agriculture: A Study of Assam. Mittal Publications.

[12]Biru, W.D., M. Zeller, M., Loos, T.K., 2020, The Impact of Agricultural Technologies on Poverty and Vulnerability of Smallholders in Ethiopia: A Panel Data Analysis. Social Indicators Research.Vol.147:517-544.

[13]Elias, A., Nohmi, M., Yasunobu, K., Ishida, A., 2015, Farmers' Satisfaction with Agricultural

Extension Services and Its Influencing Factors: A Case Study in North West Ethiopia. Journal of Agricultural Science Technology.Vol.18: 39-53.

[14]Feder, G., Just, R.E., Zilberman, D., 1985, Adoption of Agricultural Innovations in Developing Countries: A Survey. Economic Development and Cultural Change.Vol.33(2): 255-298.

[15]Hayami, Y., Ruttan, V.W., 1985, Agricultural Development: An International Perspective. Baltimore, MD: Johns Hopkins University Press.

[16]Hegde, N. G., 2005, Traditional Extension Methods in Modern Agriculture. Indian Farming Special Issue on World Food Day. 45-47.

[17]Justice, S., Biggs, S., 2020, The Spread of Smaller Engines and Markets in Machinery Services in Rural Areas of South Asia. Journal of Rural Studies. Vol.73: 10-20.

[18]Kanyenji, G. M., Oluoch-Kosura, W., Onyango, C. M., Karanja Ng'ang'a, S., 2020, Prospects and Constraints in Smallholder Farmers' Adoption of Multiple Soil Carbon Enhancing Practices in Western Kenya. Heliyon. Vol. 6(3): 1-10.

[19]Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., Mekuria, M., 2013, Adoption of Interrelated Sustainable Agricultural Practices in Smallholder Systems: Evidence from Rural Tanzania. Technological Forecasting and Social Change. Vol.80(3): 525-540.

[20]Kassie, M., Teklewold, H., Marenya, P., Jaleta, M., Erenstein, O., 2015, Production Risks and Food Security under Alternative Technology Choices in Malawi: Application of A Multinomial Endogenous Switching Regression. Journal of Agricultural Economics. Vol.66(3): 640-659.

[21]Kassie, M., Marenya, P., Tessema, Y., Jaleta, M., Zeng, D., Erenstein, O., Rahut, D., 2018, Measuring Farm and Market Level Economic Impacts of Improved Maize Production Technologies in Ethiopia: Evidence from Panel Data. Journal of Agricultural Economics.Vol.69(1): 76–95.

[22]Kebede, Y., Gunjal, K., Coffin, G., 1990, Adoption of New Technologies in Ethiopian Agriculture: The Case of Tegulet-Bulga District, Shoa Province. Agricultural Economics. Vol.4(1): 27-43.

[23]Khan, M.H., 1970, Mechanization in West Pakistan World Crops. Indian Journal of Agricultural Economics.Vol.22(1): 23-25.

[24]Khonje, M. G., Manda, J., Mkandawire, P., Tufa, A. H., Alene, A. D., 2018, Adoption and Welfare Impacts of Multiple Agricultural Technologies: Evidence from Eastern Zambia. Agricultural Economics. Vol.49(5): 599-609.

[25]Kumar, G., Engle, C., Tucker, C., 2018, Factors Driving Aquaculture Technology Adoption. Journal of the World Aquaculture Society. Vol.49(3): 447-476.

[26]Mallick, D., 2009, Marginal and Interaction Effects in Ordered Response Models. MPRA paper No. 13325.

[27]Martin, S. W., Roberts, R. K., Larkin, S. L., Larson, J. A., Paxton, K. W., English, B. C., Marra, M.C., Reeves, J. M., 2008, A Binary Logit Estimation of Factors Affecting Adoption of GPS Guidance Systems by Cotton Producers. Journal of Agricultural and Applied Economics. Vol.40(1): 345-355.

[28]McNamara, K. T., Wetzstein M. E., Douce G.K., 1991, Factors Affecting Peanut Producer Adoption of Integrated Pest Management. Review of Agricultural Economics.Vol.13: 129-139.

[29]Mishra, A. K., El-Osta, H. S., Morehart, M. J., Johnson, J. D., Hopkins, J. W., 2002, Income, Wealth, and the Economic Well-Being of Farm Households. Washington DC: U.S. Department of Agriculture, Economics Research Service, Agricultural Economic Report Number 812.

[30]Pfarr, C., Schmid, A., Schneider, U., 2010, Estimating Ordered Categorical Variables Using Panel Data: A Generalized Ordered Probit Model with an Autofit Procedure. https://ssrn.com/abstract=1624954, Accessed on June 1st, 2023.

[31]Pingali, P., 2007, Agricultural Mechanization: Adoption Patterns and Economic Impact. Handbook of Agricultural Economics, Vol. 3: 2779-2805.

[32]Polson, R. A., Spencer, D. S., 1991, The Technology Adoption Process in Subsistence Agriculture: The Case of Cassava in South Western Nigeria. Agricultural Systems. Vol.36(1): 65-78.

[33]Rahman, S., 2003, Environmental Impacts of Modern Agricultural Technology Diffusion in Bangladesh: An Analysis of Farmers’ Perceptions and their Determinants. Journal of Environmental Management.Vol.68: 183-191.

[34]Rahman, M. S., Kazal, M. M. H., Rayhan, S. J., 2020, Improved Management Practices Adoption and Technical Efficiency of Shrimp Farmers in Bangladesh: A Sample Selection Stochastic Production Frontier Approach. Bangladesh Journal of Agricultural Economics. Vol. 41(1): 47-58.

[35]Ruttan, V. W., 2000, Technology, Growth and Development: An Induced Innovation Perspective. OUP Catalogue.

[36]Sarmah, G. N., Das, D. K., 2012, Micro finance, self-help groups (SHGS) and the Socio-Economic development of rural people (A case study with special reference to the Lakhimpur district of Assam). Asian Journal of Research in Business Economics and Management. Vol.2(4): 145-159.

[37]Selvaraj, P., Sundaresan, R., 1972, Farm Mechanization Problems and Possibilities in Farm Mechanization. Fact. Vol.6(3): 34-35.

[38]Shiferaw, B., Prasanna, B. M., Hellin, J., Bänziger, M., 2011, Crops that Feed the World 6. Past Successes and Future Challenges to the Role Played by Maize in Global Food Security. Food Security. Vol.3: 307-327.

[39]Suri, T., 2011, Selection and Comparative Advantage in Technology Adoption. Econometrica.Vol.79(1): 159-209.

[40]Takahashi, K., Muraoka, R., Otsuka, K., 2020, Technology Adoption, Impact, and Extension in Developing Countries’ Agriculture: A Review of the Recent Literature. Agricultural Economics.Vol.51: 31-45.

[41]Wollni, M., Lee, D. R., Thies, J. E., 2010, Conservation Agriculture, Organic Marketing, And

Collective Action in the Honduran Hillsides. Agricultural Economics. Vol.41(3-4): 373-384.

[42]World Bank, 2010, Gender and Governance in Rural Services: Insights from India, Ghana, and Ethiopia. Washington DC, United States: World Bank Publications & International Food Policy Research Institute.

[43]Yamano, T., Luz, M., Habib, A., Kumar, S., 2018, Neighbours Follow Early Adopters under stress: Panel Data Analysis of Submergence-tolerant rice in Northern Bangladesh. Agricultural Economics.Vol.49: 313-323.

[44]Zeng, D., Alwang, J., Norton, G. W., Shiferaw, B., Jaleta, M., Yirga, C., 2017, Agricultural Technology Adoption and Child Nutrition Enhancement: Improved Maize Varieties in Rural Ethiopia. Agricultural Economics. Vol.48(5): 573-586.

[45]Zeng, Q., Gu, W., Zhang, X., Wen, H., Lee, J., Hao, W., 2019, Analyzing Freeway Crash Severity Using a Bayesian Spatial Generalized Ordered Logit Model with Conditional Autoregressive Priors. Accident Analysis & Prevention. Vol.127: 87-95.

[46]Zhang, N., Wang, M., Wang, N., 2002, Precision Agriculture—A Worldwide Overview. Computers and Electronics in Agriculture. Vol.36(2-3): 113-132.

DEVELOPMENT OF SEED DRILL MACHINE TO CULTIVATE RICE GRAINS IN HILLS BETWEEN FURROWS

Asaad DERBALA[1], Adel ELMETWALLI[1], El-Amine ARIF[2], Hany HASHEM[2], Mohamed I. EL-DIDAMONY*[1]

[1]Tanta University, Faculty of Agriculture, Agriculture Engineering Department, Tanta 31527, Egypt, Emails: asaadderbala@yahoo.com, agri.mid@gmail.com
[2]Agricultural Engineering Research Institute (AEnRI), Agricultural Research Center (ARC), Giza 12611, Egypt, Email: hh_atef@yahoo.com

Corresponding author: hh_atef@yahoo.com, hanyatef_152392@agr.tanta.edu.eg

Abstract

Rice is one of the strategic crops in Egypt and the world. Therefore, the main objective of the research was to modify and develop the seed drill to suit the cultivation of rice and add the digger to make a path for the cultivation area to direct the irrigation water. The modification and development were done in the workshop of the Rice Mechanization Center (RMC) in Kafr El-Sheikh Governorate, and field experiments were carried out on the rice variety "Sakha Super 300" with the planting seasons 2021 and 2022. The field experiments were carried out using the modified hill seed drill under four different planting forward speeds, namely, 2.55, 4.01, 6.11, and 8.38 km/h.; three different hills spacing between within the row, namely, 12.5, 15.5 and 17.5 cm; and three different cell volumes of feeding rollers namely, 354, 428 and 509 mm^3 with a fixed depth of 6 mm. The results showed that when the forward speed of cultivation increased, the field capacity increased and power requirements, and a decrement percentage in field efficiency and energy consumption at any given load for modified hill drill. The minimum values of grain yield (3.45, 3.41, and 2.94 Mg/fed) were obtained at planting forward speed of 8.38 km/h., for grain cell volume of 354 mm^3 under 12.5, 15, 17.5 cm hill spacing, respectively. However, the maximum values of grain yield (4.79, 4.74, and 4.34 Mg/fed) were obtained at planting forward speed 2.55 km/h., and grain cell volume of 509 mm3 under 12.5, 15, and 17.5 cm hill spacing, respectively.

Key words**:** *direct-seeded rice, rice grain hill drill, hill spacing, planting rice in furrow*

INTRODUCTION

More than half of the population in Egypt depends on rice (Oryza sativa L.), making it one of the most significant crops in that country. An imputed value of 1.186235 million feddan of Egypt's rice areas are cultivated, yielding 4.84 million metric tonnes annually [7]. Mechanized rice planting methods can be divided into two categories: direct seeding and transplanting [1]. Direct-seeded rice DSR is an alternative cultivation technique to conventionally transplanted rice. It does not require seedlings due to sow seeds directly in the field and eliminating the need for nursery raising and its related processes [24]. DSR can generally be divided into dry-DSR (sowing dry seeds in dry soil), wet-DSR (sowing pre-germinated seeds in moist soil), and water-seeding (sowing dry or pre-germinated seeds in standing water) [15].

As direct seeding of rice crops has a shorter development period than traditional transplanting, it establishes rice fields more quickly and requires roughly 25% less work overall, reduces the need for energy, reduces the need for water (by 35–40%), matures the plant sooner (7–10 days), improves the efficiency with which fertilizer is used, and increases yields by 10% at low production costs [3, 16]. Therefore, compared to puddled transplanted rice, direct-seeded rice (DSR) with optimum management methods provided a comparable or greater yield with an overall net benefit up to 4,400–5,000 Rs/ha while utilizing 30–50 % less irrigation water (CTPR) [9]. For high-value rice harvests, mechanical transplanting may be more practical but is more expensive to utilise than direct seeding [26]. As the primary goal of sowing operations is to plant seeds in rows at the required depth and spacing between seeds, cover the seeds with soil, and provide sufficient compaction over the seeds. The sowing machine is therefore a tool that aids in planting seed in the appropriate location, helping the farmer save time and money [14].

Precision hill seeding and drill seeding give an alternative measure to current problems such as large amounts of seeds, high missed hill percentages, and uneven seedling taking in the process of machine transplanting rice [24]. Precision direct seeding technology has emerged as the direction for developing mechanized rice planting for both rows and hills released the seeds at a fixed spacing, not in a flowing stream with a uniform spacing between plants within a row and contributes to crop productivity and field efficiency by making sure that the precise number of seeds is planted [26, 21, 22]. Rice seeds are uniformly distributed in the population thanks to mechanized precision hills direct seeding, which also improves aeration and light transmission, prevents damage to the root system, results in well-developed individual roots, more productive tillers, a high ear-forming rate, and increases yield. Furthermore, the hill direct-seeded rice had much greater productivity than the drill direct-seeded rice, which might be attributed to a higher proportion of efficient tillers [5, 27].

Because there was less rivalry among the plants for scarce resources like light, water, and nutrients, there was more output as a result of uniform seed dispersion in the soil. Many elements, including the seed metering mechanism, tube-delivered seed, furrow opening design, physical features of the seed, and soil conditions, influence how seeds are distributed in the soil [10]. One of the most crucial factors that leads to an appropriate plant population and enhances crop quality and production is uniformity of longitudinal seed deposition [20]. Improving seed distribution uniformity during the sowing process contributes to the proximity of the plant growing area per seed relative to each other, resulting in an increase in yield [19]. The coefficient of variation (C.V.%) of longitudinal scattering increased from 10.2 to 12.2, and from 13 to 13.4%, with increasing planting speeds from 0.64 to 0.89 and 1.19 to 1.42 m/sec [8].

Increasing sowing forward speed from 6.8 to 11.17 km/h resulted in fuel consumption figures falling from 7.164 to 5.360 L/ha, having a substantial impact on seeding rate, fuel consumption, and effective field capacity [11, 13]. When the machine's forward speed is between 2.8 and 3.2 km/h, the sowing depth pass percentage is at least 75%, the qualifying row spacing rate is at least 80%, the rate pass row spacing rate is at least 90%, and the quantity of seeds per hill is at least 75%, all of these conditions are met [25]. In comparison to other sowing speeds, the 11.43 km/h speed had a higher effective field capacity of 1.08 ha/h, a lower fuel consumption per unit area of 8.11 l/ha, a lower total operating cost per unit area of 13,594 ID/ha (10.875 US$/ha), and a lower energy requirement of 29.40 kW/ha. The slip percentage was also within acceptable bounds at 10.98%. The first sowing depth of 3 cm outperformed other sowing depths by recording lower slippage percentage (4.64%), higher effective field capacity (0.87 ha/h), higher field efficiency (71.72%), lower fuel consumption per unit area (8.38 L/ha), lower operating costs for machinery units (16,721 ID/ha; 13.376 US$/ha), and lower energy consumption [12].

The main objective of the study is to find alternatives to the traditional methods of rice cultivation that consume large amounts of water and seeds. As Egypt and the world tend to save water due to the global water problems and seek to use optimal methods for agriculture that require less water needs and give high productivity. Therefore, the seeding machine was developed to suit the cultivation of rice, in addition to adding a digger that works on digging lines and paths to direct irrigation water.

MATERIALS AND METHODS

Experimental work

The machine was manufactured and developed in the central workshop of the Rice Mechanization Center (RMC) in Mait El Diba in Kafr El-Sheikh affiliated to the Agricultural Engineering Research Institute (AERI), Agricultural Research Center (ARC) in Giza, and field experiments were conducted at (RMC) farm. During 2021 and 2022 growing seasons using rice grain variety of "Sakha Super 300" to study the factors affecting on the sowing accuracy and uniformity of modified hill drill in a "clayey soil" according to the soil mechanical analysis of the experimental field in "Soil, Water and Environment Research Institute" as shown in Table (1).

Table 1. Soil mechanical analysis of the experimental field

Clay %	Slit %	(Clay + Slit) %	Sand %	Caco$_3$ %	Organic matter %	Soil type
53.32	17.63	70.95	29.05	1.3	1.71	Clay

Source: Soil, Water and Environment Research Institute.

The seed drill machine before developed

The seed drill machine was of the type (Tye), USA made, it consists of a main frame, grain hopper, metering device, furrow openers, grain tubes, drill wheels and transmission gearbox, as shown in Table (2). It was originally designed for cultivation on flat ground.

Table 2. Specification of the seed drill machine (Tye) before development.

Items		Seed drill
Dimensions	Length. mm	1,500
	Width, mm	3,000
	Height, mm	1,400
	Row spacing, mm	150
	No. of rows	20
	Operating width, mm	3,000
	Total mass, kg	560
Seed hopper capacity, kg		350
Feeding type		Fluted wheel
Grain tubes		Smooth
Furrow opener		Hoe type
Covering device		U-shaped knife
Marker		Knife
Tractor power used, kW		45
Coupling method		3-point direct coupling
Transmission system		Chain
Number of wheels		2

Source: Authors' calculation.

Main frame: The main frame of the seed drill (Tey-type) made from welded square and rectangular hollow iron tubes.

Grain hopper: the grain hopper of the seed drill is made of galvanized sheets 15 mm thick, 3,000 mm long, 400 mm wide, and 550 mm high, and the sides of the seed hopper, at a height of 120 mm from the bottom of the hopper, were at an inclination of 54° with a suitable cover. 20 circular holes in the bottom of the hopper, with a diameter of 70 mm, allow seeds to exit into the feeding system.

Metering device*:* the metering device of the seed drill was consisted of a plain flanged disc that interfered with an internally fluted feed wheel. The seeding rate can be controlled by the exposed length of the internally fluted feed wheel by moving. The seed maximum flow rate occurs when the fluted wheel covers the entire width of the gate, the flow rate also varies with the rotational speed of the fluted wheel as shown in Photo 1.

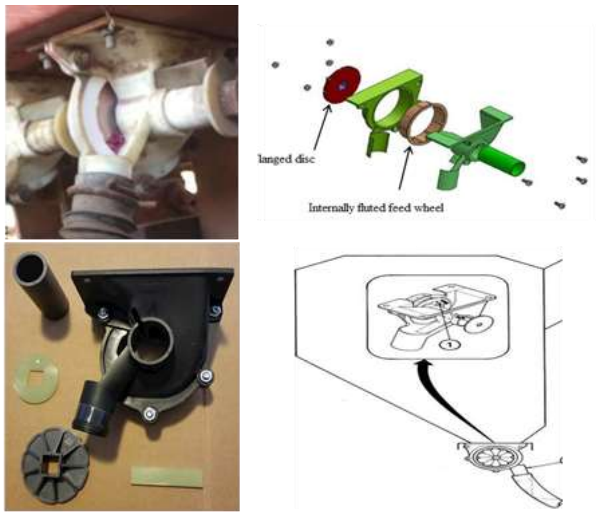

Photo 1. Metering device of the seed drill before developed.
Source: Authors' own illustration.

Grain tubes: the seed tube has a smooth inner surface and a 25 mm diameter. It is attached to the end pipe of the seed delivery funnel in the bottom of the hopper that receive grains from metering device and transport them to the furrow.

Furrow openers: hoe type, they open a furrow on the soil surface with the required depth into which the grain will be planted.

Transmission gearbox: the power is transmitted to the feeding system from the ground wheel by two chains and three sprockets, the first with 54 teeth attached to the ground wheel, the second with 21 teeth in a double row attached to an intermediate shaft fitted in front below the main frame, and the third with 21 teeth attached to the feeding shaft.

Drill wheels: two wheels (with a diameter of 710 mm, a circumference of 2,250 mm, and a width of 177.8 mm) were fitted on the main axle of the seed drill with suitable attachments. The ground wheels are used to transmit power to operate grain feeding mechanism.

The seed drill machine after developed

The modified hill drill used in this study mainly consists of a main frame, seed hopper, metering (feeding device) transmission gearbox, seed tubes, furrow openers, seed covering device, additional attached bed ridgers, and markers. The main technical specifications of the modified hill drill are shown in Table 3. While, the side view, Elev. Charts and photo of the modified hill seed drill are shown in Fig. 1 and Photo 2.

Table 3. Main specifications of the modified hill drill

Items		Modified hill drill
Dimensions, mm	Length	1,350
	Width	2,700
	Height	1,400
	Operating width	240
	Row spacing	15
	No. of rows	12
	Ridgers spacing	26
	No. of ridgers	3
	Total mass, kg	500
Seed hopper capacity, kg		280
Feeding mechanism		regular roller with 5 cells on the circumference
Grain tubes		Smooth
Furrow opener		Shoe type
Coupling method		3 Point direct coupling
Transmission system		Chain
Number of wheels		2

Source: Authors' calculation.

Grain hopper: the grain hopper of the modified hill drill made of a galvanized sheet 15 mm thick, 2,400 cm long, 400 cm wide, and 550 mm high, and the sides of the seed hopper were modified at an inclination of 41° to ensure free flow of seeds inside the hopper, with a suitable cover.

A 12 rectangular holes were created at equal distances in the bottom of the hopper, with a length of 72 mm and a width of 40 mm, to setup the modified feeding rollers inside the hopper with a height of 15 mm.

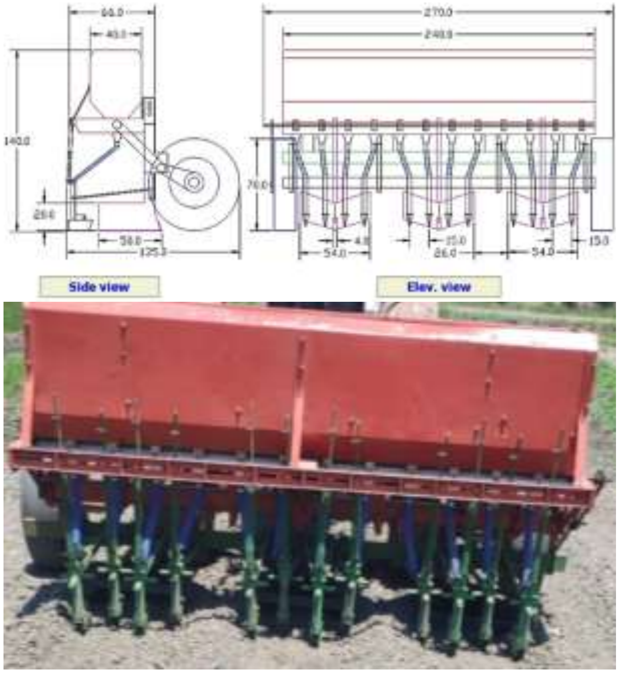

Fig. 1 and Photo 2. Side view and Elev. of the modified hill drill
Source: Authors' own illustration.

Metering device: the metering device after a modification consists of a regular roller with 5 cells on the circumference of the feeding roller, which is fabricated from Artillon Teflon material with a square inner hole (16 × 16 mm) and outer diameters of 79.6 mm, and a thickness of 38.5 mm as shown in Photo 3.

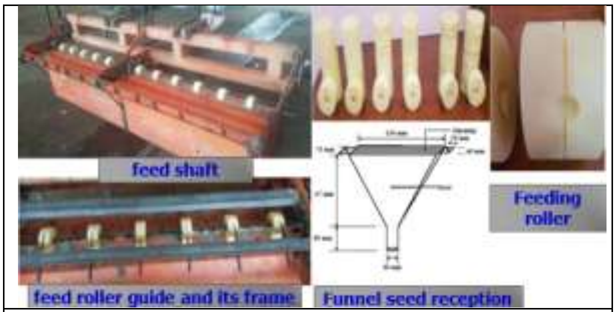

Photo. 3. Metering device after modification.
Source: Authors' own illustration.

Photo. 4. Additional soil bed ridgers
Source: Authors' own illustration.

The grain cells have a fixed depth of 6 mm with different volumes (diameters) of 354 mm^3 (10 mm φ), 428 mm^3 (11 mm φ), and 509 mm^3 (12 mm φ), respectively. The feeding rollers are installed on the feeding shaft at the internal bottom of the grain hopper. When the shaft rotated, the cells filled with rice grain and dropped them into the grain receiving funnel, which is installed on a frame at the external bottom of the grain hopper. Then rice grain enter the grain tubes and fall by the gravity force into a furrow, which has been opened by a furrow opener share as shown in Photo 4.

***Additive bed ridgers*:** an additional three soil bed ridgers were fixed on the modified hill drill frame in front of the furrow openers for making bed ridges in same time of direct sowing using the modified hill drill. The ridger penetration angle and distance between ridger were 5° and 260 mm, respectively as shown in photo (3).

***Transmission gearbox*:** The ground wheels are used to transmit power to operate grain feeding mechanism of the modified hill drill through an intermediate shaft fitted in front below the main frame and then to the feeding mechanism shaft via 4 sprockets and 2 chains of drive transmission with speed ratios of (1:2.6, 1:3, and 1:3.6) to change the hill spacing within rows of modified hill drill.

Power unit

A Yanmar tractor 500DT (50 HP (37 kW) 4WD) was used to mount the modified hill drill on its three-hitch point device during the laboratory/field calibration and field experiment.

Scope of variables

To realize the purpose of this study, a series of field experiments were carried out using the modified hill seed drill under the following different study variables:

(a)***Sowing forward speeds:*** The performance of the modified hill seed drill was tested under four different sowing forward speeds, namely, 0.71, 1.11, 1.7, and 2.33 m/s (2.55, 4.01, 6.11, and 8.38 km/h).

(b)***Intra-row hill distances:*** The performance test of the modified hill seed drill was carried out using three different distances between hills within the row, namely, 12.5, 15.5 and 17.5 cm.

(c) ***Feeding cell volume:*** Three different cell volumes of feeding rollers for the modified hill drill were used, namely, 354 mm^3 (10 mm φ), 428 mm^3 (11 mm φ), and 509 mm^3 (12 mm φ), with a fixed depth of 6 mm.

Measurements

Physical and mechanical properties of rice grains

The measurements of physical and mechanical properties of rice grain variety (Sakha super 300) at the laboratory of Rice Mechanization Center (RMC). The obtained results were tabulated in Table 4.

Table 4. Physical and mechanical properties of rice grain variety (Sakha super 300)

Rice grain Sakha super 300	Rep.	Max.	Min.	Av.	SD	CV.
Moisture content, %	5	13.5	12.8	12.9	0.2	1.55
Length, (mm)	100	7.97	6.62	7.32	0.26	3.55
Width, (mm)	100	3.62	2.92	3.3	0.15	4.55
Thickness, (mm)	100	2.39	1.78	2.12	0.11	5.19
Volume, (mm^3)	10	33.51	21.34	28.15	2.58	9.17
Arithmetic mean diameter, mm.	100	4.53	3.87	4.24	0.13	3.07
Geometric mean diameter, mm.	100	3.93	3.39	3.71	0.11	2.96
Sephericity, %.	100	54.38	46.97	50.71	1.44	2.84
Wight of 1000 seeds, (g)	100	26.35	25.85	26.18	0.25	0.97
True density, (kg/m^{-3})	10	1104	1096	1100	3.22	0.29
Bulk density, (kg/m^{-3})	10	597	592	594	3.54	0.60
Porosity, (%)	10	46.2	45.9	46	0.15	0.33
Angle of repose, (o)	5	30.94	28.42	29.3	0.96	3.28
Shape index,	100	3.11	2.49	2.77	0.12	4.33
Aspect ratio, %	100	50.22	38.69	45.09	2.36	5.23
Surface are, mm^2	100	48.58	36.14	43.26	2.66	6.15
Equivalent diameter, mm	100	3.55	3.21	3.41	0.07	2.05
Friction coefficient of iron, (m)	5	0.32	0.31	0.32	0.01	2.86

Source: Authors' calculation.

Laboratory and field calibration: rice grain damage was calculated and related to the grain discharge.

Seed damage: the percentage of rice grain damage was calculated and related to the grain discharge according to equation (1).

$$\text{Rice grain damage, \%} = \frac{M1 - M2}{\text{Total weight of the rice grain sample}} \times 100 \quad \text{.......(1)}$$

where:

M1= Mass of rice grain damaged in the sample, which are manually separated from each rice main sample before it passed through the feeding system.

M2= Mass of rice grain damaged in the sample, after passing through the feeding system.

Rice grain germination: One thousand grains of rice grains were germinated to give the germination ratio before passing through the feeder. The actual germination ratio of the rice grains after passing through the feeding system was calculated after a sample of 100 seeds was germinated and replicated three times before planting.

Emergence percentage: the number of plants per three meters of the row was counted for the four speeds (2.55, 4.01, 6.11, and 8.38 km/h) to determine the emergence percentage according to the following formula 2:

$$\text{Emergence percentage} = \frac{\text{Average No.of plant per sq.m}}{\text{Average No.of delivered grains per sq.m}} \quad ......(2)$$

Modified hill drill performance measurements

Tractor wheel slippage: the slippage percentage of tractor wheels was calculated according to Awady [2], using the following equation 3:

$$\text{Slippage, \%} = \frac{d_1 - d_2}{d_1} \times 100 \quad ......(3)$$

where:

d_1= Distance of 10 forward revolutions without load, m.

d_2= Distance of 10 forward revolutions with load, m.

Effective field Capacity and field efficiency: the theoretical field capacity (T.F.C.) was calculated using the formula 4:

$$\text{Theoretical field capacity, T.F.C.} \left(\frac{\text{fed}}{\text{h}}\right) = \frac{\text{Machine width (m)} \times \text{Speed (km/h)}}{4.2} \quad ......(4)$$

The effective field capacity (E.F.C.) at different operating speeds was estimated according to Srivastava et al [17], as follows:

$$\text{Effective field capacity, E.F.C.} \left(\frac{\text{fed}}{\text{h}}\right) = \frac{1}{\text{Total effective time (h) per feddan}} \quad ......(5)$$

While The field efficiency (η_f) was calculated using the following formula 6:

$$\text{Field efficiency, } \eta_{f\,(\%)} = \frac{\text{E.F.C.}}{\text{T.F.C.}} \times 100 \quad ......(6)$$

where:

T.F.C. = theoretical field capacity, fed/h

E.F.C. = effective field capacity, fed/h.

Power consumption and energy requirements: power consumption (EP) was determined for the modified hill seed drill according to Embaby [6], using the following equation 7:

$$EP = \left(F_c \times \frac{1}{60\times60}\right) \rho_f \times L.C.V. \times 427 \times \eta_{th} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36} \text{ (kW)} \quad ......(7)$$

where:

F_c = Fuel consumption, l/h.

ρ_f = Diesel fuel density (0.85 kg/l).

L.C.V. = Lower calorific value of diesel fuel (10,000 kcal/kg).

427 = Thermo-mechanical equivalent, kg.m/kcal.

η_{th} = Thermal efficiency of diesel engine, (40%).

η_m = Mechanical efficiency of diesel engine, (80%).

Estimation of the energy required for sowing rice crop was carried out using the following equation 8:

$$\text{Energy requirements (kW.h/fed.)} = \frac{\text{Power requirement (kW)}}{\text{Effective field efficiency (fed/h)}} \quad ......(8)$$

Sown grain scattering and uniformity.

The longitudinal scatterings and distribution uniformity of the sown grains (3 weeks after planting) were calculated for each treatment under study according to Steel and Torrie [18], also, the plant distribution was analyzed to determined coefficient of variation (CV) and to calculate the coefficient of uniformity of plants spacing using the following equations:

$$\text{Scattering} = \sqrt{\frac{\text{Sum of square of variance of seed scattering from its mean}}{\text{No. of hills}}} \quad ......(9)$$

$$\text{Coefficient of uniformity(\%)} = (1-CV) \times 100 \quad ......(10)$$

$$CV,\% = \frac{\text{SD of plant spacing}}{\text{Recommended plant spacing}} \times 100$$ ....(11)

$$SD=\sqrt{\frac{(\text{Plant spacing - Recommended plant spacing})^2}{n}}$$ ....(12)

where:
CV= coefficient of variation
SD = Standard deviation.

The coefficient of variation under 10% is considered excellent and with value under 20 % is generally considered acceptable for most field applications as reported by Coates [4].

Plant density: **t**he number of plants per hill and No. of plants/m^2 was measured as plant density after three weeks from sowing date for each treatment under study. For this measure, a wooden frame with the dimensions of 0.5 x 2 m was randomly placed in different areas for each treatment to determine the plant density.

Shape of soil surface profile: the changes in soil surface roughness before sowing effect, the bottom surface of the bed and the shape of the bed ridges top (and sides) after direct sowing rice grains using modified hill drill under different planting forward speeds with attached additional ridgers for making bed ridges were measured randomly by profile-meter according to the standard method of *ASAE*, [23] using a straight wood piece marked at 5 cm intervals and supported in both terminals on a constant height supports. A scale was used to measure the head at all points height of the soil surface profile. The mean and standard deviation for all points height of the soil surface profile were calculated to find the changes of the profile shape.

Crop yield and its components measurements

The crop yield and its components measurements were taken into consideration in this study. The grain and straw yields, in addition to the yield components such as number of productive tillers, panicle length, number of panicles per plant, number of grains per panicle, 1,000-grains weight and harvest index for each treatment under study.

RESULTS AND DISCUSSIONS

Laboratory and field calibration tests

During the laboratory and field calibration tests of modified hill drill, the visible mechanical damage; the germination ratio; No. of grain per hill, No. of grain per m^2, and calibrated seeding rate was determined and calculated under study variables of grain cell volume, hill spacing and planting forward speed.

Rice grain visible damage: the visible mechanical damage occurred in rice grains due to moving parts of metering device were measured and the values of obtained results were shown in Fig. 2.

These results indicated that, the visible mechanical damage was clearly observed in rice grain samples under calibration variables. An increase of grain cell volume or hill spacing decreased the obtained values of visible damage at any given level of planting forward speed. However, an increase in planting forward speed increased the visible mechanical damage at any given grain cell volume and hill spacing.

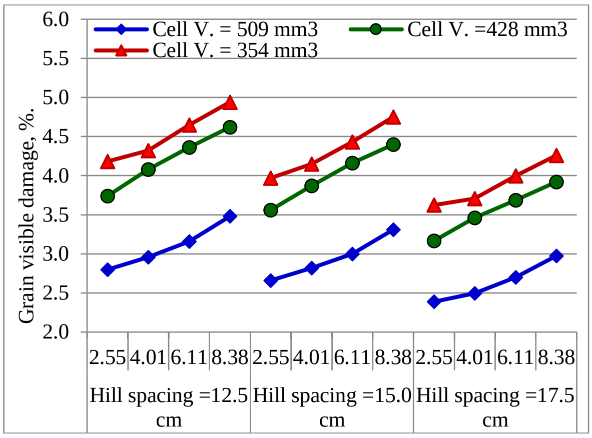

Fig. 2. Grains visible damage during field calibration of the modified seed hill drill under different levels of grain cell volumes, hill spacings and planting forward speeds.
Source: Authors' own results.

These results may be due to decreasing the velocity of moving parts for metering mechanism which decrease the chance grain damage. The highest value of visible rice grain damage of 4.94, 4.75, 4.26 % were obtained at the highest planting forward speed of 8.38 km/h, and lowest grain cell volume of 354 mm^3 under hill spacing of 12.5, 15, and 17.5 cm, respectively. However, the lowest value of visible rice grain damage of 2.8, 2.66, and 2.39 % were obtained at the lowest planting forward speed of 2.55km/h, and the highest grain cell volume of 509 mm^3 under hill spacing of 12.5, 15, and 17.5 cm, respectively.

Germination ratio: the results of germination ratio for rice grain samples obtained during laboratory and field calibration of the modified hill drill under different levels of grain cell volume, hill spacing and planting forward speed compared with same rice grain variety before putting in the modified seed hill drill hopper are illustrated in Fig. 3.

In general, the results indicated that an increasing in cell volume and hill spacing increased the obtained values of germination ratio. However, any increase in planting forward speed decreased the obtained values of germination ratio. Meanwhile, the value of germination ratio for rice grain before using it in hill drill hoper were higher than that obtained under any given calibration variables. These results may be due the visible mechanical damage values occurred for rice grain putted in the modified hill drill hopper for field calibration. Also, it could be mentioned that germination ratio was negatively affected by grain cell volume and hill spacing and positively affected by planting forward speed.

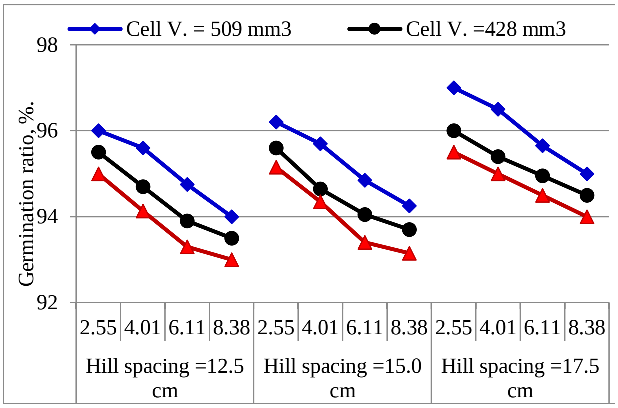

Fig. 3. Germination ratio for rice grains during field calibration of the modified seed hill drill under different levels of grain cell volumes, hill spacings and planting forward speeds.
Source: Authors' own results.

The recorded values of germination ratio of used rice grains in calibration process cleared that using the highest cell volume of 509 mm^3 gave the highest value of germination ratio of 96.0, 96.2 and, 97.0% at 2.55 km/h planting speed, under hill spacing 12.5, 15, 17.5 cm, respectively compared with 93.0, 93.15, and 94.0% when using the lowest cell volume of 354 mm^3 at 8.38 km/h planting forward speed, under hill spacing of 12.5, 15, and17.5 cm, respectively.

Calibrated seeding rate: the obtained results No. of grain per hill, No. of grain per m^2, and calibrated seeding rate listed in Table (5) indicated that, the different level of grain cell volume 354, 428, 509 mm^3 gave about 3-4, 4-6, and 7-9 grain per hill (cell), respectively. However, the count number of grains/m^2 was increased from 96 to 370 and the calibrated seeding rate (kg/fed.) was increased from 10.87 to 41.69 kg/fed. When calibrated the modified hill drill under 509 mm^3 cell volume, 12.5cm hill spacing and 2.55 km/h planting forward speed instead of 354 mm^3 cell volume, 17.5cm hill spacing and 8.38 km/h planting forward speed. Also, the obtained results in Table 5 cleared that, the values of number of grains/hill and seeding rate kg/fed., were increased by any increase in given levels of grain cell volume and planting forward speed under study and decreased with any increase in given levels of hill spacing under study.

Table 5. No. of grains per m^2 and seeding rate during field calibration of the modified seed hill drill under different levels of grain cell volumes, hill spacings and planting forward speeds

Hill Spacings, cm	Speed, km/h	Grain cell volume, mm^3								
		354		428		509		354	428	509
		grains /hill	grains /m^2	grains /hill	grains /m^2	grains /hill	grains /m^2	Seeding rate; kg/fed		
12.5	2.55	4.15	181	5.38	234	8.49	370	20.37	26.40	41.69
	4.01	3.95	173	5.17	227	8.22	360	19.52	25.54	40.62
	6.11	3.61	160	4.48	198	7.35	326	18.03	22.34	36.71
	8.38	2.87	129	3.64	163	6.27	281	14.50	18.40	31.69
15.0	2.55	4.15	151	5.55	201	8.72	316	16.98	22.70	35.66
	4.01	3.92	143	5.33	195	8.43	308	16.15	21.93	34.70
	6.11	3.61	133	4.53	167	7.38	272	15.02	18.85	30.68
	8.38	2.87	107	3.64	136	6.43	240	12.08	15.33	27.09
17.5	2.55	4.18	130	5.51	171	8.71	271	14.67	19.32	30.54
	4.01	4.01	126	5.21	163	8.29	260	14.15	18.39	29.25
	6.11	3.64	115	4.51	143	7.53	238	12.98	16.08	26.84
	8.38	3.01	96	3.74	120	6.42	205	10.87	13.49	23.15

Source: Authors' own results.

Sowing accuracy and plant density

The emergence percentage, the longitudinal scatterings and distribution uniformity of the sown grains and planting density (plant/m^2) for sown rice plants using modified hill drill under study variables of grain cell volume, hill spacing and planting forward speed were counted at 3 weeks after planting and soil irrigated.

Emergence percentage: the recorded values of emergence percentage of rice grain after planting in the field, it could be cleared that, the emergence percentage values were taken the similar trend for germination ratio among the different levels of grain cell volume, hill spacing and planting forward speed under study as shown in Fig. 4.

The planting forward speed and grain cell volume was found to be highly significant effect on the emergence percentage of rice grains after planting in the soil than that effect of hill spacing.

The highest values of emergence percentage of 83.51, 83.43, and 84.87% were obtained when using the highest grain cell volume of 509 mm^3 at 2.55 km/h planting forward speed and 12.5, 15.5, 17.5 cm hill spacing, respectively. However, the lowest values of emergence percentage of 76.94, 77.35, and 77.75 % were obtained when using the lowest grain cell volume of 354 mm^3 at 8.38 km/h planting forward speed and 12.5, 15.5, and 17.5 cm, hill spacing, respectively.

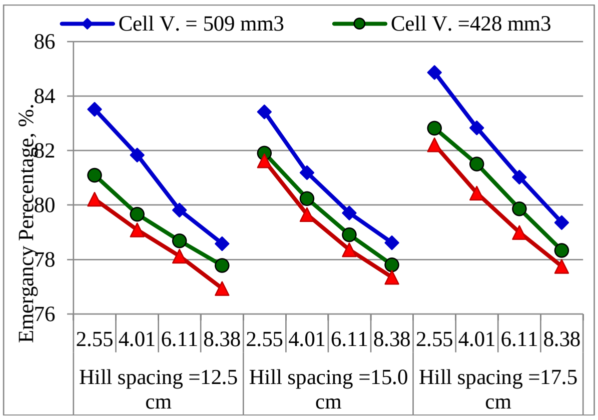

Fig. 4. Emergence percentage for rice grains during field calibration of the modified seed hill drill under different levels of grain cell volumes, hill spacings and planting forward speeds

Source: Authors' own results.

Longitudinal scattering: the distance between successive hills (plants) in each row was measured to calculate the longitudinal scattering (distribution) within the row under the different levels of grain cell volume, hill spacing and planting forward speed. Also, the coefficient of variation (C.V.) for the longitudinal scattering and the coefficient of distribution uniformity were calculated and the obtained results were illustrated in Fig. 5 and 6.

These results indicated that, there are a negative correlation for the effect of grain cell volume and hill spacing on the variation coefficient (C.V.) of longitudinal scattering values under any given level of planting forward speed and a positive correlation for the effect of planting forward speed on the variation coefficient (C.V.) values of longitudinal scattering under any given level of grain cell volume and hill spacing. Increasing the grain cell volume from 354 to 509 mm^3 decreased the variation coefficient (C.V.) of the longitudinal scattering values from 17.8 to 12; from 13.45 to 10.25; and from 12.48 to 8.59% when operating the modified hill drill at planting speed of 2.55 km/h under hill spacing 12.5, 15.0, 17.5 cm, respectively.

However, increasing the hill spacing from 12.5 to 17.5 cm decreased the coefficient of variation (C.V.) of the longitudinal scattering values, from 17.18 to 12.48; from 14.34 to 10.30; and from 12 to 8.59 % when operating the modified hill drill at planting forward speed of 2.55 km/h under different grain cell volume of 354, 428, and 509 mm^3, respectively.

Meanwhile, increasing the panting forward speed from 2.55 to 8.38 km/h results in an increase in the coefficient of variation of the longitudinal scattering from 12.48 to 20.35; from 10.3 to 18.52, and from 8.59 to 16.89 % at hill spacing of 17.5 cm under levels of grain cell volume, 354, 428, and 509 mm^3, respectively.

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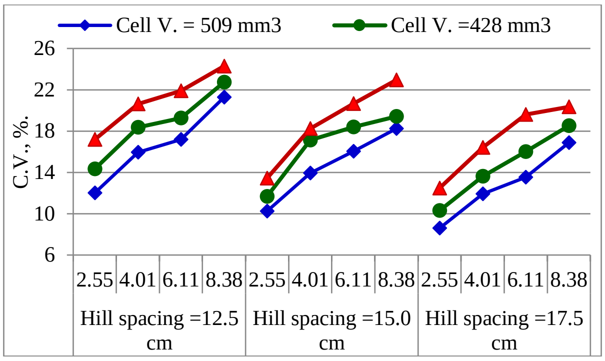

Fig. 5. Coefficient of variation (C.V.) of grain longitudinal scattering during evaluation of modified hill drill under different grain cell volumes, hill spacings and planting forward speeds
Source: Authors' own results.

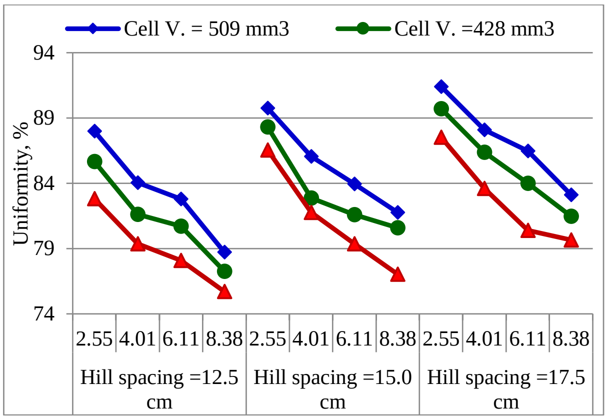

Fig. 6. Coefficient of plant distribution uniformity of modified hill drill under different grain cell volumes, hill spacings and planting forward speeds
Source: Authors' own results.

Also, from the results illustrated in Fig. 6 which shown the coefficient of plant distribution uniformity when using modified hill drill under different study variables, it could be stated that increasing the coefficient of plant distribution uniformity by increasing cell volume and hill spacings and by decreasing the planting forward speed. The highest value of uniformity of 87.52, 89.7, and 91.41% under cell grain volume 354, 428, and 509 mm^3, respectively at forward speed of 2.55 km/h, and 17.5 cm hill spacing. While the lowest value of uniformity of 75.7, 77.26, and 78.72 % under grain cell volume 354, 428, and 509 mm^3, respectively at forward speed of 8.38 km/h, and 12.5 cm hill spacing.

Planting density: regarding to the obtained results of planting density (plant/m^2) for sown rice plants using modified hill drill under study variables of grain cell volume, hill spacing and planting forward speed were counted at 21 days after soil irrigated and recorded in Table 6.

The recorded data indicated that, there is positive correlation between number of plant/m^2 and study parameters. Increasing cell volume increased the number of plant/m^2 at any given levels of planting forward speed and hill spacing under study. However, increasing planting forward speed and hill spacing decreased the number of plant/m^2 at any given levels of grain cell volume under study. The obtained results may be referred to the significant effect of study parameters on the visible mechanical damage, germination ratio and emergency percentage. The maximum values of plants/m^2 (309, 264, and 230) were obtained when using largest cell volume of 509 mm^3 at 2.55 km/h planting forward speed under hill spacing of 12.5, 15, 17.5 cm, respectively. While the minimum values of plants/m^2 (99, 84, and 75) were recorded when using the smallest level of grain cell volume (354 mm^3) at the highest level of planting forward speed (8.38 km/h) under hill spacing of 12.5, 15, and 17.5 cm, respectively.

Table 6. No. of plants/m^2 of rice crop after sowing using modified hill drill under grain cell volumes, hill spacings and planting forward speeds

Hill Spacings, cm	Planting Speed, km/h	Cell Volume 354mm^3	Cell Volume 428 mm^3	Cell Volume 509 mm^3
12.5	2.55	145	190	309
	4.01	137	181	295
	6.11	125	156	260
	8.38	99	127	221
15.0	2.55	123	165	264
	4.01	114	156	250
	6.11	105	132	217
	8.38	84	107	189
17.5	2.55	107	142	230
	4.01	101	133	215
	6.11	91	114	193
	8.38	75	94	163

Source: Authors' own results.

Modified hill drill evaluation performance

The evaluation performance of modified hill drill includes tractor slip ratio; effective field capacity and efficiency; power requirements and energy consumed were carried out during direct sowing rice grains under different planting forward speeds with normal (without making bed ridges) and full loads (for making bed ridges with attached additional ridgers) of modified hill drill.

Slip ratio: measuring values of the slip ratio for the tractor used to mount modified hill drill during evaluated it under the study variables of grain cell volume, hill spacing and planting forward speed, were plotted in Fig. 7. The obtained results of tractor slip ratio cleared that, an increase in planting forward speed, increased the values of tractor slip ratio. The average values of the tractor slip ratio were 3.13, 3.25, 4.25, and 6 % under the planting forward speed of 2.55, 4.01, 6.11, and 8.38 km/h, respectively during normal load of modified hill without attached bed ridgers compared with 5.75, 6.00, 7.25 and 8.75 % for full load of modified hill drill (with attached additional bed ridgers) under the same mentioned previous planting forward speed of normal load.

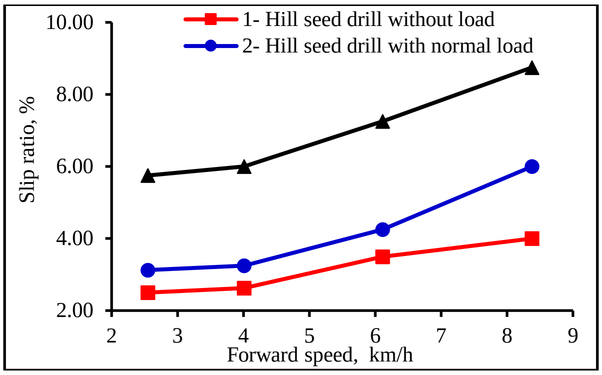

Fig. 7. Tractor slip ratio during evaluation of modified hill drill under different loads and planting forward speeds
Source: Authors' own results.

Effective field capacity and efficiency: the obtained results of the effective field capacity and efficiency for the modified hill drill under study variables illustrated in Fig. 8. From these results it could be cleared that, an increase in planting forward speed results in an increase in effective field capacity and a decrease in field efficiency at any given load for modified hill drill. Using attached additional ridgers for making bed ridges (full load) tends to decrease in the obtained values of affective field capacity and field efficiency at any given planting foreword speed. These results may be due to increase tractor wheel slip ratio with increasing hill drill load. The values of effective field capacity of 1.26, 1.82, 2.65, and 3.53 fed./h were obtained when using modified hill drill with normal load at 2.55, 4.01, 6.11, and 8.38 km/h planting forward speeds, respectively compared with 1.20, 1.75, 2.58, and 3.44 fed./h when using modified hill drill with full load under the same pervious forward speed, respectively. Meanwhile, the field efficiency values of 83.31, 79.42, 75.85, and 73.80% were obtained for using modified hill drill under normal load compared with 79.36, 76.42, 73.9, and 71.88 % for using modified hill drill under full load at 2.55, 4.01, 6.11, and 8.38 km/h planting forward speeds, respectively.

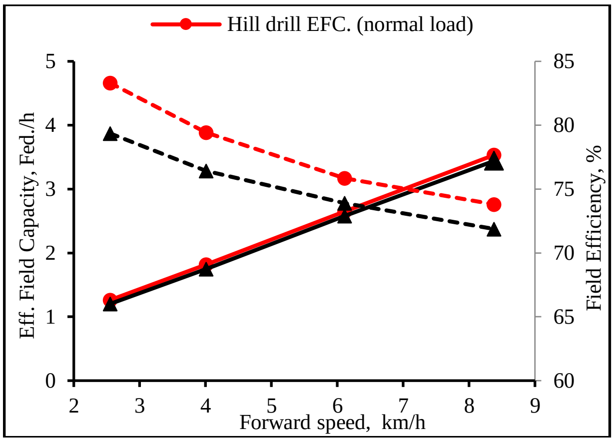

Fig. 8. Effective field capacity and field efficiency under different planting forward speeds and normal/full loads of modified hill drill
Source: Authors' own results.

Power requirements and energy consumption: the obtained values of power requirements and energy consumed under different planting forward speed and normal or full loads of modified hill drill were illustrated in Fig. 9.

With respect of the obtained results for power requirement and energy consumption due to use the modified hill drill for planting rice grains, it could be concluded that increasing planting forward speed results in an increment percentage in power requirements, and a decrement percentage in energy consumption for any given modified hill drill load used in the study. These results may be due to increasing fuel consumption with any increase of planting forward speed and modified hill drill load.

The maximum values power requirements were 14.56 and 17.16 kW for using modified hill drill at 8.38 km/h planting forward speed with normal and full load of modified hill drill, respectively.

While the minimum values of 9.61 and 10.98 kW were obtained for using modified hill drill under planting forward speed of 2.55 km/h with normal and full load, respectively.

Also, from the results of energy consumption shown in Fig. (9), it could be observed that, an increase of planting forward speed decreases the values of energy consumption at any given load of hill drill due to increasing effective field capacity with increasing planting forward speed.

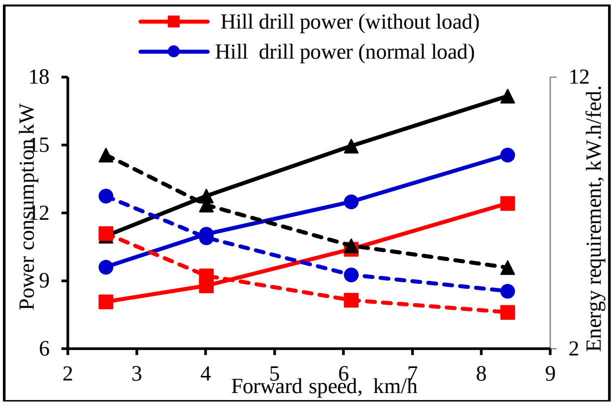

Fig. 9. Power requirements and energy consumed under different planting forward speeds and normal/full loads of modified hill drill
Source: Authors' own results.

The highest values of energy consumption of 7.62 and 9.14 kW.h/fed. Were obtained at 2.55 km/h planting forward speed with normal and full load of modified hill drill. While the lowest value of 4.12 and 4.99 kW.h/fed were obtained at planting speed of 8.38 km/h with normal and full load of modified hill drill, respectively.

Height of the ridge profile and cross-section area: According to the results obtained using the modified hill drill shown in Fig. 10, the effect of forward speed on the height of the ridge profile is as follows: the highest value of the height of the ridge profile is 12.5 cm obtained at forward speed 2.55 km/h; the lowest value of the height of the ridge is 10.1 cm at forward speed 8.38 km/h during sowing. It was observed that when increasing forward speed from 2.55 to 8.38 km/h, the highest value of the ridge profile decreased by 19.2% during sowing.

Ridge profile height after 30 days of soil irrigation (sowing) with 5 days interval irrigation: the effect of 5 days interval irrigation on ridge profile height is a decrease in the height of the ridge from 12.5 to 11.8, from 11.03 to 10.4, from 10.3 to 9.6, and from 10.10 to 9.2 cm, at forward speeds of 2.55, 4.01, 6.11, and 8.38 km/h, respectively, after 30 days of soil irrigation.

Ridge cross-section shows the same trend, where cross-section area decreased from 0.0281 to 0.0227 when forward speed increased from 2.55 to 8.38 km/h.

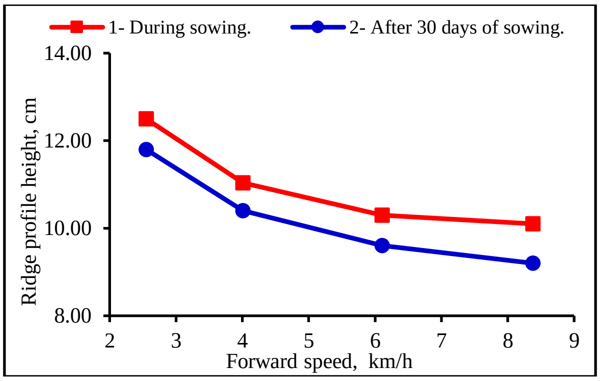

Fig. 10. Effect of forward speed on the ridge profile height, during sowing, and after 30 days of sowing
Source: Authors' own results.

Rice yield and its components:

The obtained results of yield and yield components of rice crop sown using modified hill drill under different grain cell volumes, hill spacing and planting forward speeds were listed in Table 7 and shown in Fig. 11.

The yield components including No. of grains/panicle, filled grain percentage (ripping ratio, %), 1,000 grains weight (g), straw yield (ton/fed.), harvest index (%) were taken into consideration as effective indicators for total grain yield of rice and straw under study variable. In general, the rice grain yield and straw yield values were found to be in a positive correlation with increasing grain cell volume levels and a negative correlation with increasing hill spacing and planting forward speed. The grain yield values ranged from 2.94 ton/fed., under 354 mm^3 cell volume, 17.5 (cm), hill spacing and 8.38 km/h, planting forward speed, to 4.79 ton/fed., under 509 mm^3 cell volume, 12.5 hill spacing and 2.55 km/h planting forward speed. The minimum values of grain yield (3.45, 3.30, and 2.94 ton/fed.) were obtained at planting forward speed of 8.38 km/h for grain cell volume of 354mm^3 under 12.5, 15, 17.5 cm hill spacing respectively. However, the maximum values of grain yield (4.79, 4.74, and 4.34 ton/fed.) were obtained at planting forward speed 2.55 km/h and grain cell volume of 509 mm^3 under 12.5, 15, and 17.5 cm hill spacing, respectively.

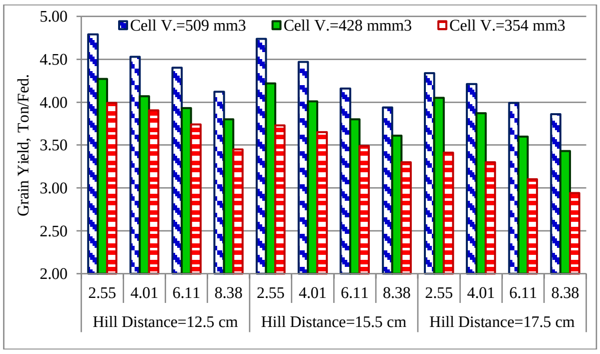

Fig. 11. Grain yield of rice crop sown using modified hill drill under different grain cell volumes, hill spacing and planting forward speeds
Source: Authors' own results.

Table 7. Grain yield and yield components of rice crop sown using modified hill drill under different grain cell volumes, hill spacing and planting forward speeds

Hill Spacings, cm		12.5			15.5			17.5		
Measuring Items	Planting Speed, km/h.	Cell Volume, mm^3								
		354	428	509	354	428	509	354	428	509
No. of Grain/Panicle	2.55	173	201	215	172	183	201	156	179	194
	4.01	161	190	208	150	173	198	145	162	183
	6.11	153	175	191	139	163	190	129	152	170
	8.38	141	170	185	133	156	182	121	143	166
1000 Grain Weight, (g).	2.55	25.53	25.22	24.92	25.57	25.39	25.13	25.59	25.47	25.19
	4.01	25.61	25.34	25.13	25.62	25.54	25.27	25.71	25.56	25.41
	6.11	25.69	25.46	25.26	25.73	25.59	25.38	25.78	25.62	25.45
	8.38	25.83	25.66	25.54	25.91	25.77	25.53	25.91	25.77	25.53
Filled Percentage (%)	2.55	96.74	95.31	93.12	97.19	96.39	93.66	97.37	96.43	95.28
	4.01	96.75	95.40	93.30	97.22	96.43	93.98	97.44	96.50	95.44
	6.11	96.89	95.89	94.05	97.43	96.52	94.66	97.82	96.90	95.70
	8.38	97.39	96.35	94.94	97.75	96.63	95.20	98.24	97.21	96.26
Grain Yield. (ton/fed.)	2.55	3.99	4.27	4.79	3.73	4.22	4.74	3.41	4.05	4.34
	4.01	3.91	4.07	4.53	3.65	4.01	4.47	3.30	3.87	4.21
	6.11	3.74	3.93	4.40	3.49	3.80	4.16	3.10	3.60	3.99
	8.38	3.45	3.80	4.12	3.30	3.61	3.94	2.94	3.43	3.86
Straw Yield. (ton/fed.)	2.55	5.10	5.82	6.78	4.55	5.29	6.47	4.04	4.80	5.88
	4.01	4.84	5.43	6.41	4.28	5.26	6.31	3.97	4.63	5.62
	6.11	4.76	5.26	6.27	4.21	5.23	6.25	3.94	4.37	5.24
	8.38	4.66	5.16	6.21	4.18	5.15	5.93	3.92	4.32	4.93
Harvest Index, (%)	2.55	43.88	42.30	41.39	45.03	44.37	42.30	45.77	45.78	42.46
	4.01	44.66	42.83	41.39	46.02	43.27	41.47	45.36	45.54	42.82
	6.11	43.98	42.76	41.22	45.34	42.07	39.97	44.04	45.14	43.22
	8.38	42.53	42.39	39.89	44.11	41.20	39.93	42.84	44.28	43.89

Source: Authors' own results.

Meanwhile, the obtained results of yield components such as straw yield, No. of grain/panicle and 1,000 grains weight were giving the same trend of grain yield under different study parameters.

However, the yield components of filled grain % results in an inverse trend compared to grain yield.in other words, increasing the level of planting forward speed and grain cell volume and hill spacing results in an increase in filled grain % as shown in Table 7.

CONCLUSIONS

Based on this research, the following conclusions were drawn:

-An increase of grain cell volume or hill spacing decreased the obtained values of visible damage at any given level of planting forward speed. However, an increase in planting forward speed increased the visible mechanical damage at any given grain cell volume and hill spacing.

-An increasing in cell volume and hill spacing increased the obtained values of germination ratio and emergence percentage. However, any increase in planting forward speed decreased the obtained values of germination ratio and emergence percentage.

-Increasing the coefficient of plant distribution uniformity by increasing cell volume and hill spacings and by decreasing the planting forward speed.

-Increasing planting forward speed results in an increment percentage in effective field capacity and power requirements, and a decrement percentage in field efficiency and energy consumption at any given load for modified hill drill.

-The minimum values of grain yield (3.45, 3.41, and 2.94 ton/fed.) were obtained at planting forward speed of 8.38 km/h for grain cell volume of 354mm^3 under 12.5, 15, 17.5 cm hill spacing respectively. However, the maximum values of grain yield (4.79, 4.74, and 4.34 ton/fed.) were obtained at planting forward speed 2.55 km/h and grain cell volume of 509 mm3 under 12.5, 15, and 17.5 cm hill spacing, respectively.

REFERENCES

[1]Asibi, A. E., Chai, Q., Coulter, J. A., 2019, Rice blast: A disease with implications for global food security. Agronomy, 9(8): 451. https://doi.org/10.3390/agronomy9080451.
[2]Awady, M. N., 1992, Farm machines. Txbk, Col. Ag., Ain Shams U.; 120 p.
[3]Bhushan, L., Ladha, J. K., Gupta, R. K., Singh, S., Tirol-Padre, A., Saharawat, Y. S., Gathala, M., Pathak, H., 2007, Saving of water and labor in a rice–wheat system with no-tillage and direct seeding technologies. Agronomy Journal, 99(5): 1288-1296.
[4]Coates, W., 1992, Performance evaluation of a pendulum spreader. Applied Engineering in Agriculture, 8(3), 285-288.
[5]Dudarev, I., Kirchuk, R., 2017, Simulation of bulk materials separation process in spiral separator. INMATEH-Agricultural Engineering, 53(3): 57-64.
[6]Embaby, A.T., 1985, A comparison of different mechanization system for cereal production. M.Sc. Thesis, Agric.Eng., Cairo Univ.
[7]FAO, Food and Agricultural Organization of the United Nations, 2021, FAOSTAT. https://www.fao.org/faostat/en/#data/QCL. Accessed on 20 April, 2023.
[8]Ibrahim, M. M., Abd El-Mageed, H. N., Abd-Alla, T. H., 2008, Evaluation the field performance of a developed planting machine suitable for soaked rice. Misr J. Ag. Eng, 25(3): 677-692.
[9]Kakraliya, S. K., Singh, L. K., Yadav, A. K., Jat, H. S., Kakraliya, S. S., Choudhary, K. M., Datta, A., 2016, Smart package and practices for direct seeded rice (DSR). Innovative Farming, 1(2): 49-55.
[10]Karayel, D., Barut, Z. B., Özmerzi, A., 2004, Mathematical modelling of vacuum pressure on a precision seeder. Biosystems Engineering, 87(4): 437-444.
https://doi.org/10.1016/j.biosystemseng.2004.01.011
[11]Kassar, F. H., 2011, The effect of sowing speeds travelling gang angle of disc harrow range and tillage depth on some of the technical parameters for the machine unit and furrow dimensions. M. Sc. Thesis., agric. Mach. and equip. Dep., Fac. of Agric., Baghdad Univ., Iraq, 45-47.
[12]Madlol, K. M., 2012, Effect of the sowing speed and depth on some economical, technical indicators and energy requirements for machinery unit. Misr Journal of Agricultural Engineering, 29(4): 1417-1436.
[13]Mohamed, M. A., Kheiry, A. N., Rahma, A. E., Yousif, H. A., 2016, Performance evaluation of two planter makes as affected by forward speeds. J. of Agricultural Science and Practice, 2: 16-22.
[14]Pundkar, M. R., Mahalle, A. K., 2015, A seed sowing machine: A review. Int J Eng Soc Sci, 3(03), 68-74.
[15]Sharma, A., Sharma, S., Yadav, P. K., Sodari, B., 2021, Direct Seeded Rice and its Prospects in Nepal: A Review. Turkish Journal of Agriculture-Food Science and Technology, 9(12), 2355-2364.
[16]Singh, N., Singh, B., Rai, A. B., Dubey, A. K., Rai, A., 2012, Impact of direct seeded rice (DSR) for resource conservation. Ind Res J Exten Edu, 2, 6-9.
[17]Srivastava, A. K., Goering, C. E., Rohrbach, R. P., and Buckmaster, D. R., 1993, Engineering principles of agricultural machines. ASAE Textbook No. 6, Published by the ASAE.35-38.
[18]Steel, R. G. D., Torrie, J. H., 1980, Principles and procedures of statistics, a biometrical approach (No. Ed. 2). McGraw-Hill Kogakusha, Ltd.
[19]Sun, X., Li, H., Qi, X., Nyambura, S. M., Yin, J., Ma, Y., Wang, J., 2022, Performance Parameters Optimization of a Three-Row Pneumatic Precision Metering Device for Brassica chinensis. Agronomy, 12(5): 1011.
[20]Teixeira, S. S., Reis, Â. V. D., Machado, A. L., 2013, Distribuição longitudinal de sementes de feijão (*Phaseolus vulgaris* L.) com dosador de disco horizontal operando com uma ou duas saídas de sementes. Engenharia Agrícola, 33: 569-574.
[21]Villalobos, F. J., Orgaz, F., Fereres, E., 2016, Sowing and planting. In Principles of Agronomy for Sustainable Agriculture (pp. 217-227). Springer, Cham.
[22]Virk, S. S., Fulton, J. P., Porter, W. M., Pate, G. L., 2020, Row-crop planter performance to support variable-rate seeding of maize. Precision Agriculture, 21(3): 603-619.
[23]Wagner, L. E., Yu, Y., 1991, Digitization of profile meter photographs. Transactions of the ASAE, 34(2), 412-0416.
[24]Wang Y.L., Zhu D.F., Xing J., Chen, H., Zhang, Y., Xu, Y., Zhang, Y., 2020, Characteristics of Seedling Raising and Mechanized Transplanting of Hybrid Rice with a Low Seeding Rate by Precise Seeding Method. Chinese Journal of Rice Science, 34(4): 332-338. DOI: 10.16819/j.1001-7216.2020.9113
[25]Wei, F., Zhiyuan, Z., Ying, Z., Xiwen, L., Shan, Z., Zaiman, W., 2017, Development and experiment of rice hill-drop drilling machine for dry land based on proportional speed regulation. International Journal of Agricultural and Biological Engineering, 10(4): 77-86.
[26]Xangsayasane, P., Phongchanmisai, S., Vuthea, C., Ouk, M., Bounphanousay, C., Mitchell, J., Fukai, S., 2019, A diagnostic on-farm survey of the potential of seed drill and transplanter for mechanized rice establishment in Central Laos and Southern Cambodia. Plant Production Science, 22(1): 12-22.
[27]Xu, K., Tang, L., Guo, B. W., Zhang, H. C., Huo, Z. Y., Dai, Q. G., Wei, H. Y., 2014, Lodging resistance of rice under the different pattern of water direct-seeding cultivation method. Acta Agriculturae Boreali-Sinica, 29(6): 226-232.

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AUTHENTICITY IN ROMANIAN RURAL TOURISM - DEFINING A CONCEPT

Carina Andreia DOBRE, Iuliana ZAHARIA, Adina Magdalena IORGA

University of Agricultural Sciences and Veterinary Medicine Bucharest, 59 Marasti, District 1, 11464, Bucharest, Romania, E-mails: dobre.carina@managusamv.ro, dobrecarina@yahoo.com, zaharia.iulia@managusamv.ro, iorga.adina@managusamv.ro

Corresponding author: dobrecarina@yahoo.com

Abstract

In the context of globalization, rural tourism offers diversity in close connection with regional specificity. In this sense, there is an increase in the tourist offer oriented towards the traditional, towards the authentic. The entrepreneurial attempts to reflect the local authentic in the field of tourism are not well defined, often the specific traditional elements are not respected, creating an inappropriate mixture of architectural, gastronomic and cultural styles. Thus, the need to define the concept of authenticity in rural tourism based on vernacular culture is noted and this is the main aim of this paper. Also, theoretical items such as rural space, rural tourism, vernacular, and authenticity are defined and systematized, and essential parameters like elements, principles and methods for substantiating authentic rural tourism are synthesized. These ideas are critically analyzed, and discussed, based on representative documentation from Romanian and foreign literature to which the authors added their modest contribution. Authentic rural tourism offers interesting experiences precisely through originality, local specificity, diversity, in a cultural and geographical framework that completes the knowledge and offers the tourist a truly authentic experience. In this way, an increase in tourist interest is achieved and the foundations are laid for sustainable, representative economic activities at the rural level.

Key words**:** *rural space, rural tourism, vernacular, authenticity*

INTRODUCTION

The complexity, richness and attractiveness of the Romanian rural space derive from the combination of the characteristics of the natural landscapes (plain, hill, mountain, Danube Delta, Black Sea) with the socio-economic reality and cultural identity. Dynamic environment, in a permanent transformation and often in confrontation with the urbanism [4], the rural is valued and capitalized also through the tourist activity. As the modern lifestyle imposes an alert rhythm with excessive exposure to technology, in a polluted environment there is a need, especially for the alienated/exhausted citizens, to relax during their free time, in a habitat far from the urban tumult, and the rural space offers a viable answer not only for the escape “from the madding crowd", but also for other fundamental human needs, which can be fulfilled through the direct encounter with the natural, cultural and social resources, valued and capitalized through rural tourism. These human needs, developed and exploited from/through economic reasons, generated rural tourism (with its various subtypes), which experienced an upward trend in the last decades [3]. Why upward trend? Because, in the present time the globalization which standardize and levels many aspects of our life, also the tourism sector, and rural tourism is offering a large variety of services in close connection with local, regional specificity, noting the increase in the rural environment related tourist offer oriented towards the traditional, towards the authentic - the so-called *glocalization* [25].

To the previousy exposed elements, we also note the fact that, in Romania, entrepreneurial attempts to reflect local authenticity in the field of tourism, although growing, are not well outlined, often the traditional elements specific to the place are not respected and/or are replaced through a disharmonious mixture of architectural styles, interior decorations, gastronomic products, the invention of festivals that do not originate in authentic rural life, etc. which generates widespread kitsch.

Taking into account the importance of rural tourism, as well as the theoretical and normative gap relative to the valorization of vernacular culture in tourism, this paper aims to clarify/define the concept of authenticity in rural tourism by identifying the elements of rural heritage that must be included in the tourist offer, as well as of the principles and methods subsumed under the branch of rural tourism, which we propose and aim to doctrinally articulate: the authentic/vernacular rural tourism.

MATERIALS AND METHODS

The lack of specialized studies in this context, but also the increased interest of Romanian and foreign tourists in knowing and experiencing the rural specifics determine the need to bring to attention the authentic/vernacular rural tourism by defining and clarifying objective criteria for assessing a level of quality of tourist services, justifying this research.

Through the analysis of national and foreign specialized literature, the theoretical foundation of the essential notions in outlining the ideas of diversity, originality, specificity offered through rural tourism was achieved.

Thus, the present work presents the necessary elements for defining a new concept for the present rural tourism - ***authenticity***, reviewing the basic elements that characterize the local/regional socio-cultural life and are able to provide specificity to each place. Basic well known notions such as: rural landscape, rural tourism, vernacular rural tourism, as well as the concept of authenticity will be defined, clarified, discussed – by case.

The expression of these theoretical principles and concepts through the entrepreneurial offer of tourist services, framed as authentic rural tourism, must consider the parameters considered characteristic of the rural space and its essential millennial functions, aspects described schematically and systematized in this work.

RESULTS AND DISCUSSIONS

The rarity of studies in this context suggests a lack of attention inconsistent with the needs of consumers and providers of hospitality services, thus underlining the need for fundamental research in this field [17, 18, 19, 20].

Supporting the importance of promoting traditional authenticity in tourism, Salazar claims that “diversity sells”. The marketing of cultural and heritage tourism, which promotes the experience of so-called authentic traditional cultures, “vividly illustrates this" [25].

On the other hand, through the expansion of tourism in rural areas which is specific to a local and global economic growth, a deconstructive tendency can be found that leads to kitsch, as Cole states: "tourism transforms culture into a commodity, packaged and sold to tourists, resulting in loss of authenticity” [7]. In fact, tourism activity leads to changes, both on the landscape and on the lifestyle and local cultural heritage, which can lead to a loss of authenticity [15].

It is of particular importance the awareness of entrepreneurs in Romania about the branding mechanisms of hospitality, as part of a tourism marketing strategy. This means the reactivation of their "social memory" related to the rural socio-cultural universe [5]. A realistic solution is the production of cultural tourism identity that can be created based on scientific criteria for the appreciation of vernacular culture which is specific to each area of Romania. Thus, several categories of impact are identified: entrepreneurs, tourists, local community. They will be able to benefit from the increase in awareness of the cultural heritage, the value of specific Romanian hospitality and consequently the economic value of tourism, sources of local sustainability [29, 10, 11, 1].

The evaluation of authenticity from the tourist perspective must consider all the elements that generate his experience in the context of Romanian traditional elements [29]. The promotion of Romanian authenticity through a private initiative in tourism proves to be a successful way that draws attention to local traditional features and helps to preserve characteristic ethnographic elements [9].

The conceptual boundaries between notions such as rural space, rural tourism, rural vernacular tourism can be taken into account through the definitions written below.

Rural space is defined as a particular way of using space and social life and is characterized by:

a) a low density of inhabitants and constructions, mainly including a vegetal expanse in the landscapes.

b) economic use of agro-forestry-pastoral farming dominance.

c) the way of life of its inhabitants, characterized by their belonging to communities of limited size and by their relationship with the geographical space.

d) a specific identity and representation, with strong connotations of village culture [14]

In conformity of actual Rural Areas European Union policy, in rural space which includes inland or coastal area villages and small towns, the land is used in different activities such as: agriculture, aquaculture and fishing and forestry; economic and cultural activities – crafts, services and local industry; development of leisure and natural reserves; and other uses [3].

One of the important components of the modern lifestyle that interferes with the rural space is tourism – not just a recreative activity, but more complex with cultural, social, economic impact – developed in rural areas implying rural communities (agritourism being a subtype).

Another simplest definition regarding rural tourism refers to tourism destinations in rural space with accommodation facilities and other variety of services [27].

World Tourism Organization emphasize the role of local population in tourism activity, local natural, sociocultural and patrimony resources, as well as building and facilities including guesthouses and agritourism farms [23].

Regarding agritourism, this form of tourism activity is based on services like accommodation, meals, leisure and others, based on local natural and human resources, capitalized in a superior way. One important consequence is rising of life standard in these areas. The peasant household and their agricultural products and also tourist participation in specific rural activities, represent the basis of this activity [27].

Taking into account the above-mentioned definitions, we propose the following conceptual delimitation for ***vernacular rural tourism***: that species of rural tourism that capitalizes among the resources available in the rural space on those that are directly and necessary correlated with the zonal, regional/national identity heritage, are recognizable, coherent in the respective space and informally transmitted, which ensured the cohesion, authenticity and specificity (originality) of a community during its history.

Authenticity is a broad concept presented in the specialized literature, with multiple references.

Thus, from the ethnographic perspective, the meaning of the term *authenticity* in the narrow sense refers to: the intrinsic character of everything that is truthful and accurate in relation to material and spiritual reality; that which cannot be disputed as such, all that acts by its own creative authority; in a broad sense: everything that integrates into a context of civilization or culture, as a constitutive and inalienable part and thereby manifests its own creative features, that which is identical to itself in the process of popular creation, reveals the essence of things, phenomena and facts of civilization or culture; what is original in a popular creation, without thereby altering the essence and the traditional style of the creation, the uniqueness of objects and ideas in their extrinsic character, the elementary condition of the crystallization of any ethnic specificity in a valuable popular creation [31].

In the view of Mac Cannell authenticity is a cultural notion that places the past (authentic) in opposition to the present (modernity) [16] but the dichotomy between a premodern (authentic) and modern (inauthentic) has been contested [24]. Thus, modernity includes elements of authenticity and promotes it as community cultural values.

As typologies of the authentic, the *objective* authenticity (the museum version), the *constructive* authenticity (something that can appear or gain social recognition as authentic) and the *existential* authenticity (a special existential state in which individuals are true to them) are differentiated [32].

Constructive authenticity takes elements of authenticity (vernacular architecture, popular customs, regional traditions, and customs) which it valorizes through cultural tourism.

Also, in relation to tourism, another perspective of authenticity is that of the relationship authenticity - alteration in which three factors are considered essential:

- community control and acceptance
- cultural meanings
- tourists' perceptions [12].

The recognition as authentic of the cultural elements is done by the members of the rural and academic community by highlighting the cultural and symbolic meanings, as it appears from the ethnographic and museum literature.

In the tourist activity, it is necessary to be aware of the danger of the transformation of culture into merchandise, of the commercialization of culture, packed and sold to tourists [6].

Other distinctions required:

• ***rural/ vernacular***

The rural can no longer and only partially overlap with the vernacular (in a very small part even) because nowadays the rural space, especially in the wealthy regions, is overflowing the civilization, technology, digitalization. Moreover, the integration into supranational structures, in the trend of globalization, in the waves of contemporary (e)migrations, have introduced values and actions specific to the market economy, resulting in massive depopulation of villages, massive sales of land at low prices, the mixing of ethnicities and implicitly diluting traditions or replacing them with recent customs.

• ***original/ vernacular***

The original is what can constitute the first copy, which served or can serve as a basis for copies, reproductions or multiplications; which was first produced in some form.

Vernacular refers to what is specific to a region, community, etc.

The vernacular also includes elements of originality that are taken over, with the associated symbols and meanings, by the members of a community.

By promoting local authenticity in tourism, the self-identity of the rural community is preserved and promoted, in its originality, in close connection and highlighting local cultural meanings, part of a vernacular culture.

In the case of Romanians, the parameters considered characteristic of rural space are:

- agricultural activities have the largest share, being associated with other activities, for example forestry activities in highland areas;
- family-type household private property predominates as a property regime;
- smaller number of population and lower density compared to urban areas;
- particular natural geographical spaces (due to landscape, water resources, soil and subsoil resources, air quality, fauna and flora, etc.);
- the lifestyle regulated by traditions, principles, norms, unwritten values but validated by millennial experience, "the village being a sanctuary where everything specific to the Romanian people is preserved. The entire social and cultural life represents an unparalleled heritage of humanity" [3];
- Aspects related to infrastructure;
- The way of organization and administration (the territorial unit is the village);

Moreover, vernacular rural tourism must consider the millennial essential functions of the rural space, presented in Fig. 1.

As principles we propose, condensed:

-regionalization of services: each area should preserve and promote its zonal specificity (the vernacular);

-rural tourism operating norms regulation of (by evaluating/classifying tourist units according to objective criteria related to the defining elements of authentic zonal, vernacular culture - architecture, interior design, local gastronomy, traditional folk customs, popular costumes, crafts, rural landscape, language) as noted and illustrated in Fig. 2.

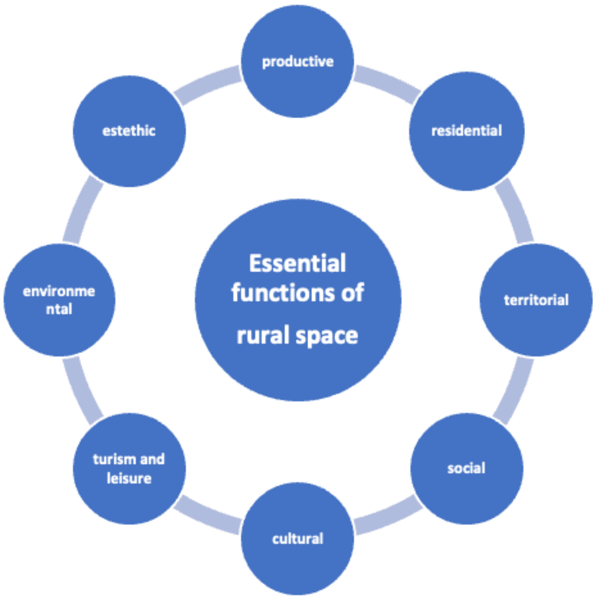

Fig.1. The essential functions of the rural space
Source: ownprocessing according to Bogan and Simon (2019) [3].

Fig. 2. Rural vernacular turism - basic elements
Source: own processing.

In the last decades, rural tourism (with its various subtypes) has experienced an upward trend [3] because it represents, a way of escaping from the urban environment aggression (multiple levels pollution), changing the digitalize system of human connections with direct contact with each other and with the nature and responds to a need for green (in the ecological sense) but also exoticism of a foreign tourist curious to explore the national specifics of cultures other than the native ones.

But what do we offer to customers, in our days, in a practical way, people which need to experience the authentic, vernacular rural space?

Concretely, unfortunately, most of the time, we offer just a kitsch.

But through interest, education - resources and information, assessment and classification, the situation can be substantially improved. A solid starting point in the study of the traditional rural space is the essential contributions of the Sociological School from Bucharest, the "theory of the joint property community" of Henri Stahl, the "characteristics of the traditional countryside" of Henri Mendras, the "conformism of the soul" of George Marica, the "rural issue" of Ilie Badescu or the "community spirit" of Bogdan Voicu [26, 22, 21, 2, 30]. Equally valuable from a documentary point of view can be the actual living in the rural community that preserved the authentic regional Romanian lifestyle.

Popular culture preserves and expresses "our eternal ethnic" [8], and the rural space is the context in which it was conceived and can be optimally valued and capitalized under the aspect of natural and cultural potential, because the village maintains its "three main functions: economic, ecological and socio-cultural" [13].

The management of popular culture, also reflected in rural tourism, is associated with the promotion of development through self-regenerative systems and calls for a theoretical doctrine to formulate its central articulations: "the principles, concepts and methods of valorizing popular creation in general and folklore in particular" [8] and precisely this theoretical space we aimed to enrich through this research. With a deep philosophy and a methodical spirit, the rural culture manager has as his first premise the research of traditions, both those of an institutional character and those of a non-institutional nature" [8] without whom its activity becomes inappropriate, deviating from the vernacular source that it should preserve, promote, and valorize thoughtfully, because it belongs to the deep Romanian identity.

CONCLUSIONS

Considering the importance of rural tourism, as well as the theoretical and normative gap relative to the valorization of vernacular culture in tourism, we assume that this paper diminished the lack previously mentioned around the concept of authenticity in rural tourism. The rarity of studies in this context demonstrates also a lack of attention inconsistent with the needs of consumers and providers of hospitality services, thus underlining the need for further fundamental research in this field.

Although the authentic vernacular rural tourism may seem like a utopia at present, the promotion of the concept at the higher educational institutional level and central and local administrative units, but also through private initiatives in this sector, proves to be a successful method that draws attention to the traditional specifics and helps to preserve local ethnographic characteristic elements.

Through authentic rural tourism based on vernacular culture, on the one hand a local entrepreneurial and economic activity is created and supported, and on the other hand a unique socio-cultural heritage is preserved, and the idea of cultural diversity is promoted.

Through these, authentic rural tourism correlates perfectly with the truly authentic experiences of tourists who come into direct contact with profoundly Romanian socio-cultural landmarks that have passed the test of time.

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REFERENCES

[1]Albu, R. G., Nicolau, L. C., 2011, Sustainable Development of the Romanian Rural Areas within the Present European Context. Bulletin of the Transilvania University of Braşov, Vol. 4 (53), No. 1, Series V, pp. 111-118.

[2]Badescu, I., 2007, Rural Sociology (Sociologie rurala), In Romanian, Mica Valahie Publishing House, pp. 4-5.

[3]Bogan, E., Simon, T., 2019, Rural tourism (Turism rural), In Romanian, Universitara Publishing House, Bucharest, pp. 8, 10-11, 13-18.
[4]Branzan, O., 2006, Rural development (Dezvoltare rurala), In Romanian, "Aurel Vlaicu" University of Arad Publishing House, pp. 2-3, https://www.academia.edu/25721806, Accessed on 10.10.2023.
[5]Catrina, S., 2016, Branding an authentic rural Maramureş in tourism practices: Interplay of hospitality, heritage and social memory. Tourism and Hospitality Research, Vol.16(3), 267-281.
[6]Cheong, S., Miller, M., 2000, Power and Tourism: A Foucauldian Observation. Annals of Tourism Research pp. 371–390.
[7]Cole, S., 2007, Beyond Authenticity and Commodification. Annals of Tourism Research, Vol. 34(4), 943–960.
[8]Constantinescu Galiceni, V, 2007, The sociology of the rural communities (Sociologia comunităților rurale) In Romanian, the Publishing House of România de Mâine Foundation, pp.388-389.
[9]Dobre, C. A., Iorga, A. M., Stoicea, P., 2022, Authentic Romanian and rural tourism in the Sub-Carpathian Muntenia area. Original case study "Satul Banului Guest House". Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(2), 293-300.
[10]Fagioli, F. F., Diotallevi, F., Cian, A., 2014, Strengthening the sustainability of rural areas: the role of rural tourism and agritourism. Rivista di Economia Agraria, Vol. 69(2–3), 155-169.
[11]Garau, C., 2015, Perspectives on Cultural and Sustainable Rural Tourism in a Smart Region: The Case Study of Marmilla in Sardinia (Italy). Sustainability, Vol. 7, pp. 6412–6434.
[12]Getz, D., 1998, Event Tourism and the Authenticity Dilemma. In Global Tourism, W. Theobald, ed., Oxford: Butterworth–Heinemann, pp. 409–427.
[13]Hoggart, K., et al , 2014, Rural Europe Routledge of taylor&Francis, apud Bogan and Simon, pp. 11.
[14]Kayser, B., 1990, La renaissance rurale. Sociologie de campagnes du monde occidental, Edition A. Colin, Paris, p.316.
[15]Lane, B., 1994, What is rural tourism? Journal of sustainable tourism, Vol. 2 (1-2), 7-21.
[16]Mac Cannell, D., 1974, The Tourist: A New Theory of the Leisure Class. New York: Schocken. Reconstructed Ethnicity: Tourism and Cultural Identity in Third World 765 Communities. Annals of Tourism Research, pp. 375–391.
[17]Manfreda, A., Presbury, R., Richardson, S., Melissen, F., King, J., 2023, A balancing act: Negotiating authenticity in luxury lodges. Journal of Vacation Marketing, Torrens University of Australia, DOI: 13567667231172995.
[18]Manfreda, A., 2022, Luxury Accommodation. In: Buhalis D (ed.) Encyclopedia of Tourism Management and Marketing. Edward Elgar Publishing, pp.104-107, DOI: 10.4337/9781800377486.
[19]Manfreda, A., Presbury, R., Richardson, S., Melissen, F., 2022, The building blocks of luxury accommodation experiences: A meta-ethnographic synthesis. Tourism Management Perspectives 41 (January 2022). Elsevier Ltd: 100926. DOI: 10.1016/j.tmp.2021.100926.
[20]Manfreda, A., Melissen, F., Presbury, R., Richardson, S., King, J., 2023, A model of luxury lodge experience quality. Journal of Hospitality and Tourism Management 54 (March). Elsevier Ltd: 486–499. DOI:10.1016/j.jhtm.2023.02.007.
[21]Marica, G., 2004, the village as a psychological and social structure: A course of Rurala Sociology (Satul ca structură psihică și socială: Curs de sociologie rurală), In Romanian, Argonaut Publishing House, p. 120.
[22]Mendras, H.,1964, Elements of Geberal Sociology (Elements de Sociologie Generala), Presses de Sciences Po, Hors Collection, p. 97.
[23]Nistoreanu, P., coord., 2003, Ecotourism and rural tourism (Ecoturism si turism rural) In Romanian, ASE Publishing House, Bucharest, p.190.
[24]Olsen, K., 2002, Authenticity as a Concept in Tourism Research. Tourist Studies, pp. 159-180.
[25]Salazar, N. B., 2005, Tourism and glocalization “local” tour guiding. Annals of Tourism Research, Vol. 32(3), 628-646.
[26]Stahl, H.H., 1988, Contributions to the study of the Romanian joint property villages (Contribuţii la studiul satelor devălmaşe româneşti), Vol. II, In Romanian, Cartea Românească Publishing House, Bucharest.
[27]Stanciulescu, G., Lupu, N., Ţigu, G., Ţitan, E., Stancioiu, F., 2002, Lexicon of tourist terms (Lexicon de termeni turistici), In Romanian. Oscar Print Publishing House, Bucharest, p.180
[28]Tureac, C. E., Turtureanu, A. G., Bordean, I., 2008, General Considerations on Rural Tourism. Scientific of „Alexandru Ioan Cuza” University of Iaşi, Vol. 55, pp. 220–228.
[29]Ursu, C.D., Gherasim, R., Popa, A. I., Rad, A.R., 2020, Valorisation of the vernacular heritage A case study: IAPA. Territorial Planning: from theory to practice. Case studies from Maramures Land (Valorificarea patrimoniului vernacular. Studiu de caz: IAPA. Planificare teritorială: de la teorie la practică. Studii de caz din Tara Maramureșului), Presa Universitară Clujeană, pp. 4-5
[30]Voicu, M., Voicu, B., 2006, The Romanian village in the way to Europe (Satul romanesc pe drumul catre Europa) In Romanian, Polirom Publishing House, Iasi, pp. 42.
[31]Vulcanescu R., 1979, Dictionary of Etnology, (Dictionar de Etnologie) In Romanian, Albatros Publishing House, Bucharest, pp.49.
[32]Wang, N., 1999, Rethinking Authenticity in Tourism Experience. Annals of Tourism Research N. 837, pp. 349–370.

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DEMOGRAPHIC CHANGES AND INEQUALITIES: REGIONAL DIFFERENCES WITH A FOCUS ON RURAL AREA IN BULGARIA

Julia DOITCHINOVA[1], Elitsa LAZAROVA[2]

[1]University of National and World Economy, Students city, 1700 Sofia, Bulgaria, Phone/Fax: +35928195280; E-mail: juliadoj@unwe.bg
[2]D. A. Tsenov Academy of Economics, 2 Emanuil Chakarov Str., 5250 Svishtov, Bulgaria, Phone/Fax: +359889223924; Email: e.lazarova@uni-svishtov.bg

Corresponding author: juliadoj@unwe.bg

Abstract

The goal of the paper is to analyze and evaluate the demographic development trends in Bulgaria as well as to identify demographically problematic rural areas and the consequences of their development. Based on information from the National Statistical Institute, the demographic processes in the rural areas of Bulgaria for the period 2011-2021 are analyzed. The obtained results show the high rate of population decline in some regions of Bulgaria and the unfavorable values of the coefficients for demographic dependence and replacement. Rural areas of our country are experiencing faster depopulation than cities. This leads to significant territorial disparities in the manifestation of the observed processes. The last part emphasizes the need to implement regional demographic policies aimed at stimulating families with children and reforming professional education. It is also recommended to implement a proactive immigration policy to attract Bulgarians living abroad and immigrants from third countries with the necessary educational and professional qualifications to reduce the negative effects of the labor shortage in rural areas.

Key words: *depopulation, demographic processes, demographic dependence, demographic replacement*

INTRODUCTION

Depopulation has been observed in rural Europe over the past two centuries. The processes of urbanization and economic development are viewed as inevitably leading to a decrease in population density and the depletion of human capital in rural areas.

Researchers [32] view rural depopulation or chronic population loss as a cumulative demographic process that can be tracked historically through specific components of demographic change such as birth rates, death rates, and migration. Depopulation implies the collapse of small towns and rural areas.

In contrast to urbanization, a number of rural areas have been identified as dynamically developing and prosperous in the last decade [26]. The need to change the perception of all rural areas as "shrinking" and to investigate the diversity of rural environment types became apparent.

The population of the EU-27 has increased by 4% since the beginning of the twenty-first century, reaching 447 million in 2021. According to the results of the censuses, there is an increase in the population in seventeen countries, while in the rest it is decreasing. Our country has one of the fastest population declines in the EU. Its quantity dropped by 21.6% (compared to 2001). This indicator is even higher in rural areas of the country and is strongly related to poverty problems there. According to Eurostat data [20], four of the five poorest regions in the EU in 2020 are Bulgarian: the North-West region (36% of the EU average indicator, gross value added per capita), the North-Central region (37%), the South-West (39%), and the South-Central Region (40%).

Some of the highest rates of poverty are found in these rural and remote regions of Italy, Spain, and Romania [18].

The research question in this context is what demographic processes have occurred in Bulgarian rural areas and how these changes affect rural communities' ability to develop viable rural areas. This determines the goal of the paper, which is to analyze and evaluate the demographic development trends in Bulgaria as well as to identify demographically problematic rural areas and the consequences for their development.

Literature review

According to research, population change is influenced by a variety of factors, including demographic, social, economic, political, geographic, and cultural influences, as well as temporal and spatial influences [17]. At the same time, most papers have only focused at a few of the factors and how they affect each other [7]. The majority of existing studies are carried out within various scientific fields and disciplines [33], [2].

Researchers in economics are particularly and the role that those processes play in the development of rural areas [28], [31], [13], regionalists [21], sociologists and others. There have been a number of studies that have been conducted on topics such as the characteristics and changes of human capital [35], the educational structure in rural areas [36], the model of agriculture and its impacts, and the rate at which demographic change [14], [15], is occurring, and these studies have reached a diverse set of conclusions. Because different studies focus on different factors and influences across disciplinary boundaries while ignoring others, existing research on population change frequently generates different and sometimes contradictory results [8], [9].

Regardless of the methodological approaches used, the findings of a number of studies lead to the conclusion that the way rural areas evolve is dependent on the capacity of rural communities, i.e., their ability to respond to external changes by adapting the functions and structure of their internal components. Moreover, today's depopulation is unevenly distributed [21]. It is most significant and at a high rate in remote areas, far from major centers of employment, with an aging population, low fertility, and little (if any) immigration [22].

According to some researchers [22], recognizing the historical interaction between net migration and natural increase is required to fully understand rural population dynamics. Continued rural population losses are a result of fundamental changes in the structure of local populations, particularly low birth rates and population aging, both of which reduce the prospect of population growth. Young adults are highly selected for out-migration, which leaves behind an aging population that is increasing and cannot be replaced [23].

Researchers studying negative demographic processes in rural areas [5] emphasize that the negative impact is not only population loss but also the negative impact on the economy and society [30]. The authors identify several cascading effects and extreme negative consequences for community transformation and regional identity formation [16]. Depopulation worsens conditions for rural development not only because local markets shrink but also because skilled and talented workers decrease and are often insufficient to develop rural industries [34], [6], [24]. In practice, the entry into a vicious circle—a declining local economy and depopulation, which not only coexist but also reinforce each other—could be observed.

The uneven spatial distribution of depopulation is a result of historical connections in the rural economy between the decrease in agricultural jobs caused by mechanization and the concentration of agricultural production, as well as the effects of globalization and automation on rural production [1]. Furthermore, with a high share of agricultural employment, greater population losses are observed as reductions in agricultural activities or increases in labor productivity lead to out-migration from the regions [4]. Johnson and Lichter [22] link the decline of small farms in the United States to rural depopulation, which supports this conclusion.

A study of the significance of demographic changes in rural Austria links them to potential regional development approaches to overcome the negative consequences of population loss [10]. The goal of these approaches is to take advantage of specific local assets and show that the diversity of regions is a valuable trait [11]. Transformations of social management and cooperation between different stakeholders in accordance with common values and attitudes are observed in communities that have successfully renewed their local economies, adapting them to market demand. Local social capital is a prerequisite for establishing effective interactions with the external environment and for accessing financial and political capital that improves development outcomes [27].

MATERIALS AND METHODS

The demographic processes in Bulgaria's various rural areas are the object of this paper. The subject of research includes the analysis of changes in the number of the population and its age characteristics and structures. This predetermines the traditional set of indicators for assessing the demographic situation and development for the period 2011–2021. Among them are the coefficients for evaluating changes in population size and its age structure, as well as these demographic replacements for age dependence, predicted changes, etc. The information is from the National Statistical Institute, and the techniques for defining and calculating the indicators are shown in Table 1.

Table 1. Indicators in use and their definition

Indicators	**Content of indicators (definitions)**
Population in rural areas	population of territories (municipalities) that meet the national definition of rural areas
Under, at, and over working age population (young, working age and elderly population)	based on the current retirement age, the age limits for distribution of the population by categories under, at, and over working age.
Population age structure	ratio between the population of different age groups
Age dependency ratio (Calculated as a percentage)	number of people in the "dependent" ages (those under the age of 15 (young population) and those aged 65 and older (elderly population) per 100 people in the "independent" ages (working age population) (from 15 to 64 years).
The coefficient of demographic replacement (Calculated as a percentage)	the proportion of the working-age population in the entering working age group of 15-19 years and the exiting working age group of 60-64 years.
The rate of natural increase (RNI) (calculated in parts per million)	the ratio of the difference between the number of live births and deaths during the year and the average annual population number

Source: [29].

RESULTS AND DISCUSSIONS

Assessment of demographic changes

The population of the Republic of Bulgaria dropped by 11% in 2021 when compared to the previous census in 2011. Against this background, and as a result of the change in the definition of rural areas in the new program period, there is a noticeable deepening of the negative trends in rural areas. In 2011, there were 2.891 million people living in rural areas, which represented 39% of the total population. For the ten-year period to 2021, it decreased by 5% to 2.474 million people (or 34%). The year 2021 is used as a reference point for data analysis in order to determine what demographic changes have occurred since the implementation of the new programming period's modifications. Then this trend deepens by another 3% (totalling -8%) due to the loss of 16 settlements by definition, and already the change in rural areas compared to 2011 is even more drastic—it decreases to 1.990 million people (or 27%).

At the NUTS 1 level, the inverse asymmetry between the regions is observed, and if the population in North and South-Eastern Bulgaria in 2011 prevailed (51%), then in 2021 it was reduced to 49%. In the period 2011–2021, more than half of the country's population was located in South-Western and South-Central Bulgaria (49% in 2011 and 51% in 2021). Even though the population is shrinking, the proportion of people living in rural areas in North and South-East Bulgaria (from 22% in 2011 to 18% in 2021) has always been likely to be higher than in South-West and South- Central Bulgaria (from 17% in 2011 to 12% in 2021).

At the NUTS 2 level, the demographic problems worsen in all six regions by 2021. However, the South-West region has been least affected by the changes between 2011 and 2021, even though it also went down by 1%. At the same time, the relative share of the population in the Southwest region in 2021 increased to 31%, making it the region with the largest concentration of population.

This trend is also confirmed when studying the population in rural areas (Table 2): the region with the largest population of this type is South-Central (7%), and the region with the smallest population of this type is North-Central (4%). It is important to note that in 2011, the North-Central region was a laggard along with the North-Eastern region, but in 2021, the North-Central region was permanently behind. Another important point is that the number of people living in rural areas is going down, and not just in the South-West. In 2011, 6% of this population lived in the North-West.

In the remaining regions, in 2021, cohesion was observed according to this indicator (5% of the population in rural municipalities). Similarly, in all regions, the rural population was decreasing, with only the North-Eastern region maintaining the relative share of the population in 2011 and 2021 at the level of 5%.

Table 2. Population distribution in total and by rural areas at NUTS 2 level in 2011 and 2021

Indicators	**Population at NUTS 2 level (total)**			**Rural population (NUTS 2)**		
	Structure by regions 2011	Structure by regions 2021	Absolute change	% change	Relative share of the country's population 2011	Relative share of the country's population 2021
North-West	12%	11%	-156,453	-2.1%	6.4%	5.1%
North-Central	12%	11%	-160,878	-2.2%	4.5%	3.8%
North-Eastern	13%	13%	-134,144	-1.8%	5.1%	4.7%
South-East	15%	15%	-118,826	-1.6%	5.9%	4.6%
South-West	29%	**31%**	-108,444	**-1.5%**	7.6%	5.1%
South-Central	20%	20%	-166,036	-2.3%	9.6%	**7.1%**
Total:	100%	100%	-844,781	-11.5%	39.1%	30.4%

Source: Own calculations.

At the NUTS 3 level (Table 3), a decrease is reported in 6 provinces (Dobrich, Pleven, Silistra, Smolyan, Vratsa, and Veliko Tarnovo). Most provinces (18 of them) managed to keep their relative share of the population in 2021 as well. Only in 4 provinces is there an increase in the population (Plovdiv, Sofia Province, Sofia (capital), and Varna). There is no increase in the population in any of the rural areas, but the preservation of the relative share of the rural population in 19 provinces stands out as a positive trend. In 8 provinces within which the rural population lives, a decrease is observed (Burgas, Blagoevgrad, Gabrovo, Pazardzhik, Plovdiv, Sliven, Vidin, and Vratsa). Upon closer examination of the data, it is noticeable that in 5 provinces the relative share of the rural population is insignificant (Gabrovo, Kyustendil, Pernik, Sliven, and Vidin are 0%), where Pernik and Kyustendil retain the same relative share in 2011 and 2021.

It is important to note that in 2021, changes occur in 10 provinces due to the dropping of 16 municipalities from rural areas in connection with the Strategic Plan for the Development of Agriculture and Rural Areas for the period 2023–2027, and they fall from 231 to 215 rural area municipalities. In this way, strategic factors are added to demographic ones, and the rural population reduction by province reaches -9% by 2021.

The rate of natural increase

In 2021, the rate of natural increase for the country amounts to -13.2‰. At the NUTS 1 level, the trend toward faster depopulation of North and South-Eastern Bulgaria is confirmed. In South-West and South-Central Bulgaria, a negative rate of natural increase is also observed, but the rates of population decline are lower. This imbalance is evident

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in Figure 1, which depicts NUTS level 2 regions.

Table 3. Distribution of provinces (NUTS level 3) by direction of population changes (total and in rural areas) by 2021 compared to 2011

Direction of changes	Changes in population at NUTS 3 level compared to 2011		Changes in the population in rural areas (NUTS 3) compared to 2011	
	Total	Provinces	Total	Provinces
Decrease	6	Dobrich, Pleven, Silistra, Smolyan, Vratsa, Veliko Tarnovo	8	Burgas, Blagoevgrad, Gabrovo, Pazardzhik, Plovdiv, Sliven, Vidin, Vratsa
Retain the same	18	Burgas, Blagoevgrad, Gabrovo, Haskovo, Yambol, Kyustendil, Kardjali, Lovech, Montana, Pazardjik, Pernik, Razgrad, Ruse, Shumen, Sliven, Stara Zagora, Targovishte, Vidin	19	Dobrich, Haskovo, Yambol, Kyustendil, Kardjali, Lovech, Montana, Pernik, Pleven, Razgrad, Ruse, Sofia region, Shumen, Silistra, Smolyan, Stara Zagora, Targovishte, Varna, Veliko Tarnovo
Increase	4	Plovdiv, Sofia region, Sofia (capital), Varna	0	-

Source: Own calculation.

The region with the highest rate of natural increase in 2021 is the North-West region (-20.7‰), followed by the North-Central region (-18.1‰), and the two regions with the smallest decreases according to this indicator are the South-West region (-9 .9‰) and South-East (-11.6‰).

At the NUTS 3 level, the provinces with the lowest rate of natural increase are Sofia district (the capital) (-6.58‰), followed by Sliven province (-9.0‰), and Burgas province (-9.9‰). (table 4). Regardless of the lowest reported rates for natural increase, these areas anticipate losing between 20,000 and 50,000 people over the course of the new program period. Because of this, it will be necessary to mobilize the labor potential in order to maintain the levels that were achieved in 2021. The provinces with the most serious deterioration according to this rate are Vidin (-25.7‰), Montana (-23.1‰), Gabrovo (-22.0‰), and Kyustendil (-22.0‰).

At the same time, the rates of natural increase in cities for the country are -10.5‰, and at the NUTS 2 level, by region, they vary between -8.2‰ and -16.1‰, with marginal values in the South-West and North-West regions, respectively. The fastest depopulating cities are in Gabrovo (-18.7‰) and Silistra (-8.6‰) provinces, and the villages in these provinces, on the other hand, have above-average values for this indicator. The rate of natural increase in the villages in Bulgaria decreases by -20.2‰, and the trend is also preserved at the NUTS 2 level; the border regions according to this indicator are: (a) the fastest depopulating - North-Western (-28.7‰), and (b) the South-East has more slow rates of depopulation of villages (-16.2‰).

At the NUTS 3 level, Vidin province has the worst indicators (-39.9‰); however, despite the fact that there have been no changes in the new program period, it emerges as the region with the greatest concentration of negative demographic trends. On the other hand, villages in Sliven province (9.3‰) have the slowest rates of depopulation.

The most unfavorable are the tendencies to reduce the population in the villages. In 16 oblasts of the country (57% of all oblasts), the population has decreased by more than 20%. Among these districts are the four in which the population has shrunk by more than 30%.

Changes in the population age structure

When analyzing the population age structure in the Republic of Bulgaria, it is found that it is maturing. This is clearly evident from the demographic replacement rate: 56.7% of the population is in the "dependent" age groups (those under the age of 15 (young population) and those aged 65 and older
(elderly population). And accordingly, only 43.3% of them are of an age that allows full-time work.

At the NUTS 1 level, South-West and South-East Bulgaria have a more positive age structure (53.8% of the population is of working age), whereas North and South-East Bulgaria have 59.9%.

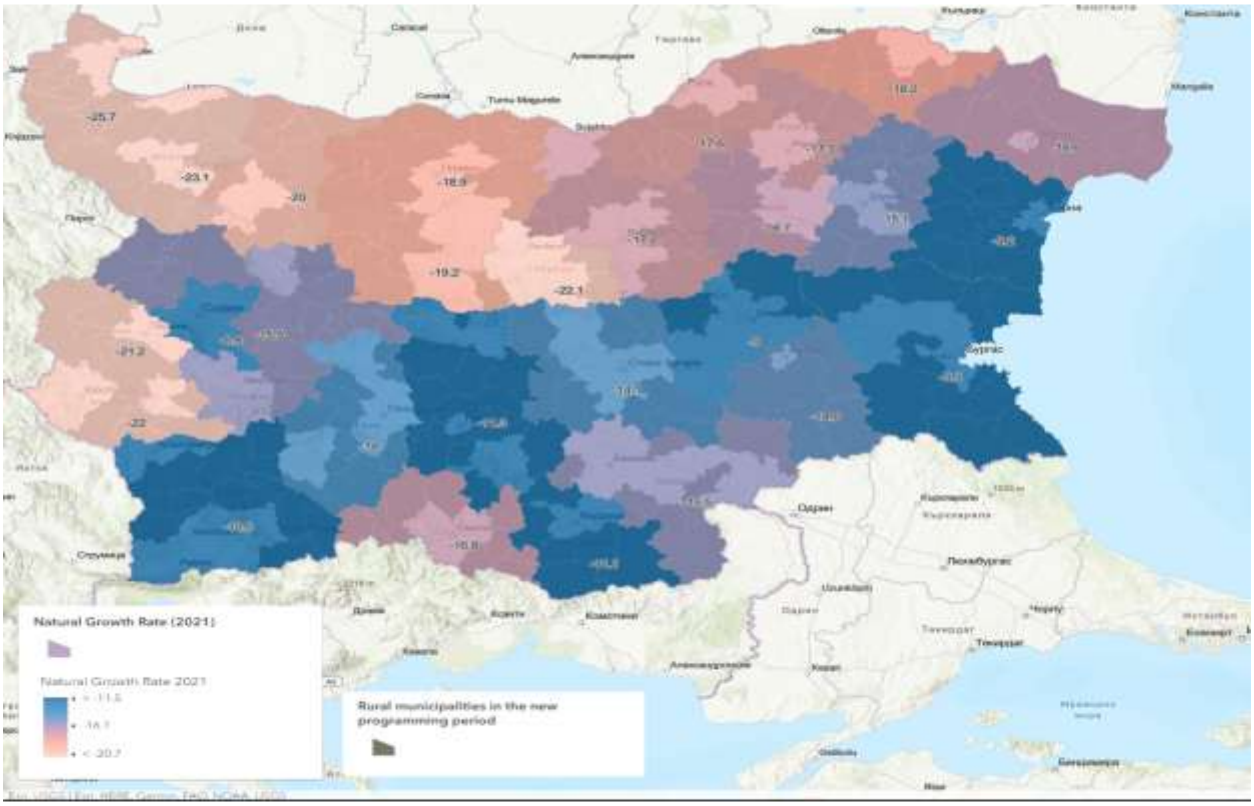

Fig. 1. The rate of natural increase by region at NUTS 2 level (in ‰)
Source: Own calculations in ArcGIS Online.

The worst demographic structure at the NUTS 2 level is in North-West Bulgaria, where the indicator reaches 66.9%, followed by North-Central (60%) and South-East (59.8%). As expected, the South-West region had the lowest indicator values (51.7%), followed by the North-Eastern (54.8%).

The indicator's dynamics deepen at the NUTS 3 level. Outside of working age, the population in Vidin province is 71.4%, while in Gabrovo province it is 68.6%. Sofia (the capital) has the only population below 50% outside of working age, at 48.2%.

When the demographic replacement analysis is applied to the ratio of the population of retirement age to the population of working age, it is discovered that 34% of the population is of retirement age in the country, and the trend at the NUTS 1 level is sustained in favor of the South-West and South-Central Bulgaria with 31.3%. North-West and North-Central regions have the worst ratios, 44% and 39.2%, respectively, while South-West Bulgaria has 29.5%. The trend is also confirmed at the NUTS 3 level, with Vidin (50.9%) and Gabrovo (49.2) having the highest proportion of elderly people, while Sofia (the capital) has the lowest (25.7%).

According to the analyzed data, the deterioration of the age structure of the population in the country and in rural areas has an impact on the labor market, exacerbating the difficulty of locating suitable labor, but it also has the potential to constrain rural economic growth in the country. At the same time, the percentage of the country's population that is 65 and older in comparison to the population that is under the age of 14 reaches 34%, but there are areas where it reaches 50%, which is an indication of a significant aging of the population.

Two provinces stand out in the study in 2021, which have achieved an optimal demographic situation in all indicators (Sofia-region and Varna) against the background of the general decrease.

Table 4. Rural areas at the NUTS 3 level by province in 2021 and in the new planning period

	Rural Population (2021) -Persons-	**Population in rural areas (planning period)**	**The rate of natural increase (2021)**			**Age dependency ratio (2021)**	
			Total (‰)	City (‰)	Village (‰)	Young and elderly to working age population (%)	Elderly to working age population (%)
Blagoevgrad	223,149	109942	-10.6	-8.5	-13.9	53.7	31.0
Burgas	183,704	137,383	-9.9	-8.9	-13.2	55.7	31.8
Varna	112,585	112,585	-9.2	-7.7	-16.8	52.6	29.5
V. Tarnovo	64,602	64,602	-17.2	-12.0	-29.0	58.7	38.2
Vidin	27,561	27,561	**-25.7**	-17.9	**-39.9**	**71.4**	**50.9**
Vratsa	91,071	91,071	-20.0	-15.8	-26.2	62.7	39.8
Gabrovo	37,326	**16,830**	-22.1	**-18.7**	-35.4	68.8	49.2
Dobrich	76,251	76,251	-16.6	-15.2	-19.6	57.9	36.0
Kardjali	79,172	79,172	-11.1	-7.4	-13.5	56.0	34.1
Kyustendil	**24,861**	24,861	-22.0	-17.2	-33.2	66.3	46.2
Lovech	77,695	50,811	-19.2	-15.7	-24.9	68.3	45,5
Montana	73,679	52,431	-23,1	-16.6	-34.7	66.6	43.7
Pazardjik	138,446	68,669	-14.0	-12.8	-16.2	57.0	33.2
Pernik	29,815	29,815	-21.2	-17.1	-35.8	60.7	40.5
Pleven	112,989	112,989	-18.9	-15.6	-25.3	67.8	44.1
Plovdiv	257,284	210,500	-11.3	-9.3	-17.0	55.6	32.2
Razgrad	59,565	59,565	-17.3	-16.5	-18.1	56.4	35.0
Ruse	52,127	52,127	-17.6	-14.7	-26.9	57.9	37.5
Silistra	56,004	56,004	-18.2	-18.6	-17.8	62.6	40.1
Sliven	59,800	29,231	-9.0	-8.7	-9.3	63.8	33.2
Smolyan	62,596	62,596	-16.8	-12.2	-22.8	59.8	41.6
Sofia (capital)	-	-	-15.5	-11.5	-21.4	58.7	37.0
Sofia Province	231,989	165,887	-6.8	-6.5	-11.6	48.2	25.7
St. Zagora	86,573	86,573	-14.1	-11.2	-20.9	60.8	36.4
Targovishte	49,071	49,071	-16.7	-13.8	-20.1	57.8	34.8
Haskovo	85,591	43,204	-15.5	-12.1	-24.3	60.9	37.5
Shumen	72,298	72,298	-15.1	-13.5	-17.5	56.2	34.7
Yambol	47,927	47,927	-14.6	-10.4	-24.0	66.4	41.0
For the country	2,473,731	1,989,956	-13.2	-10.5	-20.2	56.7	34.0
The lowest value of the indicator							
Highest values of the indicator (in 3 cases)							

Source: [29] and own calculations.

CONCLUSIONS

Changes in human capital and its characteristics are among the main factors influencing the development of a territory. Rural areas of our country are experiencing faster depopulation than cities. This leads to significant territorial disparities in the manifestation of the observed processes and to a "greater strengthening of polarization in the demographic space" [3].

Depopulation and population aging cause a variety of problems, including: reproductive potential depletion; a reduction in the population under working age and working age, making it difficult for the labor market to function; access to healthcare, education, and other social infrastructure objects; etc.

Several highly depopulated areas have been identified by researchers [3], including the North- West region, Central Stara Planina and Pre-Balkan, Sakar-Strandzhan region, and Kraishte, for which the concept of "demographic deserts" is already in use. According to the most pessimistic forecast, they will continue to grow and will cover more than half of the country's territory by 2030 [3]. Another concerning trend is the growing number of villages that will be completely depopulated. Settlements without a population made up 4.4% of the village structure in 2011, and they will account for nearly 25% of Bulgarian settlements by 2040. The number of villages with more than 1000 inhabitants is expected to fall from 10.9% in 2011 to 5.04% in 2040.

Changes in the intensity of development are also a result of the constant population decrease. The small number of residents in a number of municipalities is the reason for the lack of the necessary critical mass of active local residents to develop and implement strategies for local development. This necessitates the cooperation between interested parties from several neighboring territories in order to create local capacity to implement projects with European funding.

The structure of local labor markets has been deteriorating as a direct result of unfavorable demographic processes, which has led to a reduction in the potential labor force. As a result, a lack of human capital can limit investment inflows and reduce the region's development potential. Investing in human capital is seen as the principal method of reversing unfavorable trends in changing demographic structures and processes in all countries affected by accelerated aging and depopulation [19]. The latter involves improving the system of healthcare, education, and other social services as well as raising the standard of living for people who live in rural areas [25]. To reach this goal, regional demographic policies need to be made that take into account the demographic and socioeconomic characteristics of each region. Families with two or more children and single parents need financial incentives and tax reductions, under the conditions of a minimum educational threshold for the parents [12]. There should be a place in regional programs for reforming vocational education, which should be fully linked to the needs of business and the labor market and carried out on a modern material and technical basis while providing production practices, scholarships, and securing successful jobs for graduates.

Last but not least, it is necessary to develop and implement a proactive immigration policy to attract Bulgarians living abroad, ethnic Bulgarians in foreign countries, and immigrants from third countries with the necessary educational and professional qualifications to actively join the labor market in Bulgaria and reduce the negative effect of labor shortages.

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REFERENCES

[1]Anderlik, J.M., Cofer, R., 2014, Long-Term Trends in Rural Development and Their Implications for Community Banks. FDIC Quarterly 8(2):44–59.

[2]Baerwald, T. J., 2010, Prospects for geography as an interdisciplinary discipline, Annals of the Association of American Geographers, Vol. 100(3), 493–501.

[3]Bardarov, G., Ilieva, N., 2020, Horizon 2030 – demographic trends in Bulgaria. Horizont 2030 – demografski tendentsii v Bulgaria, Sofia: http://library.fes.de/pdf-files/ bueros/sofia/14730.pdf

[4]Brezzi, M., Piacentini, M., 2010, Labour mobility and development dynamics in OECD regions, Paper presented at the OECD workshop "Migration and Regional Development", Paris, 7 June 2010.

[5]Brown, D. L., Shucksmith, M., 2016, A new lens for examining rural change. European Countryside, 8(2), 94–188. doi:10.1515/euco-2016-0015

[6]Carr, P.J., Kefalas, M.J., 2009, Hollowing Out the Middle: the Rural Brain Drain and what it Means for America. Beacon Press, Boston.

[7]Chi, G., 2010, The impacts of highway expansion on population change: an integrated spatial approach," Rural Sociology, Vol. 75(1), 58–89.

[8]Chi, G., Marcouiller, D., 2011, Isolating the effect of natural amenities on population change at the local level," Regional Studies, Vol. 45(4), 491–505.

[9]Chi, G., Ventura, S., 2011, Population Change and Its Driving Factors in Rural, Suburban, and Urban Areas of Wisconsin, USA, 1970–2000, International Journal of Population Research Volume 2011, Article ID 856534, doi:10.1155/2011/856534

[10]Dax, T., Fischer, M., 2017, An alternative policy approach to rural development in regions facing population decline, European Planning Studies,

[11]Dax, T., 2015, The evolution of European Rural Policy, chapter 3. In A. K. Copus & P. De Lima (Eds.), Territorial cohesion in rural Europe, the relational turn

in rural development, Series Regions and Cities 76, (pp. 35–52). Abingdon: Routledge.
[12]Dermendzhiev, A., Doykov, M., 2020, The demographic processes and the regional disparities in Bulgaria, International scientific conference GEOBALCANICA 2020, pp. 423-430.
[13]Doitchinova, J., Wrzochalska, A., 2022, Demographic processes and problems in rural areas of Poland and Bulgaria, in Innovative development of agricultural business and rural areas, UNWE Publishing complex, p. 115-124.
[14]Doitchinova, J., Miteva, A., 2020, Agriculture and rural development: paths of change and consequences, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 20(3), 207-214.
[15]Doitchinova, J., Stoyanova, Z., 2020, Regional Differences and Impact of Agriculture in Rural AREAS. Ikonomika i upravlenie na selskoto stopanstvo, 65(4), 66-73.
[16]Emery, M., Flora, C., 2006, Spiraling-up: Mapping community transformation with community capitals framework. Community Development, 37(1), 19–35. doi:10.1080/15575330609490152
[17]Entwisle, B., 2007, Putting people into place, Demography, Vol. 44(4), 687–703.
[18]EPRS, 2021, Demographic Outlook for the European Union.
[19]European Commission, 2020, Report on the Impact of Demographic Change. https:// ec.europa.eu/info/sites/default/files/demography_report_2020.pdf, Accessed on 11/2/2023.
[20]Eurostat regional yearbook – 2022 edition
[21]Ilieva, N., Bardarov, G., 2021, Regional demographic imbalances in Bulgaria. Quantitative dimensions, causes, policies and measures to optimize the situation, Friedrich Ebert Foundation.
[22]Johnson, K. M., Lichter D. T., 2019, Rural Depopulation: Growth and Decline Processes over the Past Century, Rural Sociology 0(0), 2019, pp. 1–25 DOI: 10.1111/ruso.12266
[23]Johnson, K.M., Richelle W., 2015, Migration Signatures across the Decades: Net Migration by Age in U.S. Counties, 1950–2010, Demographic Research 22(38):1065–80.
[24]Karwat-Woźniak, B., 2022, Procesy depopulacyjne na obszarach wiejskich – implikacje dla rolnictwa, [w]: M. Wigier, W. Wrzaszcz (red.), Społeczne uwarunkowania rozwoju rolnictwa i obszarów wiejskich w Polsce w latach 2004-2030, IERiGŻ-PIB, Studia i Monografie nr 196, Warszawa, s. 107-141.
[25]Lazarova, E., Pavlov, P., Petrova, M., Shalbayeva, S., 2023, Analysis and Assessment of Infrastructural Potential in Rural Territories. Economics. Ecology. Socium 2023, 7, 1-14.
[26]Li, Y., Westlund, H., Liu, Y., 2019, Why some rural areas decline while some others not: An overview of rural evolution in the world, Journal of Rural Studies, Volume 68, May 2019, Pages 135-143.
[27]Li, Y.H. et al., 2016, Bottom-up initiatives and revival in the face of rural decline: case studies from China and Sweden, Journal of Rural Studies, Volume 47, Part B, October 2016, Pages 506-513.
[28]Mitova, D., 2018, Demographic processes in Bulgaria after EU Accession and problems of human resource development in rural areas (based on the European zoning typology) Bulgarian Journal of Agricultural Economics and Management**,** 63, 2/2018, 60-74.
[29]National Statistical Institute, 2022, Population - demography, migration and projections.
[30]Nikolova, M., Linkova, M. Nenova, R., 2018, Development of rural areas. Razvitie na selskite rayoni. AE "Tsenov", Svishtov.
[31]Sugareva, M., Murgova, M., 2021, What are the real demographic problems of Bulgaria?. Kakvi sa realnite demografski problem na Bulgaria? Statistika, p. 9-40.
[32]Veneri, P., Ruiz, V., 2013, Urban-to-rural population growth linkages: evidence from OECD TL3 regions.
[33]Ward, N., Brown, D.L., 2009, Placing the rural in regional development, Regional Studies, Vol. 43(10), 1237–1244.
[34]Wood, R.E., 2008, Survival of Rural America: Small Victories and Bitter Harvests, University Press of Kansas, Kansas.
[35]Wrzochalska, A., 2015, Selected determinants of human capital of rural population in Poland, Bulgarian Journal of Agricultural Economics and Management**,** 60(3), 2015, 81-95.
[36]Wrzochalska, A., Łaba, S., 2022, Demographic and educational structural changes in Polish villages, 2000–2021. Ikonomika i upravlenie na selskoto stopanstvo, 67(4), 45-59 (Bg).

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FACTORS AFFECTING THE COMPLIANCE OF SUSTAINABLE RICE PRODUCTION IN THE MEKONG DELTA, VIETNAM

Le Canh DUNG, Vo Van TUAN

Mekong Delta Development Research Institute, Can Tho University, Vietnam. Phone: (+84) 292 3833256; Fax: (+84) 0292 3831270; E-mails: lcdung@ctu.edu.vn, vvtuan@ctu.edu.vn, mdi@ctu.edu.vn

Corresponding author: lcdung@ctu.edu.vn

Abstract

This study aims to determine the factors affecting compliance with Sustainable Rice Platform (SRP) standards in rice production in the Mekong Delta, which is considered the largest rice granary in Vietnam and is of great importance in the world rice export market. The study was conducted based on survey data for 426 rice-growing households and implementing SRP standards in the region by 2022. The study results showed that only 6.57% of rice-growing households could fully comply the SRP standard, while the majority of households encountered certain obstacles. The analysis results from the binary regression show that some factors that positively affect the compliance with SRP standards are the education level of the household head, the size of rice land and contract farming. Meanwhile, large demographic size has a negative effect on compliance with SRP standards. In addition, infrastructure factors such as intra-field road condition and post-harvest straw collection services are community-level constraints affecting compliance with SRP standards. Based on the results of this study, some solutions and policy implications are proposed.

Key words: *binary logistic, education, Mekong Delta, rice, Sustainable Rice Platform (SRP)*

INTRODUCTION

Vietnam's economy basically based on agriculture so that the rice economy - an important subsector in agriculture, needs to positively change to meet crave of increasing producer's income and adapting to climate change. One of the most necessary transformations for the rice industry was to change the farming mindset from highly intensive farming to reducing investment in inputs and reducing green house gas (GHG) emissions. Particularly for the field of GHG reduction, statistics showed that, Vietnam's agricultural sector annually emitted to the environment 88.3 million tons of CO_2 equivalent, accounting for 33.2% of the total national GHG emissions, in which wet rice cultivation emitted 44.8 million tons of CO_2 equivalent, accounting for 51% of the total agricultural sector's emissions [20]. Mekong Delta was the largest rice producing region in Vietnam, contributing 53.8% of the area and 55.4% of the country's rice production [10]. Reducing GHG emissions in rice production was a national strategy that significantly contributed to achieving the target of "Net zero CO_2" by 2050 [9, 28, 4].

The concept of Sustainable Rice Platform (SRP) was launched over a decade ago in 2011 and it has gradually promoted resource-use efficiency and climate change resilience in rice systems (both on-farm and throughout value chains). Significantly, it pursues voluntary market transformation initiatives by developing sustainable production standards, indicators, incentive mechanisms, and outreach mechanisms to boost wide-scale adoption of best practices throughout rice value chains. SRP's goal was to minimize environmental impacts of rice production and consumption while enhanced smallholder incomes and contributing to food security (www.sustainablerice.org version 2.1, 2020) [27].

SRP has recently applied in several rice-developed economy such as Thailand [23], Cambodia, India and Vietnam [15]. In Vietnam, SRP application played an important role in enhancing qualified rice as well as rice export value, and reducing GHG emission [5]. The SRP package was recognized one of the measures for restructuring the rice industry, which recently piloted in several provinces in the Mekong Delta [18, 34]. One of the SRP implementation pilots was the "Market Oriented Smallholder Value Chains (MSVC)" project funded by GIZ and collaborated with a private sector Olam Group was practiced in four target provinces/city in the Mekong Delta, including An Giang, Dong Thap, Can Tho and Bac Lieu. The objective of this pilot is to strengthen the capacity of rice farmers to implement SRP standards on rice, thereby gradually upgrading the rice value chain and improving the livelihoods of rice farmers and reducing greenhouse gas emissions in the rice industry.

Given the situation that rice farmers in the Mekong Delta and in the project area in particular have inherited experiences and capacities upgraded by previous extension programs like the Integrated Pest Management (IPM) programs [24, 13, 14], 1 Must 5 Reductions [22, 30], and VNSAT project [29], not many farmers in the above pilot could fully comply with the SRP standard as expected. What restrictions and barriers have impeded compliance with the SRP standard was a matter of concern for the rice sub-sector.

In order to better understand the factors that positively affect or hinder compliance with the SRP standard, this study directly investigated rice farmers under the aforementioned pilot project in 2022.

We based on the SRP requirements and guidelines (https://sustainablerice.org/) [27] to assess compliance with the SRP standard in this investigation. This article attempted to present the investigation's findings including the characteristics of rice farmers, difficulties they faced in complying with the SRP standard, and finally, to determine statistically the factors affecting the ability to meet the SRP standard.

MATERIALS AND METHODS

Data collection and SRP scoring

Data were collected in the year 2022 from 426 rice farmers in An Giang, Dong Thap, Can Tho and Bac Lieu provinces, where rice is intensively cultivated in the Mekong Delta. These were farmers who have been trained to carry out SRP rice production under the MSVC project of GIZ and OLAM organization in the years 2020 and 2021. The content of the survey focused on assessing the extent to which farmers are achieving in term of sustainable rice production based on SRP guidelines (www.sustainablerice.org version 2.1), 2020 [27].

The survey was conducted by Can Tho university research team using a structured questionnaire sheet designed according to the SRP guideline strictly. This questionnaire includes 41 requests spanning 8 topics as shown in Table 1.

Each of the requirements in this questionnaire is assigned the highest score that rice farmers can achieve when they comply with all the contents of that requirement, and it also has corresponding scores to graded according to the level of compliance that the farmer household has made during the rice cultivation process. The number of points marked with an asterisk is referred to as the threshold for that requirement, which means the minimum number of points that a farmer needs to achieve for that requirement in order to qualify for the SRP once their cumulative score is above 90 for all 41 requirements.

The SRP score for each household is the actual score for compliance with the 41 requirements out of the maximum possible score, and is expressed as a percentage, so this score is usually less than 100%. According to the scale guided by SRP, there are 2 levels of SRP scores, a level below 90 is called "toward sustainable rice cultivation" and a level of 90 and above 100 is called "sustainably rice cultivated" as shown in Figure 1. In order to really meet the SRP standard, a farmer must achieve at least 90 points and not violate any threshold of the 41 requirements mentioned above.

The SRP standard was designed and applied to many countries, so there were a few exceptions where not all 41 requirements were applied. In the Mekong Delta where this study was carried out, there were a number of requirements that were not applicable due to the unique characteristics of the site, and are bold highlighted as shown in Figure 1.

Table 1. Eight themes and forty-one requirements in the SRP Standard

1. Farm management	**2. Preplanting**	**3. Water use**	**4. Nutrient management**
1.Crop calendar (3), (1*) 2.Record keeping (3), (1*) 3.Training (3), (1*)	4.Heavy metals (3), (1*) 5. Soil salinity (3), (1*) 6.Land conversion and biodiversity (3), (1*) 7.Invasive species (3), (3*) 8.Leveling (3), (2*) 9. Pure seed quality (3), (2*)	10.Water management (3), (1*) **11. Irrigation system at community level** (3), (1*) **12. Inbound water quality** (3), (1*) **13. Groundwater extraction** (3), (2*) **14. Drainage** (3), (2*)	15.Nutrient management (organic and/or non-organic) (6), (4*) 16.Organic fertilizer choice (3), (2*) 17.Inorganic fertilizer choice (3), (3*)
5. Integrated pest management	**6. Harvest and postharvest**	**7. Health and safety**	**8. Labor rights**
18.1 Weeds (3), (2*) 18.2 Insect (3), (2*) 18.3 Diseases (3), (2*) 18.4 Molluscs (3), (2*) 18.5 Rodents (3), (2*) 18.6 Birds (3), (1*)	19. Timing of harvest (3), (2*) 20. Harvest equipment (3), (2*) 21.Drying time (3), (3*) **22.Drying technique** (3), (2*) **23.Rice storage** (3), (1*) 24. Rice stubble (3), (1*) 25. Rice straw (3), (1*)	26.Safety instructions (3), (1*) 27. Tools and equipment (3), (1*) 28.Training of pesticide applicator (3), (1*) 29.Personal protective equipment (3), (1*) 30.Washing and changing (3), (1*) 31. Applicator restrictions (3), (2*) 32.Re-entry time (3), (1*) 33.Pesticide and chemical storage (3), (1*) 34. Pesticide disposal (3), (1*)	35. Child labor (3), (3*) **36. Hazardous work** (3), (3*) **37. Education** (3), (1*) **38.Forced labor** (3), (3*) **39. Discrimination** (3), (3*) **40.Freedom of association** (3), (3*) **41. Wages** (3), (3*)

(x): maximum score attainable; (x^*) minimum required score to meet mandatory compliance level (threshold)
Source: www.sustainablerice.org version 2.1, 2020 [27].

For example, the water management requirements (No. 11, 12, 13, 14) were not applicable since this was an intensive rice growing area for many years, irrigation was complete and no groundwater was used. Or No. 22 and 23 also did not apply due to the custom of selling paddy immediately after harvest without drying at home. Requirements related to labor rights and child labor (No. 36, 37, 38, 39, 40 and 41) did not apply since they were not infringed under the provisions of applicable law.

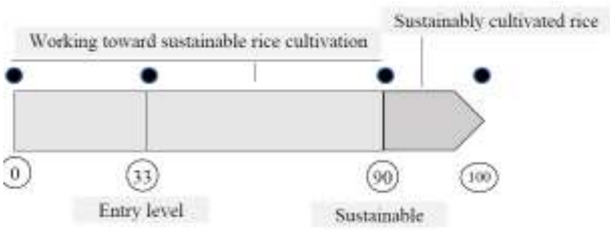

Fig. 1. SRP scoring claim
Source: www.sustainablerice.org version 2.1, 2020 [27].

$$\text{Score standard (0-100)} = \frac{Total\ number\ of\ points\ corresponding\ to\ actual\ performance}{Maximum\ number\ of\ points\ possible} x100$$

Data analysis

We used the cut-off line at 90 points to divide the observed sample into two groups of households, respectively called the SRP group for the households achieved 90 and above 90 points and the Non-SRP for those below 90 points, were then correspondingly assigned for 1 and 0 values. We used these dichotomous outcomes as dependent variables in a binary logistic function [3] to determine explanatory variables that affected the possibility of meeting SRP standard.

Explanatory variables selected were the demographic as well as essential resources of the household like age, education, gender of the household head, family size, number of male workers, number of female workers, children or workers engaged in non-agricultural activities. Variables of rice land and contract farming performance were also taken into account to see how they impact SRP compliance.

As the binary logistic regression analysis performed, a term of Odds was calculated, whereby Odds referred to the state at which the likelihood of an event occurring or not occurring. If the probability of an event occurring was p, the probability of the event not occurring was (1-p), then the corresponding Odds was a value given by:

Odds of event=p/(1-p)

The form of binary logistic regression model in the study was given below

$$log_e\left[\frac{p}{1-p}\right] = \beta o + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \quad (1)$$

where:
p: probability of attaining SRP standard ($0 \leq p \leq 1$)
1– p: probability of attaining Non-SRP standard
β_0: intercept parameter
β_1, β_2, … βn: coefficients of regression model
X_n: explanatory variables (covariates), including as follow:
X_1: Age of household head (year)
X_2: Gender of household head (0: female, 1: male)
X_3: Education of household head (year of schooling)
X_4: Experience of rice farming of household head (year)
X_5: Household size (person)
X_6: Labor (person)
X_7: Non-farm labor (person)
X_8: Rice land (ha)
X_9: Contract farming (0: no, 1: yes)

The probability of farm household attained SRP standard was p under certain conditions was written as $p = P(Y=1|X_1, X_2, \ldots, X_n)$, and could be estimated by the formula below:

$$p = \frac{e^{(\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n)}}{1 + e^{(\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n)}} \quad (2)$$

The p value ranged from 0 to 1, when $p > 0.5$, the probability of an event meeting the SRP standard occurred, the closer it was to 1, the higher this possibility was. Conversely, when $p < 0.5$, the possibility of not meeting the SRP standard were occurred.

For estimating parameter of the logistic regression model, method of Maximum Likelihood Estimation (MLE) was used. This method was designed to maximize the livelihood of obtaining the data given its parameters estimates. The null hypothesis stated that all β_i parameters equal to zero. A rejection of null hypothesis indicated that at least one β not equalled to zero. The MLE typically used value of -2log-livelihood (-2LL) to determine the suitability of the model, the smaller this value was, the more fit the model was. Besides, the R^2 of Cox and Snell [2] and R^2 of Nagelkerke [21] with values ranging from 0 to 1 were also used to evaluate the goodness of fit of the model.

The larger these values were, the better the model fitted, however, in binary regression models, the model fit measures were of certain importance, but the values of the regression coefficients and their statistical significance were equally important [11]. Wald test was used to evaluate the level of statistical significance as well as the contribution of individual regression coefficients in the model [1].

RESULTS AND DISCUSSIONS

Characteristics of rice farm households

As mentioned in the method section, only households that satisfied both conditions of SRP score ≥ 90 and passing all threshold points, are classified as SRP group, and vice versa the Non-SRP group. Accordingly, only 28 households were classifying into SRP group, accounting for 6.57% of the total 426 households assessed. Characteristics of rice farmers in the two groups are summarized in Table 2.

Among the characteristics of the rice-growing households that were compared, only a few characteristics were statistically different between the two groups of households. First of all, the age of the household head who was the most important person in the household's production activities shows that their age was 49.36 years, this was a rather high age and partly affects the management and decisive making process. The age of the SRP group was younger than that of the Non-SRP group and was statistically significant.

The second feature with statistical difference was the education level of the household head. On average, the head of household had 7.3 years of schooling, but the number of years of schooling in the SRP group was 8.75 years and was higher than 7.2 years in the Non-SRP group. Whether this feature had an impact on the ability to qualify for SRP would be examined in the next section.

The average area of rice land was 1.97ha/household, in which the SRP group tended to have a larger area, but they did not significantly differ between two groups. Accumulation of land in rural areas has recently taken place, but it has not caused too big changes [32]. Another important feature was the proportion of farmers practiced contract farming with rice-trading enterprises. In this study, an average of 18.1% of farmers did contract farming, of which the SRP group had a contract farming rate of 42.9% compared to 16.3% of the Non-SRP group. The percentage of rice farmers having contract farming with enterprises in Mekong Delta was also not high for many reasons [31, 26, 17, 7, 6]. The practice of contract farming was usually a subjective decision between the two parties - farmer and the company, and was signed at the beginning of rice crop. This agreement could influence the behavior of rice farmers to ensure that the quality of rice corresponded to the price of rice that the company has committed to buy. This sometimes certainly effected on compliance with the SRP standard during rice cultivation, and should be tested in the binary regression section of this article.

Table 2. Main household characteristics by household group

		Total (n=426)	**Non-SRP (n=398)**	**SRP(n=28)**	**T value**
Age (year)		52.80 ± 10.34	53.04 ± 10.36	49.36 ± 9.60	1.826^{*}
Gender	0	72	68	4	$\chi^2 = 0.702^{ns}$
	1	354	330	24	
Edu (year)		7.30 ± 3.12	7.20 ± 3.14	8.75 ± 2.38	-3.250^{***}
Exp (year)		28.03 ± 10.93	28.17 ± 10.99	26.00 ± 10.02	1.015^{ns}
Member (person)		4.57 ± 1.62	4.59 ± 1.65	4.32 ± 1.22	0.143^{ns}
Labor (person)		3.12± 1.43	3.11± 1.44	3.18± 1.31	-0.234^{ns}
Non-farm labor		0.90 ± 0.99	0.89 ± 0.99	1.04 ± 0.92	-0.739^{ns}
Land (ha)		1.97± 1.71	1.90± 1.35	2.91± 4.26	-1.245^{ns}
Contract farming	0	349 (81.9%)	333 (83.7%)	16 (57.1%)	$\chi^2 = 12.430^{***}$
	1	77 (18.1%)	65 (16.3%)	12 (42.9%)	

***, ** and * significant at 1%, 5% and 10% respectively; ns: not significant
Source: Author's calculation.

Achievement of SRP score

The average SRP score of all 426 households in the project area was 81.6, of which the mean scores of the two groups of households were quite different (Table 3).For the SRP group, their scores were definitely above 90 points, which averaged of 92.3. For the Non-SRP group, their scores were mostly fallen into the range of 80 - <90 points (accounting for 58%), followed by the range of 70 - <80 points (33%), below 70 points (6.8%), and finally over 90 points (2%).

Table 3. Range of SRP score attained by SRP group

Range	**Total**		**Non-SRP**		**SRP**	
	Freq.	(%)	Freq.	(%)	Freq.	(%)
<60 – <70	27	6.3	27	6.8	0	0
70 – <80	132	31.0	132	33.0	0	0
80 – < 90	230	54.0	230	58.0	0	0
90 – 100	37	8.7	9	2.0	28	100.0
Total	426	100.0	398	100.0	28	100.0
Mean	81.6 ± 6.6		80.8 ± 6.2		92.3 ± 1.6	

Source: Author's calculation.

The percentage of households scoring above 90 points out of the total number of surveyed households was only 8.7%, which could be considered as pioneers in the process of adopting a new technology. This ratio was similar to the new technical diffusion theory [25].

Figure 2 comparatively showed the theme-specific SRP scores for the two groups. SRP scores in the four themes namely "Preplanting", "Water management", "Integrated pest management" and "Labor right" were very similar between the two groups. These were topics considered favorable, both groups of households have the same ability or skill to complete. As for the remaining four themes including "Farm management", "Nutrient management", "Harvest and post-harvest", and "Health and safety", the scores of the two groups were quite different. This implied capacity of farmers was different when they have to implement these themes, and they could be the weakness of farmers in the compliance of SRP standards.

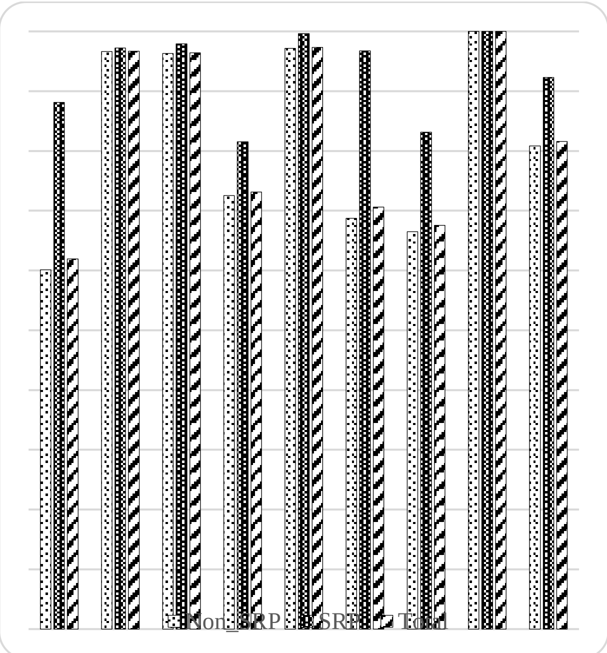

Fig. 2. Scores attained by group and theme
Source: Author's calculation.

The number of thresholds that the Non-SRP group could not pass was statistically shown in Table 4. On average, one household could not pass 2.8 thresholds, particularly few households could not pass up to 11 thresholds. Farmers often failed to pass the thresholds of the requirements that fallen under the four themes of farmer weakness as shown in Figure 2.These thresholds that were difficult for farmers to overcome became issues that the rice sub-sector must pay attention to find solutions to support farmers to comply with the SRP standard.

Table 4. Number of thresholds encountered by Non-SRP group

Theme	Mean	Maximum	Minimum	Std. Dev.
Farm management	0.37	3.00	0.00	0.74
Preplanting	0.00	1.00	0.00	0.05
Water management	0.00	1.00	0.00	0.05
Nutrient management	0.21	2.00	0.00	0.43
Integrated pest management	0.00	0.00	0.00	0.00
Harvest and post-harvest	1.12	4.00	0.00	1.11
Health and safety	1.09	6.00	0.00	1.13
Labor right	0.00	0.00	0.00	0.00
Total	2.80	11.00	0.00	2.13

Source: Author's calculation.

Figure 3 detailed the frequency as well as the percentage of farmers in the Non-SRP group that did not pass the thresholds. For the two requirements No. #24 and No. #25 referring straw and stubble treatment were the biggest challenges for farmers because over 46% of farmers did not exceed these thresholds. The post-harvest treatment of rice straw depended not only on farmers' awareness and their available means, but also on factors outside the household such as the service of straw collection machine or infrastructure condition. In the case of harvesting in the rainy season, it was even more difficult to collect rice straw, especially for rice fields located far from rural roads.

Requirement No. #26 (safety instruction) referred about instructions for farmers to raise awareness of work safety or first aid when encountering a work accident was also a difficulty for farmers. This was a requirement that requires the support of the public health system as well as the local government. Requirement No. #27 on maintenance and adjustment of farming tools was also a limitation of farmers because it involved changing habits of farmers who were already getting old. A requirement No. #32 (re-entry) was also a difficult threshold to overcome because it was more related to the neighbors' consciousness than to the farmer himself who owned the field. In addition, the requirement referring to keeping farming records was also an obstacle worthy of attention, up to 20.35% of households were encountered.

Fig. 3. Specific thresholds encountered by Non-SRP group
Source: Author's calculation.

Determinants for compliance of SRP standard

Although full compliance with the 41 SRP requirements was a challenge for the majority of farmers, there were still a number of farmers who passed the thresholds to meet SRP standards. In this survey, there were 28 households, accounting for 6.57% who fully complied the SRP standard. This raised the question that there were some differences in household characteristics between the two groups of households meeting and not meeting the SRP standard in terms of their ability to comply with the SRP standard given the similarity of communal socio-economic conditions they lived in.

In search of answers to the above questions, a binary regression function was performed and the results were presented in the followings. Firstly, we tested the appropriateness of the regression model by considering the value of -2 Log Livelihood (-2LL) of 180,753 in Table 5.

The value of -2LL was not too large, so the regression model could be accepted. Additionally, the values of Cox & Snell coefficients R^2 and Nagelkerke R^2were 0.059 and 0.153 respectively, which allowed to conclude that the established regression model was suitable (Table 5).

Table 5. Statistical results of model fitness

-2 Log likelihood (-2LL)	Cox & Snell R Square	Nagelkerke R Square
180.753	0.059	0.153

Source: Author's calculation.

At the same time, the value of $\chi^2 = 25.828$ (df = 9) in the Omnibus test of the model's coefficients was statistically significant at $\alpha = 0.01$ (Table 6), so we rejected the null hypothesis H_0 ($\beta 1, \beta 2, \dots \beta n = 0$). This meant that this study accepted the hypothesis H_1 that at least one of the regression coefficients was non-zero and they statistically effected to dependent variable.

Table 6. Result of Omnibus test of model coefficients

	Chi-square	df	Sig.
Step	25.828	9	0.002
Block	25.828	9	0.002
Model	25.828	9	0.002

Source: Author's calculation.

Table 7 additionally showed the correctness of the model prediction. The first row showed that out of a total of 398 observations that did not conform to the SRP standard, the model predicted that all such 398 households did not meet the SRP standard, which meant that the prediction was 100% correct. Next, out of 28 observations that met the SRP standard, only 1 case was predicted to meet the SRP standard, the correct prediction rate was 3.6%. Overall, the model's correct prediction rate was 93.7%.

Table 7. Classification table of correct prediction

Observation	**Prediction**		**Correction (%)**
	SRP		
	0	1	
0	398	0	100.0
1	27	1	3.6
			93.7

Source: Author's calculation.

After accepting tests of fitness as well as correctness of the model, we finally used the Wald test to determine the level of statistical significance of the independent variables. Wald tested results in Table 8 showed that out of nine socio-economic factors, there were four variables that had a statistically significant impact on the ability of households to meet SRP standards with α = 0.1 to α = 0.01. The first was the education variable of the household head, which had a positive and statistically significant effect on the ability to meet the SRP standard. The level of impact of the education variable was expressed through the value Exp(B) = 1.171 (=$2.7182^{\wedge 0.157}$), that meant when the education of the household head increased by one school year, the probability of meeting the SRP standard increased by 1.17 times as long as other factors remained unchanged.

Table 8. Factors affecting the ability of farmers to meet SRP standards

	B	**S.E.**	**Wald**	**df**	**Sig.**	**Exp(B)**
X_1: Age	-0.037	0.035	1.127	1	0.288	0.963
X_2: Gender	0.225	0.588	0.147	1	0.702	1.253
X_3: Education	**0.157**	0.073	4.691	1	**0.030**	1.171
X_4: Experience	0.021	0.031	0.457	1	0.499	1.021
X_5: Member	**-0.334**	0.198	2.850	1	**0.091**	0.716
X_6: Labor	0.182	0.204	0.794	1	0.373	1.199
X_7: Non-farm labor	0.311	0.241	1.661	1	0.198	1.364
X_8: Land	**0.172**	0.088	3.832	1	**0.050**	1.188
X_9: Contract	**1.276**	0.429	8.867	1	**0.003**	3.583
Constant	-2.900	1.785	2.640	1	0.104	0.055

***, ** and * indicate significant different at α = 1%, 5% and 10%, respectively; ns: not significant
Source: Author's calculation.

The family member variable had a negative effect on the ability of meeting the SRP standard with an effect level Epx(B) of 0.716 (equivalent to $2.7182^{\wedge -0.334}$), that was, when the number of family members increased by one person, the probability of meeting the SRP standard decreased by 0.716 times. This could be explained as an increase in family demographics that were often dependents, such as children, which might create certain barriers to SRP compliance, for example when they involved requirement No.#33 and No.#34 for pesticide and chemical storage and pesticide disposal, respectively. Another reason was that an increase in the number of dependents in the family also meant an aging rate of labor due to the fact that young people often migrated in search of income in urban areas [16, 32], adversely affected rice cultivation, which would have a high degree of mechanization [19].

The variable rice land area had a positive effect on the ability to meet the SRP standard with an Exp(B) level of 1,118 (equivalent to $2.7182^{\wedge 0.172}$), meaning that when increased 1 ha of rice land, the possibility of achieving SRP standard increased by 1,118 times once other factors kept unchanged. This could be explained by the "economic to scale" effect that many authors have discovered, which made farm management more convenient and related to SRP compliance [12, 8, 26, 17].

Another independent variable namely "contract farming" had a great impact on the ability to meet the SRP standard, with an impact level of Exp(B) = 3,583 (equivalent to $2.7182^{\wedge 1.276}$). That was, when a farmer practiced a contract farming signed with a rice

purchasing company, the probability of meeting the SRP standard increased by 3.583 times as long as other factors remain unchanged. It was understandable that signing a contract with a rice purchasing company has affected farm management behavior, consequently positively affected the level of compliance of SRP standards.
Table 9 has showed somewhat a correlation between the signing of contract farming and the selling price of rice regardless degree of SRP compliance. In this survey there were 77 households, equivalent to 18% of the total surveyed households that signed a contract with the company with an average price of 6,134 VND.kg^{-1}, while the remaining 349 households (82%) did not signed a contract, consequently the selling price was much lower of 5,815 VND.kg^{-1};.
(Exchange rate: 1 USD = 23,680 VNDhttps://www.sbv.gov.vn/TyGia/faces/ExchangeRate.jspx?_afrLoop=20471777466753466&_afrWindowMode=0&_adf.ctrl-state=1bt04b3u9f_4)
[33].

Table 9. Output price (VND.kg^{-1}) in a matrix of contract farming and SRP compliance level

		Contract farming		Total (n=426)
		No (n=349)	Yes (n=77)	
Compliance level of SRP	Non-SRP	5,817 (78%)	6,115 (15%)	5,865
	SRP	5,781 (4%)	6,236 (3%)	5,976
Total		5,815 (82%)	6,134 (18%)	5,873

Source: Author's calculation.

We verified the probability of qualifying for the SRP based on the binary regression results. Based on the independent variables that had a statistically significant impact in Table 8, combined with the established function (2) and the parameters describing the characteristics of the households in Table 2, the probability of the two groups of households with two levels of SRP compliance were estimated. For the group of Non-SRP households, the probability of meeting the SRP standard was only 0.53, equivalent to 53%. This is a rate that has just crossed the threshold of 0.5, or in other words the probability that this group of households with the current characteristics of households would be difficult to comply with the SRP standard.

$$P_{Non-SRP} = \frac{e^{(0.157*7.2-0.334*4.59+0.172*1.9+1.276*0.163)}}{1+\ e^{(0.157*7.2-0.334*4.59+0.172*1.9+1.276*0.163)}} = 0.53$$

For the group of households reaching the SRP standard, the probability of achieving SRP standard was estimated to be 0.73, equivalent to 73%. This was a much larger rate than the threshold of 0.5, which meant that this group of households was possible to comply the SRP standard, however, it did not mean they would definitely possible complied SRP standard.

$$P_{SRP} = \frac{e^{(0.157*8.75-0.334*4.32+0.172*2.91+1.276*0.429)}}{1+\ e^{(0.157*8.75-0.334*4.32+0.172*2.91+1.276*0.429)}} = 0.73$$

For all surveyed households, the probability of meeting the SRP standard is also quite low, only 0.55, equivalent to 55%. It proved that the current capacity of rice farmers towards compliance with SRP standards was quite uncertain.

$$P_{total} = \frac{e^{(0.157*7.3-0.334*4.57+0.172*1.97+1.276*0.181)}}{1+\ e^{(0.157*7.3-0.334*4.57+0.172*1.97+1.276*0.181)}} = 0.55$$

CONCLUSIONS

Rice cultivation according to SRP standards was a sound strategy, contributing to achieving the Net-zero target on GHG emission of the Vietnamese government. However, given the current situation, this was still challenging, at least for the rice-growing provinces in the Mekong Delta.
The percentage of rice-growing households meeting SRP standards was low, only about 6.57% of surveyed households. The majority of farmers had SRP compliance levels between 80 and less than 90 points compared to above 90 points, meaning they could meet SRP standards but were still weak in a few certain capacities.
Requirements on post-harvest handling of rice straw, pesticide and chemical storage, and farming diary recording were prominent barriers that made it difficult for farmers to comply with SRP standards. Besides the weak

capacity of farmers, community capacity such as rural transport, mechanized service for collecting straw after harvest also affected compliance with SRP standards.

Household characteristics that positively affected SRP eligibility were the education level of the household head, land size and contract farming with rice consumption company. Meanwhile, demographic size had a negative effect on the ability to meet SRP standards.

Recommendations to increase compliance with SRP standards were firstly rejuvenating farmers through how to attract young people into rice production and the agricultural sector in general to improve farm governance capacity as well as recording the farming diary. Secondly, it was to strengthen horizontal farmer linkage as well as link with consumption companies according to value chain approach so that farmers were motivated to comply with SRP standards. Finally, local authorities needed to improve in-field transport to support the development of post-harvest straw handling services.

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REFERENCES

[1]Bewick, V., Cheek, L., Ball, J., 2005, Statistics review 14: Logistic regression. Crit Care 9, 112, 2005. https://doi.org/10.1186/cc3045

[2]Cox, D.R., Snell, E.J., 1989, Analysis of binary data. Chapman and Hall/CRC, London.

[3]Cramer, J.S., 2002, The origin of logistic regression. Tinbergen Institute Discussion Paper. Faculty of Economics and Econometrics, University of Amsterdam, and Timbergen Institute.

[4]Dang, P.T., Buruah, B., 2022, An evaluation of Vietnam's pathway to net zero by 2050: Reconciling the Developmental State and Civil Society. Conference: The 11th Congress of the Asian Association of Environmental and Resource Economics (AAERE 2022) - A Pathway Towards Carbon Neutrality in Asia At: Hochiminh City – Vietnam.

[5]Demont, M., Rutsaert, P., 2017, Restructuring the Vietnamese Rice Sector: Towards Increasing Sustainability. Sustainability 2017, 9, 325; doi:10.3390/su9020325

[6]Dung, L.C., Tuan, V.V., Thoa, N.T.K, Son, N.P., Eiligmann, A., 2022, The Potential of the Rice Value Chain in the Mekong Delta to Develop High Value Export Markets. Int. J. Food System Dynamics 13 (3), 2022, 335-348. www.centmapress.org. DOI: https://dx.doi.org/10.18461/ijfsd.v13i3.C7

[7]Dung, L.C., Tuan, V.V., Thoa, N.T.K., 2019, Assessing the impact of cooperative economy on profit of rice production in the Mekong Delta. Journal of Vietnam Agricultural Science and Technology. Vol. 10 (107), 138-144. https://tapchi.vaas.vn. Accessed on June 17th, 2023.

[8]Duyen, N.L., Khiem, N.T., 2019, Influence of land size and labor size on labor productivity of rice farmers in the Mekong Delta. Journal of Science Open University Ho Chi Minh City, 14(1), 76-87.

[9]Government, 2022, Decision No. 888/QD-TTg dated July 25, 2022 of the Prime Minister approving the Scheme on tasks and solutions to implement the results of the 26th Conference of the Parties to the United Nations Framework Convention about climate change (UNFCCC).

[10]GSO, 2021, Agriculture, forestry and fishery data in 2021. https://www.gso.gov.vn/ , Accessed on May 17, 2023.

[11]Gujarati, D., 2011, Econometrics by Example. Palgrave Macmillan Publisher.

[12]Ho, T.T., Shimada, K., 2019, Technical Efficiency of Rice Farming in the Vietnamese Mekong Delta: A Stochastic Frontier Approach. The Ritsumeikan Economic Review, Vol. 67 No.5.6.

[13]Huan, N.V., Thiet, L.V., Chien, L.V., Heong, K.L., 2005, Farmers’ participatory evaluation of reducing pesticides, fertilizers and seed rates in rice farming in the Mekong Delta. Vietnam. Crop Prot. 24, 457–464. doi: 10.1016/j.cropro.2004.09.013, Accessed on November 4th, 2021.

[14]Huelgas, Z.M., Templeton, D., Castanar, P., 2008, Three Reductions, Three Gains (3R3G) Technology in South Vietnam: Searching for Evidence of Economic Impact. Contributed paper at the 52nd Annual Conference of the Australian Agricultural Resource Economics Society held at Rydges Lakeside, Canberra ACT, Australia, 5-8 February 2008.

[15]Hung, N.V, Balingbing, C., Sandro, J., Khandai, S., Chea, H., Songmethakrit, T., Meas, P., Hitzler, G., Zwick, W., Viriyangkura, L., Bautista, E., Gummert, M., 2022. Precision land leveling for sustainable rice production: case studies in Cambodia, Thailand, Philippines, Vietnam, and India. Precision Agriculture (2022) 23:1633–1652. https://doi.org/10.1007/s11119-022-09900-8

[16]Huy, H.T., Khoi, L.N.D., 2011, Analysis of Labour Migration Flows in the Mekong Delta of Vietnam. n book: Environmental Change and Agricultural Sustainability in the Mekong Delta, Advances in Global Change Research 45Chapter: 7Publisher: Springer Editors: M.A. Stewart and P.A. Coclanis.DOI: 10.1007/978-94-007-0934-8_8

[17]Kiet, N.T., Duc, T.C., 2017, Effect of large field models: empirical evidence in Can Tho and Soc Trang. National Journal of Science and Technology, 26: 212-222.

[18]MARD, 2021, Decision No. 555/QD-BNN-TT dated January 26, 2021 on approving the Agricultural Restructuring Program for the period to 2025 and vision to 2030.

[19]Matsubara, T., Truong, C.T., Dung, L.C., Kitaya, Y., Maeda, Y., 2020, Transition of Agricultural Mechanization, Agricultural Economy, Government Policy and Environmental Movement Related to Rice Production in the Mekong Delta, Vietnam after 2010. AgriEngineering 2020, 2, 649–675; doi:10.3390/agriengineering2040043. http://www.mdpi.com/journal/agriengineering, Accessed on June 17th, 2023.

[20]MONRE, 2014, GHG inventory report 2010. Project "Strengthening capacity for national greenhouse gas inventory in Vietnam".

[21]Nagelkerke, 1991, A note on general definition of the coefficient of determination. Biometrika.

[22]Phung, N.T.M., Du, P.V., Singleton, G., 2014, One Must Do, Five Reductions (1M5R): Best Management Practices for Lowland Irrigated Rice in the Mekong Delta. Ministry of Agricultural and Rural Development: Vietnam and International Rice Research Institute, Philippines.

[23]Rattanacharoen, N., Yamada R., 2021, Contribution of Sustainability Rice Cultivation Practice for Farmers according to SRP Standard: A Case Study of Ubon Ratchathani Province, Thailand – International Journal of Environmental and Rural Development (2021) 12-2

[24]Rejesus, R. M., Palis, F.G., Lapitn, A.V., Chi, T.T.N., Hossain, M., 2009, The Impact of Integrated Pest Management Information Dissemination Methods on Insecticide Use and Efficiency: Evidence from Rice Producers in South Vietnam. Review of Agricultural Economics. Vol. 31, No. 4 (Winter 2009), pp. 814-833.

[25]Rogers, E.M., 2003, Diffusion of innovations (5th ed.). New York: Free Press.

[26]Son, N.P., Quan, L.B.M., Trang, P.H., 2017, Economic efficiency of rice production of households participating in large rice fields in the Mekong Delta. Journal of Industry and Trade, 12:86-93.

[27]SRP, 2020, The SRP Standard for Sustainable Rice Cultivation (Version 2.1), Sustainable Rice Platform. Bangkok: 2020. http://www.sustainablerice.org, Accessed on May 15th, 2023

[28]Take, K., Nguyen, T.L., Ota, T., Hirayyama, T., Motoki, Y., Hibino, G., Ochi. Y., Masui, T., 2022, Net Zero Emission Scenarios in Vietnam. Global Environmental Research.

[29]Tran, V.T., Mai, V.T., Nguyen, T.D.T., Le, H.A., Richards, M.B., Sebastian, L, Wollenberg, E., Vu, D.Q., Sander, B.O., 2019, An investment plan for low-emission rice production in the Mekong River Delta region in support of Vietnam's Nationally Determined Contribution to the Paris Agreement. CCAFS Working Paper no. 263. Wageningen, Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). www.ccafs.cgiar.org, Accessed on June 17th, 2023.

[30]Tho, L.C.B., Dung, L. C., Umetsu, C., 2021, One Must Do, Five Reductions. Technical Practice and the Economic Performance of Rice Smallholders in the Vietnamese Mekong Delta. Sustainable Production and Consumption 28(195). DOI: 10.1016/j.spc.2021.07.018

[31]Tuan, V.V., Dung, L.C., Thoa, N.T.K., 2020, Assessing effectiveness of the linkage models in producing and consuming of specialty and aromatic rice in the Mekong Delta. Scientific Journal of Can Tho University, Volume 56 (5D), Pd: 269-277. DOI:10.22144/ctu.jvn.2020.137

[32]VCCI and Fulbright, 2020. Annual economic report: Improving competitiveness for sustainable development.

[33]VNDhttps://www.sbv.gov.vn/TyGia/faces/ExchangeRate.jspx?_afrLoop=20471777466753466&_afrWindowMode=0&_adf.ctrl-state=1bt04b3u9f_4 Accessed on May 15th, 2023.

[34]World Bank, 2022, Towards Green Agriculture Transformation in Vietnam: Switch to low carbon rice model. Report No: AUS0002201. Washington, DC: World Bank.

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PHYSIOCHEMICAL AND PHYSIOLOGICAL QUALITIES OF SOYBEAN SEED YIELD AS A RESPONSE TO DIFFERENT IRRIGATION PRACTICES IN EGYPT

Wael Fatthy EL METWALLY, Abdel Gawad SAAD, Mahmoud El-Sayed EL IRAQI, Tarek Mahmoud ATTAFY

Institute of Agricultural Engineering, Agricultural Research Center, Dokki District, Giza Governorate, Egypt, Phone: 00201065074853, 00201065326186, 00201000213778, 00201027367157; E-mails: wfa_agr@yahoo.com, en_gawad2000@yahoo.com, mahmoud_iraqi@yahoo.com, tarek.attafy@yahoo.com

Corresponding author: tarek.attafy@yahoo.com

Abstract

The aim of the paper is the analysis of the response of soybean seed yield and its component including (plant height, number of pods/plant, and 100-seed weight), water productivity and quality properties (physiochemical including protein and fats content and physiological including germination ratio, length of seedling shoots and roots, seedling dry weight, and seed vigor index) to seven irrigation practices were evaluated in a field experiment based on a randomized complete block design; the irrigation practices including sprinkler and drip system at full irrigation with 100% ETc (S100 and D100) and deficit irrigation with 80 and 60% ETc (S80, D80, S60, D60) and compared to furrow irrigation (F). Findings revealed that, S100 and D100 improved seed yield by 10.8 and 16.8% compared to F treatment. The highest yield components and water productivity was achieved by D100 treatment with values of 113 cm plant height, 115 pods/plant, 14.4 g weight of 100 seeds and 0.62 kg/m^{3}respectively. With the irrigation regime, protein content had a positive correlation while fat content had a negative correlation; the highest protein content was 28.75 and 28.20% achieved by S100 and D100, while the highest fats content was 22.91 and 22.63% achieved by D60 and S60. There is a positive correlation between the physiological properties and the irrigation regime; the highest physiological properties were germination ratio 98.3 and 96.7%, root length 8.7 and 7.33 mm, shoot length 1.98 and 1.87 mm, seedling dry weight 0.69 and 0.67 g and seed vigor index 117.9 and 110.8 achieved by D100 and S100.

Key words: *irrigation practice, deficit irrigation, soybean quality*

INTRODUCTION

Egypt as one of the countries located in arid to the semiarid zone is presently suffering a water scarcity as a result of current climatic changes, posing a danger to sustainable agricultural production and water productivity; as a result, the impact of water scarcity on agriculture has become more serious under the climatic changes [4]. It becomes increasingly difficult to continue using the current low-efficiency irrigation methods, and it is important to investigate relevant factors affecting productivity, such as careful planning and management of irrigation strategies, innovative irrigation techniques that required for sustainable use of water in irrigated agricultural systems [16].

The soybean has a significant impact on the global food supply and is one of the major sources of vegetable oil, providing more than 30% of global oil production. Also, it is a rich in dietary fiber, phospholipids, minerals, and vitamins [13]. The cultivated area in Egypt in 2021 was 20,600 ha, producing approximately 62,580 tons [17]. Soybean crop is highly sensitive to water shortage at various growth stages, so it is must be watered during important growth stages such as flowering, pod initiation, and seed filling [29]. Water deficit can reduce germination percentage and healthy plant growth, and development of seeds which significantly decreased seed yield, especially during the pod set and seed filling stage [28]. Application of water stress to soybeans upon critical growth stages is detrimental to protein contents[1]; yield and its components [25]; relative water content, chlorophyll content, and growth traits [14]. Irrigation water is considered the main environmental factor in arid and semi-arid climates, being responsible for several metabolic processes related to plant growth and development; also, it is an essential element that impacts physical and chemical processes that affect the yield and quality of soybean seeds [32]. Response of soybean to five irrigation regime (100, 75, 50, 25, and 0 %) as a percentage of evaporation by a Class A pan was estimated, the maximum production was achieved with full irrigation (100%); while under water scarcity conditions soybean can be irrigated as much as 75% of the evaporation pan as an option [9], the same effect obtained by [3] in sandy soil. Three irrigation regimes (100, 90 and 80%) of irrigation requirement in Kafr El-Sheikh Governorate, Egypt for a furrow-irrigated soybean crop were investigated, irrigation regime had a significant effect on yield and yield components; 100% treatment was the superior and achieved the highest values, no significant differences between the 100% and 90% irrigation regimes [22]. Irrigation system has a vital role in determining the yield and nutritional quality of the soybean seeds [6, 30].

Seedling vigor indicates seedling weight or height, and is an essential indication of seed quality, determining the probability of quick and uniform plant emergence under a range of different field circumstances [27]. The recent researches still have only focused on saving significant amounts of irrigation water, improving water use and developing high performance irrigation programs for growing high quality crops that utilize less water, whereas, research on the effects of agricultural practices on seed composition is limited. Therefore, the present experiment was carried out by keeping this in view, aimed to study and evaluate the effect of different irrigation practices on soybean yield and its components, and seeds quality (physicochemical and physiological properties).

MATERIALS AND METHODS

Experimental layout

A field experiment was carried out during the summer season of 2022 at Rice Mechanization Center (RMC), Meet El-Deyba, Kafr El-Sheikh Governorate, Egypt, which is located at 31° 6′N latitude, 30° 50′E longitude, and an elevation of about 6 meters above sea level. The experimental field was prepared according to traditional land preparation and the furrows were raised at a distance of 70 cm. Giza 111 soybean variety was manually planted in May and harvested in October. All agronomic practices were done in accordance with agricultural recommendations for soybean. The soil mechanical analysis of the experimental field was performed in Soils, Water and Environmental Res. Institute Lab., Kafr El-Sheikh, Agricultural research center, Egypt (Table 1). The meteorological data of the research site is presented in Table 2.

Table 1. Mechanical analysis of the experimental soil

Soil depth, cm	Particle size distribution			Texture	FC, %	PWP ,%
	Clay, %	Sand, %	Silt, %			
0-15	55.40	32.24	12.36	Clay	45.16	21.33
15-30	53.02	32.85	14.13	Clay	43.02	21.20
30-45	54.26	29.16	16.58	Clay	41.00	21.07
45-60	54.00	28.64	17.36	Clay	39.13	19.77

FC: Field capacity, PWP: Permanent wilting point
Source: Own calculation.

Table 2. Average monthly meteorological data for the research site

Month	T_{mini},°C	$T_{max..}$,°C	$T_{avg.}$,°C	RH, %	WS, m/sec
May	15.7	33.0	24.4	50.5	2.8
Jun.	19.3	37.3	28.3	40.3	3.0
Jul.	21.8	39.5	30.7	43.0	2.8
Aug.	22.5	39.6	31.1	45.6	2.7
Sept.	22.4	38.9	30.7	49.2	2.7

Source: Central Laboratory for Agricultural Climate (CLAC), Agricultural Research center, Egypt.

Irrigation system components

The main components of the irrigation systems as shown in Fig. 1 were a centrifugal pump (30 m^3/h nominal discharge and 3 inch inlet and outlet diameters) driven by a 3.75kW internal combustion engine, a control unit consisting of (control valves, pressure gauges, and flow-meter), main line, lateral lines and emitters. The main line was made of HDPE with an outer diameter of 75 mm. In the sprinkler (S) system; the laterals were made of PVC with an outer diameter of 32 mm connected to the main line by control valves. In the drip (D) system; sub main line made of HDPE with an outer diameter of 55 mm was installed to transfer the irrigation water from the main line to the laterals via a manifold with an outer diameter of 32 mm. Polyester screen filter, 120 mesh with a diameter of 32 mm were installed to prevent clogging of sprinklers and drip tapes. An angle impact sprinkler made of plastic with a mail inner diameter of ½ inch, single nozzle with a diameter of 4 mm, trajectory angle of 27°C, throw diameter of 18 m, and discharge rate of 750 L/h at 125 kPa operating pressure were installed on the laterals at a distance of 9 m in a square layout and overlapping 50% of the throw diameter. Radial gross and net precipitation rates were 2.9 and 2.45 mm/h. Lateral drip tapes made of PE with an inner diameter of 16 mm, length of 30 m, spacing between emitters of 10 cm, and a discharge rate of 1,400L/h/100 m of length at 60 kPa operating pressure. Distribution uniformity along the drip line was classified excellent and the manufacturer's coefficient of variation was less than 0.05.

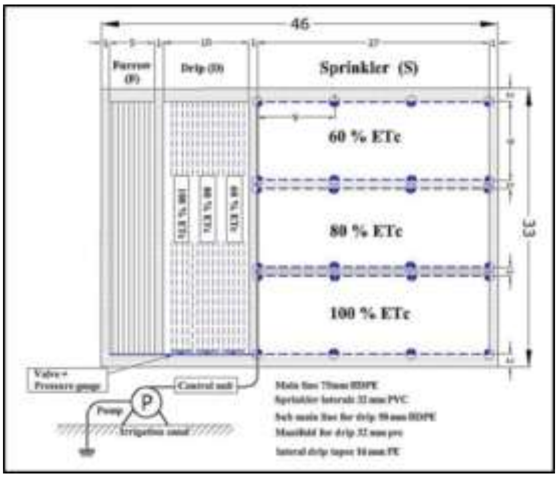

Fig. 1. Irrigation system components and treatments distribution
Source: Own design.

Experimental Treatments

Three irrigation regimes as a percentage of crop evapotranspiration (100%, 80% and 60% ETc) for the two irrigation systems (sprinkler, S and drip, D) were investigated and compared with furrow irrigation method.

The seven experimental irrigation treatments could be explained as follows:

S100: sprinkler system at full irrigation 100% ETc; S80: sprinkler system at deficit irrigation with 80% ETc; S60: sprinkler system at deficit irrigation with 60% ETc; D100: drip system at full irrigation 100% ETc; D80: drip system at deficit irrigation with80% ETc; D60: drip system at deficit irrigation with 60% ETc and F: furrow irrigation (traditional method).

Irrigation water requirements

Using the CROPWAT 8 software program, water requirements for the soybean crop was calculated based on Penman-Monteith formula [5]as follows:

$$ETc = ETo * K_c \quad (1)$$

where:

ETc: Crop evapotranspiration (mm/day);
ETo: Reference evapotranspiration (mm/day) and;
K_c: The soybean crop's coefficient values.

In furrow treatment, irrigation was suspended when irrigation water reached the field's low end. For all treatments, surface irrigation was applied for two events (pre-planting and subsequent irrigation), and then irrigation practices were applied.

Table 3 shows the mean values of total applied irrigation water for various treatments (m^3/ha).

Table 3. Total applied irrigation water for different treatments under study

Treatment	Applied water, m^3/ha	Treatment	Applied water, m^3/ha
S100	6,826	D80	4,976
S80	5,741	D60	4,083
S60	4,657	F	7,729
D100	5,869		

Source: original values calculated based on the experimental data obtained.

Furrow treatment consumed the highest irrigation water compared to other treatment; surface irrigation is known to have a low efficiency of 40 to 60%, meaning that nearly half of the applied water is lost due to drainage and/or deep percolation.

Full treatments (S100 and D100) saved approximately 11.7 and 24.1% respectively of the irrigation water compared to furrow treatment.

Experimental measurements

To realize the main objective of this study many measurements including soybean yield and its components, soybean water productivity, and soybean seeds quality (physiochemical and physiological properties) were taken into consideration and recorded as following:

Soybean seed yield

The soybean seed yield was calculated by completely harvesting and threshing the experimental plot for each treatment. The collected seeds per plot were weighted and then adjusted to 13% moisture content and converted to kg/ha basis.

Yield components

Random samples of 20 plants from each experimental plot treatment were taken from different locations per central rows for measuring yield components of soybean plants including plant height; cm, number of pods/plant, and 100-seed weight; g.

Water productivity (WP, kg/m^3)

The water productivity explains how each irrigation treatment converts water into a seed yield. It was computed as the ratio of the harvested seed yield (kg/ha) to the total applied irrigation water for each treatment under study according to [26].

$$WP = \frac{Harvested\ seed\ yield, kg/ha.}{Total\ applied\ irrigation\ water, m^3/ha.}$$

....(2)

Soybean seed quality

Physiochemical properties

Three samples (25 seeds each) of dried mature soybean seeds from each treatment were prepared for chemical analysis in the Food Technology Research Institute. Protein and fats content; % was determined in the laboratory using the methodology of laboratory protocol.

Physiological properties

Germination ratio (G, %): three replications were carried out with 50 seeds each study treatments (from the produced soybean seeds under different irrigation treatments) which were uniformly distributed on two sheets of paper towel and covered by an additional one. The paper sheets were moistened at the rate of 2.5 times the weight of dry paper and placed in 12 cm diameter Petri dishes. They were kept in paper rolls in the seed germinator at 20ºC of RMC laboratory. Evaluations consisted of counting the number of normal seedlings produced from germinating seeds per day from the fourth day of cultivation until the eighth day. Good seeds have more than 80% germination rate [21]. The obtained results were expressed in percentage of normal seedlings according to the following equation [31].

$$G, \% = \frac{No.of\ germinated\ seeds}{No.of\ sample\ seeds} \times 100$$ ....(3)

Length of Seedling shoots and roots: itwas a measurement of the number of plant tissues with supportive functions (roots) compared to the amount of plant tissue with growth functions (shoots).It was performed from the germinated normal seedlings obtained in the germination test on the 8th day after the beginning of the test. The shoot and root lengths of the normal seedlings were measured, using a graduated ruler in mm/seedling [21].

Seedling dry weight (SDW, g/10 seedling): it was conducted with the germinated normal seedlings obtained in the length of Seedling shoots and roots test; these parts (shoots and roots) were cut and separated from the rest of the seed (reserve tissue) and placed in paper bags and dried in an oven at 65°C for 72 hours (or until stabilization of weight) according to [21].

Seed vigor index (V): it is considered an important index of seed quality that determines the potential for rapid and uniform emergence of the seedlings and then grown plants. It was calculated from the results of seed germination ratio and seedling dry weight using the formula as described by [2].

V= (G, %) × (SDW, g/10 seedlings).......(4)

Statistical analysis

The treatments were laid out in a randomized complete block design. Analysis of variance (ANOVA) was performed using Co-Stat program for windows. The means for different treatments were compared at a significance level of 5%.

RESULTS AND DISCUSSIONS

Soybean seed yield

The obtained results of soybean seed yield under different treatment cleared that the response of soybean seed yield was varied from treatment to other and there is a significant difference between treatments on soybean seed yield at probability of 0.05 (Fig. 2). In comparison to a seed yield of 3,107 kg/ha for furrow irrigation, the seed yield ranged from 3,443 to 2,224 kg ha^{-1} under sprinkler irrigation treatments and from 3,629 to 2,398 kg ha^{-1} under drip irrigation treatments. Full irrigation treatments S100 and D100 increased seed yield by 10.8 and 16.8 % compared to F treatment, while deficit treatments did not improve seed yield compared to F treatment. Application of deficit irrigation with 60% ETc (S60 and D60) reduced seed yield compared with full irrigation by 35.4 and 33.9% under sprinkler and drip irrigation systems respectively. In general, any water stress imposed on soybean plants results in a significant decrease in seed yield compared to the full irrigation water, given that it is a summer crop where the high temperature exceeded 39°C in July and August (Table 2) caused high transpiration rates, which exposes the plants to severe water stress under deficit irrigation. The highest three seed yield values were 3,629, 3,443, and 3,107 kg ha^{-1} which obtained at D100, S100, and F treatments respectively, while the lowest values were 2,398 and 2,224 kg ha^{-1} which obtained at D60 and S60 treatments respectively. In the same concern, [12] referred to the influence of climate conditions on the management of irrigation water. The highest soybean seed yield obtained at full irrigation [19, 22]. The drip system was superior to the sprinkler system in grain yield under different irrigation regimes; the same result obtained by [24, 29].

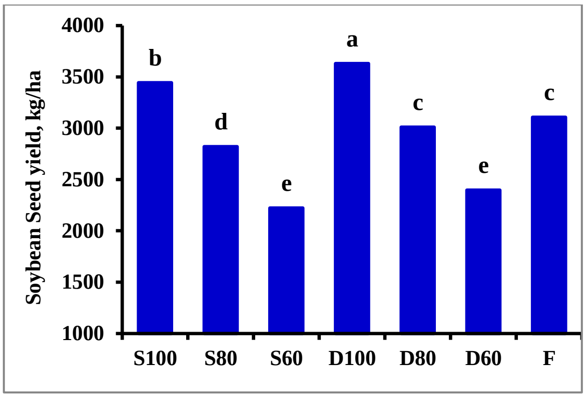

Fig. 2. Soybean seed yield for different treatments
*The same letters indicated not significantly different at 0.05 level.
Source: Own calculation based on experimental data.

Soybean yield components

The obtained results of yield components including plant height; cm, number of pods/plant, and 100-seed weight, g is recorded in Table 4. The results revealed that there is a significant difference between treatments on soybean yield components at probability of 0.05. As the amount of irrigation water reduced, the yield components decreased, that is, the full irrigation treatments (S100 and D100) surpassed the deficit in the yield components; bearing in mind that there is no significant difference between the S100 and D100 treatments in plant height and between S100 and F treatment in number of pods/plant and 100 seeds weight. Drip treatments surpassed corresponding sprinkler treatments. Water stress has a comparable influence on soybean yield components as [25, 9] revealed that subjecting soybean plants to water stress by increasing irrigation intervals or decreasing applied water during the growth stages has a detrimental impact on yield components. The same effect of water stress on the number pods per plant and the weight of 100 seeds observed by [11], but that effect on plant height fluctuated from one cultivar to another. Water deficit stress slowed the plant's height;

this restraint is related closely to the level, duration, and frequency of the irrigation deficit [12]. The highest yield component was achieved by D100 treatments with values of 113 cm plant height, 115 pods/plant, and 14.4 g weight of 100 seeds, reflecting an increase of 6.6, 10.6, and 10.5% respectively compared to F treatment.

Table 4. Soybean seeds yield components (plant height; cm, number of pods/plant, and 100-seed weight, g) for different treatments

Treatments	Plant height, cm	Number of pods /plant	100 seeds weight, g
S100	111 ab	106 b	13.1 b
S80	106 c	88 d	12.37 c
S60	100 e	77 e	11.03 d
D100	113 a	115 a	14.4 a
D80	109 b	97 c	12.4 c
D60	103 d	85 d	12.2 c
F	106 c	104 bc	13.03 b

The same letters in a column indicated not significantly different at 0.05 level
Source: Own calculation based on experimental data.

Water productivity

Water productivity for different treatments is showed in Fig. 3. The results revealed that there is a significant difference in water productivity between the different treatments; the water productivity was significantly influenced by three irrigation systems; deficit irrigation had a significant effect on water productivity in the drip irrigation system whereas this effect did not occur in the sprinkler irrigation system. Compared to sprinkler and surface treatments, drip irrigation improved water productivity since a higher crop was produced with less water. D100 treatment had the highest water productivity with a value of 0.62 kg/m^3, considering that there was no significant difference between it and the D80 treatment, Whereas the F treatment had the lowest water productivity with a value of 0.4 kg/m^3. The findings indicated that the irrigation technique that increases the soybean yield provides the highest water productivity. According to the results obtained, an optimal supply of irrigation water was necessary to produce the highest yield. The results are consistent with the findings reported by [23] that stated increasing water stress decreases water productivity. Improving water productivity under full irrigation recorded by many researchers where the seed yield improved [8]. On the other hand, many researchers stated an increase in water productivity underwater stress [10, 20]. These differences attributed to the soybean cultivars as well as the environmental conditions in which the experiments were carried out [9].

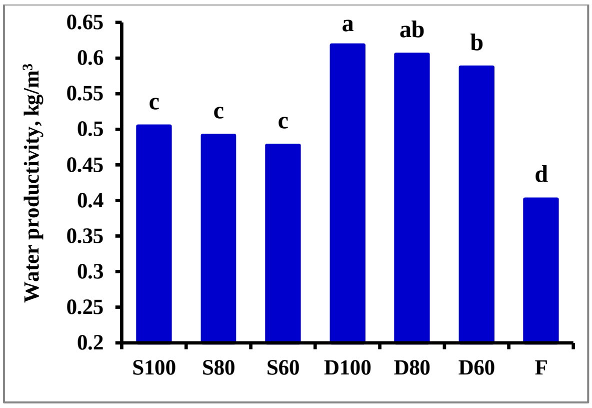

Fig. 3. Water productivity for different treatments
*The same letters indicated not significantly different at 0.05 level
Source: Own calculation based on experimental data.

Soybean seed quality

Physiochemical properties

The obtained results of physiochemical properties including seed protein and fats content for different treatments is listed in Table 5. It could be cleared that there is a significant difference between treatments on protein and fats content at probability of 0.05, there is a positive correlation for protein content and a negative correlation for fat content with the irrigation regime. The significant differences were found in protein and fat content of soybean seeds might be due to the differences in the water amount of irrigation treatments which affecting the growth rate of soybean crop plants. The highest effect on protein content was achieved by S100 and D100 treatments with values of 28.75 and 28.20% respectively, taking into consideration that there was no significant difference between the two treatments; followed by furrow treatment which surpassed deficit treatments in protein content. The lowest effect on protein content was obtained by D60 treatment with a value of 24.55%. The highest effect on fats content was achieved by D60 and S60 treatments with values of 22.91 and 22.63% respectively, taking into consideration that there was no significant difference between the two treatments; followed by D80 treatment with a value of 22.35% which had no significant difference between it and S60 treatment. The lowest effect on fats content was obtained by S100 and D100 treatments with values of 19.65 and 20.49% respectively. Our results were in agreement with the interior results of [32]. Fats content increased as water deficit increased this mean the higher fats content obtained at low soil moisture content. So the relationship between protein content and oil content was negatively correlated. In the same manner an inverse relationship between soybean protein and oil content was found by [27] where as a 1% increase in seed protein content resulted in a 1.5% reduction in oil content.

Table 5. Soybean seeds protein and fats content for different treatments

Treatment	Protein, %	Fats,%
S100	28.75 a	19.65 f
S80	26.15 c	21.65 c
S60	25.25 d	22.63 ab
D100	28.20 a	20.49 e
D80	25.80 cd	22.35 b
D60	24.55 e	22.91 a
F	27.25 b	21.21 d

The same letters in a column indicated not significantly different at 0.05 level
Source: Own calculation based on experimental data.

Physiological properties

Germination ratio: regarding the physiological property of the germination ratio, a significant difference between treatments was found at a probability of 0.05 level. There is a positive correlation between the germination ratio and the irrigation regime, which means that decreasing the applied water during the growing phases decreased the germination ratio of the recovered seeds Fig. 4. D100 and S100 treatments had the most significant effect, with values of 98.3 and 96.7%, respectively, followed by F treatment with a value of 95.8%, considering that there was no statistical difference between D100 and S100 treatments or between S100 and F treatments. The germination ratio was reduced by about 10.2 and 17.3%, respectively, for drip and sprinkler treatments, when the water regime was reduced from 100 to 60% ETc. Our results correspond with the prior findings of [19] through which they reflect that deficit irrigation reduced germination compared to full irrigation. Water deficit stress leads to a decreased accumulation of seed reserves and thereby reduces the germination rate [32]. All treatments provided an appropriate germination rate, not less than 80% according to [21].

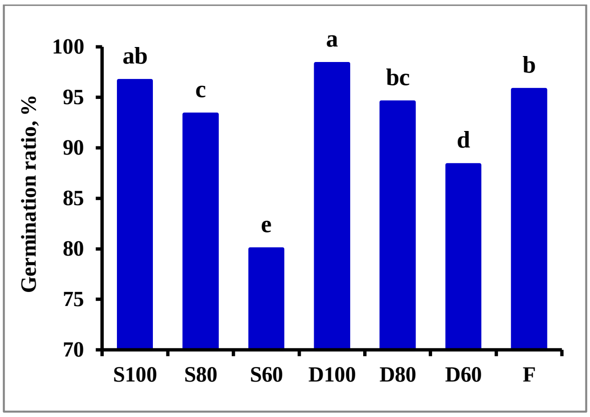

Fig. 4. Soybean seed germination ratio for different treatments
*The same letters indicated not significantly different at 0.05 level
Source: Own calculation based on experimental data.

*Length of Seedling shoots and roots:*the obtained results showed a significant difference in length of seedling shoots and roots between different treatments Fig. 5. Deficit irrigation decreased length of seedling shoots and roots compared to full and furrow irrigation. The highest effect obtained by D100 and S100 treatments with root length of 8.7 and 7.33 mm and shoot length of 1.98 and 1.87 mm respectively; bearing in mind there is no significant difference in root length between S100 and F treatments. The lowest effect obtained by S60 and D60 treatments with root length of 3.58 and 4.66 mm and shoot length of 1.46 and 1.49 mm respectively; taking into account there is no significant difference in shoot length between the two treatments. These results aligned with those published by [7] who observed the negative effect of water stress on shoot length. The length of seedling shoots and roots was negatively impacted when the seedlings came from seeds exposed to water stress [19].

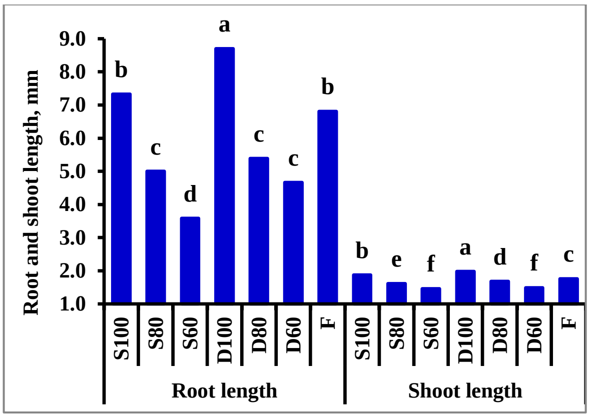

Fig. 5. Length of soybean seedling shoots and roots for different treatments
*The same letters for the same property indicated not significantly different at 0.05 level (ANOVA analysis)
Source: Own calculation based on experimental data.

Seedling dry weight: The soybean seedling dry weight as one of the physiological properties for produced soybean seeds under different irrigation treatments was determined and the obtained results were presented in Fig. 6.

These results indicated a significant difference in soybean seedling dry weight between different treatments at the probability of 0.05, there is a positive correlation between soybean seedling dry weight and the irrigation regime, as the increase in the water regime increased the seedling dry weight. Full irrigation (D100, S100, and F) treatments achieved the highest seedling dry weight with values of 0.69, 0.67, and 0.65 g, considering there was no significant difference between D100 and S100 treatments or between S100 and F treatments. Decreasing the water regime under drip irrigation from 100 to 60% ETc results in a decrement percentage of 23.2% in seedling dry weight compared with 32.8 % decrease under sprinkler irrigation. The lowest seedling dry weight was 0.45 g which obtained by S60 treatment. Similar findings were obtained by [15, 18] in which, water deficit stress is encourage leaf senescence and shortens the duration and weight of seed filling, mainly by restricting photosynthesis and nutrient supply to growing seeds. Water deficit stress causes reductions in seedling dry weight, because of the reduction in shoot and root length [7].

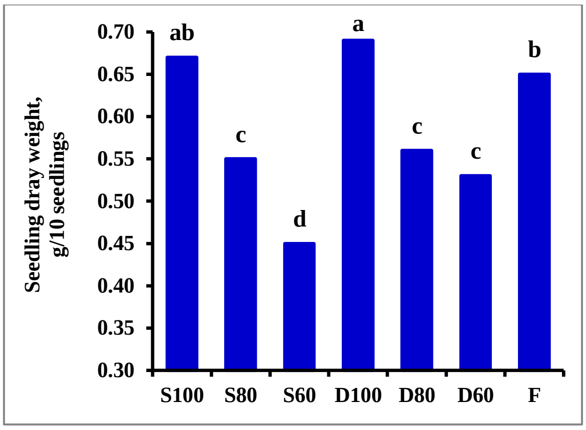

Fig. 6. Soybean seedling dry weight under different irrigation treatments
*The same letters indicated not significantly different at 0.05 level.
Source: Own calculation based on experimental data.

Seed vigor index: The obtained results of seed vigor index referred to significant difference between different treatments at the probability of 0.05 level Fig. 7. There is a positive correlation between vigor index and the irrigation regime, where vigor index increased as the water regime increased.

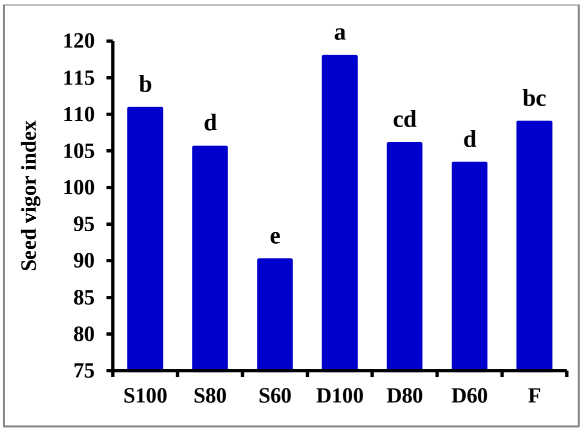

Fig. 7. Soybean seedling dry weight under different irrigation treatments
*The same letters for the same property indicated not significantly different at 0.05 level
Source: Own calculation based on experimental data.

Since the vigor index is related to the germination ratio and the seedling dry weight, the effect of various treatments on the vigor index follows the same pattern. The highest effect obtained by full irrigation treatments (D100, S100, and F) with values of 117.9, 110.8, and 108.9 respectively, considering there was no significant difference betweenS100 and F treatments. Deficit treatments tended to decrease vigor index, decreasing the water regime from 100 to 60% ETc decreased vigor index by about 12.4 and 18.7 % under drip and sprinkler treatments respectively. The lowest effect obtained by S60 treatment with a value of 90.1. The obtained results were harmonious with the preceding results of [33] in which drought stress increased the percentage of small and medium seeds which had lower germination and vigor than large seeds.

CONCLUSIONS

Considering the results obtained, it is feasible to conclude that a gradual increase in the water regime was accompanied by an increase in soybean yield and its components, water productivity, protein content, and physiological properties, whereas fats decreased. Drip irrigation with the full regime had the highest results, followed by sprinkler irrigation with the full regime and then furrow irrigation. Deficit irrigation reduced soybean yield and quality properties. Drip and sprinkler irrigation systems with the full regime are the most appropriate and efficient practices for improving soybean yield and quality.

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REFERENCES

[1]Abdel-Mohsen, A.A., Mahmoud, G.O., Safina, S.A., 2013, Agronomical evaluation of six soybean cultivars using correlation and regression analysis under different irrigation regime conditions, Journal of Plant Breeding and Crop Science, Vol. 5(5): 91-102.

[2]Abdul-Baki, A.A., Anderson, J.D., 1973, Vigor determination in soybean seed by multiple criteria1, Crop Science, Vol. 13(6): 630-633.

[3]Admasu, R., Asefa, A., Tadesse, M., 2019, Determination of optimal irrigation scheduling for soybean (*Glycine max* L.) yield and water productivity at Jimma, South West Ethiopia, Agricultural Research and Technology Journal, Vol. 19(4): 179-183.

[4]Ali, O.A.M., Abdel-Aal, M.S.M., 2021, Importance of some soil amendments on improving growth, productivity and quality of soybean grown under different irrigation intervals, Egyptian Journal of Agronomy, Vol. 43(1): 13-27.

[5]Allen, R.G., Pereira, L.S., Raes, D., Smith, M., 1998, Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. FAO, Rome, 300(9), D05109.

[6]Aminah, A., Syam, N., Palad, M.S., 2022, Application of water provision on the growth and production of soybean (Glycine max L). The Agricultural Sciences Journal, Vol. 9(1): 59 – 65.

[7]Ammar, M.H., Anwar, F., El-Harty, E.H., Migdadi, H.M., Abdel-Khalik, S.M., Al-Faifi, S.A., Farooq, M., Alghamdi, S.S., 2015, Physiological and yield responses of faba bean (*Viciafaba* L.) to drought stress in managed and open field environments, Journal of Agronomy and Crop Science, 201: 280-87. https://doi.org/10.1111/jac.12112.

[8]Arora, V.K., Singh, C.B., Sidhu, A.S., Thind, S.S., 2011, Irrigation, tillage and mulching effects on soybean wield and water productivity in relation to soil texture, Agricultural Water Management, 98: 563-568.

[9]Aydinsakir, K., 2018, Yield and quality characteristics of drip-irrigated soybean under different irrigation levels, Agronomy Journal, Vol. 110(4): 1473-1481.

[10]Candogan, B.N., Yazgan, S., 2016, Yield and quality response of soybean to full and deficit irrigation at different growth stages under sub-humid climatic conditions, Journal of Agricultural Science, 22:129–144.

[11]Comlekcioglu, N., Simsek, M., 2011, Effects of deficit irrigation on yield and yield components of vegetable soybean [*Glycine max* L. (Merr.)] in semi-arid conditions, African Journal of Biotechnology, Vol. 10(33): 6227-6234.

[12]Dong, S., Jiang, Y., Dong, Y., Wang, L., Wang, W., Ma, Z., Yan, C., Ma, C., Liu, L., 2019, A study on soybean responses to drought stress and rehydration, Saudi Journal of Biological Sciences, Vol. 26(8): 2006–2017. doi: https://doi.org/10.1016/j.sjbs.2019.08.005.

[13]El-Hamidi, M., Zaher, F.A., 2018, Production of vegetable oils in the world and in Egypt: an overview. Bulletin of the National Research Centre. https://doi.org/10.1186/s42269-018-0019-0.

[14]El-Shafey, A.I., 2017, Response of soybean to water stress conditions and foliar application with

salicylic and ascorbic acids. Zagazig Journal of Agricultural Research, Vol. 44(1): 1-22.
[15]Fageria, N.K., 2013, The role of plant roots in crop production. CRC Press, Boca Raton, FL, USA.
[16]FAO, 2020, FAOSTAT: Food and Agriculture Data. USA: Food and Agriculture Organization of the United Nations. http://www.fao.org/faostat/en/#home.Accessed on 06. 11, 2020.
[17]FAOSTAT, 2021, FAOSTAT data, 2021 book of productions, FAO, Rome.
[18]Ghassemi-Golezani, K., Lotfi, R., Norouzi, M., 2012, Seed quality of soybean cultivars affected by pod position and water stress at reproductive stages, International Journal of Plant, Animal and Environmental Science, 2: 119-125.
[19]Grahl, T.D., Rockenbach, A.P., Casassola, A., 2022, Outcomes of water deficit stress on the physiological quality of soybean seeds, Journal of Seed Science, 44: 1-12. https://doi.org/10.1590/2317-1545v44260716.
[20]Irmak, S., Specht, J. E., Odhiambo, L. O., Rees, J. M., Cassman, K. G., 2014, Soybean yield, evapotranspiration, water productivity, and soil water extraction response to subsurface drip irrigation and fertigation, Transaction of the ASABE 57:729–748.
[21]ISTA, 2010, International rules for seed testing, seed vigor testing, Chapter 15, pp: 1-57.
[22]Khaffagy, A.E., Mazrou, Y.S.A., Morsy, A.R., El-Mansoury, M.A.M., El-Tokhy, A.I., Hafez, Y., Abdelaal, Kh., Khedr R.A., 2022, Impact of irrigation levels and weed control treatments on annual weeds, physiological traits and productivity of soybean under clay soil conditions, Agronomy, 12, 1037, https://doi.org/10.3390/agronomy12051037.
[23]Kirnak, H., Dogan, E., Turkoglu, H., 2010, Effect of drip irrigation intensity on soybean seed yield and quality in the semi-arid Harran plain, Turkey, Spanish Journal of Agriculture Research, 8:1208–1217. doi:10.5424/sjar/2010084-1239.
[24]Kresović, B., Gajic, B.A., Tapanarova, A., Dugalić, G., 2017, Yield and chemical composition of soybean seed under different irrigation regimes in the Vojvodina region, Plant Soil Environmental, Vol. 63(1): 34–39.
[25]Mahmoud, G.O., Almatboly, M.A., Safina, S.A., 2013, Effect of irrigation intervals and fertilization systems on soybean seed yield and its quality, Journal of Plant Production, Mansoura Univ., Vol. 4(7): 1109–1118.
[26]Michael, M.A., 1997, Irrigation Theory and Practice: Evaluating Land for Irrigation Commands, Vikas Publishing House PVT Ltd: New Delhi. India.
[27]Pinnamaneni, S.R., Anapalli, S.S., Bellaloui, N., Reddy, K.N., 2021, Effects of irrigation and planting geometry on soybean (*Glycine max* L.) seed nutrition in humid climates, International Journal of Agronomy, Article ID 6625919, 9 pages, https://doi.org/10.1155/2021/6625919.
[28]Rajjou, L., Duval, M., Gallardo, K., Catusse, J., Bally, J., Job, C., Job, D., 2012, Seed germination and vigor, Annual review of plant biology, 63: 507–533.
[29]Rotundo, J.L., Borras, L., Westgate, M.E., Orf, J.H., 2009, Relationship between assimilate supply per seed during seed filling and soybean composition. Field Crop Research, Vol. 112(1): 90-96.
[30]Saied, M.M., Ragab, M.M., El–Barbary, S.M., El–Shahawy, M.I., 2008, Effect of pressurized irrigation system on soybean and flax yields, and some water relations in old lands, Misr Journal of Agricultural Engineering, Vol. 25(1): 87- 101.
[31]Sharma, A., Nair, R., Ramakrishnan, R. S, 2022, Coriander seed quality and vigour assessment as affected by bio regulators and varied irrigation regimes based on climatological approach, International Journal of Environment and Climate Change, Vol. 12(11): 2554-2565.
[32]Wijewardana, C., Reddy, K.R., Krutz, L.J., Gao, W., Bellaloui, N., 2019, Drought stress has transgenerational effects on soybean seed germination and seedling vigor, Plos One, 14 (9): 1-20. https://doi.org/10.1371/journal.pone.0214977.
[33]Yang, Y., Guan, H., Batelaan, O., McVicar, T.R., Long, D., Piao, S., Liang, W., Liu, B., Jin, Z., Simmons, C.T., 2016, Contrasting responses of water use efficiency to drought across global terrestrial ecosystems, Scientific Reports | 6:23284 | DOI: 10.1038/srep23284.

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PROFITABILITY AND CONSTRAINTS OF POULTRY PRODUCTION AMONG HOUSEHOLDS IN SOUTH - SOUTH, NIGERIA. IMPLICATIONS FOR PROTEIN INTAKE SUSTAINABILITY

Peter Otunaruke EMAZIYE*, Sarah ENWA*, Ufuoma Godstime SORHUE, Favour Ogheneoyoma EFE***

Delta State University, Faculty of Agriculture, *****Department of Agricultural Economics, ******Department of Animal Science, Emails: peteremaziye63@gmail.com*, sarahenwa647@gmail.com*, gtsorhue@yahoo.com**, efefavour999@gmail.com*

Corresponding author: peteremaziye63@gmail.com

Abstract

The study's main objective was to examine the profitability of poultry production and its constraints. Data were collected with the aid of a structured questionnaire which was evaluated using descriptive statistics, 4 Likert scale and regression analysis. The data analysis reveals that most poultry farmers were male with a mean farming experience of 8 years. Most respondents were married while the mean family size was 7 persons with a secondary educational level. The study revealed that sex (0.002), age (0.000), farming experience (0.000) and education (0.000) have significant positive effect on the poultry production profitability while household size (0.739) had an insignificant positive effect on the poultry production profitability. The study recommends that poultry farmers' inputs should be subsidized by Government to reduce the cost of inputs and give technical support to poultry farmers to enhance poultry business development thereby resulting in more profit.

Key words: *constraints, households, poultry, profitability, production, protein*

INTRODUCTION

The rearing of birds such as ducks, chickens, quails, geese and turkeys with the intent of raising them for the production of eggs, meat and their products used as feathers and faecal droppings in natural organic materials production [21]. Poultry eggs and meat are highly desirable in all parts of the country. Just two (2) eggs a day are sufficient to meet 17.2% of an adult person's protein needs as well as essential vitamins and trace elements [11]. Poultry meat contains more proteins than beef in addition, poultry housing can be provided at a relatively low cost and the growth period is short (usually about 6 - 10 weeks for broilers). The Poultry industry has become very popular during the past few years due to the growing rate of unemployment and population explosion in Nigeria [14]. Though Nigeria has the largest number of poultry meat farms in this region [10]. the country is the fourth-largest producer of broiler meat with South Africa being the leading producer [22]. In 2013 and 2016, poultry meat production in Nigeria stood at about 300,000 and 450,000 metric tons respectively [22].

The Nigeria poultry business has experienced a significant change from a peasant, backyard and primitive domestic oriented small-holder to large-scale and modern poultry business since early fifties till date. Though the value of livestock resources has grown in absolute terms in recent years, its overall contribution to agricultural output remains dismally low [3]. It is thus advantageous to recognise likely areas that need improvement hence this study on poultry farming profitability was carry out.

However, in spite of ever-increasing biological activity, inadequate attention has been devoted to the viability of the business itself. According to [13], poultry production involves more than the biological processes of birds growth. It also includes paying critical attention to the financial aspects of the production. Efficient financial management of poultry can make the difference between profits and losses [12]. The poor regard of poultry as an economic activity has made it difficult to promote its commercialization, as investors were not convinced that poultry could be a profitable enterprise [13]. This could be a result of a lack of economic information on the profitability of the poultry business which has adversely affected poultry production. It affect decision making when evaluating possible investment options, accessibility to the financing needed for investment and it makes insurance of such investments difficult [19]. These factors will negatively impact poultry investment and its development [13]. The research conducted by [4] showed that the feed cost is a key constraint in poultry enterprise in conjunction with other constraints such as disease outbreaks breeding process, and the absence to access capital. These have resulted in the business liquidation of numerous broiler farmers.

The Nigeria livestock business is occupied with abundant complications, which have occasioned a gross shortage of meat, eggs and other animal products. The agricultural sector growth rate in Nigeria is quiet under country's human resources and natural potential due to agricultural inputs high cost, insufficient private section participation, insufficient functional infrastructural facilities, and inconsistencies of government agricultural policies, poor mechanized farming, poor funding of agriculture and little or no implementation of some simple agricultural technologies developed by scientists.

In spite of the advantages, the poultry industry is yet to attain the desired level of productivity in Nigeria due to the production high cost [17]. For example, poultry farmers are confronted with the difficulty of tremendous increase in drugs, day-old chicks, and other poultry inputs. The situation has forced small-scale poultry farms to close down and those still managing to survive are producing at very high cost and also contending with serious input limitations.

Availability of credit and capital accumulation within the agricultural sector, poultry sector inclusive is very slow [5] and [14]. There is also a low level of productivity [17].

The author [1] argued that luck alone does not explain the differences in the profitability levels of farms or ranches with the same resource endowment. Financial management is, therefore, a key factor determining the success or failure of a business enterprise; be it a firm or a farm. [7] reported that business is economically rewarding and viable considering the poverty level present in the rural area; therefore, poultry production like any other agricultural business activity requires that a farmer has a wealth of experience in the financial management of the enterprise. The farmer is out to make a profit and in order to actualize this; he should be able to produce at a level that will make him recoup his cost. Based on the above premise, this study is aimed at comparing the poultry production profitability with the intention of the following objectives achievement.

Objectives of the Study were to:

(i)describe the poultry farmers' socioeconomic characteristic

(ii) determine poultry farmers' revenue

(iii) analyse the poultry farmers cost of production per cycle

(iv)determine the poultry farmers' profitability per cycle

(v) determine the poultry farmers cost and return per cycle

(vi) determine the poultry farmers constraints faced.

The Hypothesis of the Study

The hypothesis of the study was tested in a null form as follows:

Ho I: socio-economic characteristic has no significant influence on poultry profitability in the study area.

MATERIALS AND METHODS

South-South Nigeria was chosen for the study as most inhabitants were farmers that mostly rear livestock (especially poultry), fishing, petty trading and arable crops. The area has inhabitants of roughly 6 million people of different ethnic races [15]. South-South Nigeria is made up of six states namely, Akwa Ibom, Cross Rivers, Delta, Bayelsa, Rivers, and Edo. Multi-stage method of sampling was incorporated into the study. Firstly, five states were selected randomly followed by four local government areas (LGAs) each was chosen randomly amounting to 20 LGAs. Thirdly, five farming communities each were selected randomly giving a total of 100 rural farming communities and lastly, three poultry farmers each were wisely picked from the 100 communities giving an aggregate of 300 poultry farmers. Studied data were realized with the aid of well-ordered questionnaires administered to respondents. Data were tested by descriptive statistics such as median, mode, mean, percentages and frequency, budgetary technique and multiple regression techniques.

Model Specification

Π = TR- TC………………………..Eq. (1)
TR= PQ…………………………...…. Eq. (2)

where:
Π = Total Profit (N)
TR=Total revenue (N)
TC= total Cost (N)
P= Unit price of output (N)
Q= Total quantity of output (N)

The Regression Model

In order to decide on the influence of socioeconomic variables on the level of poultry profitability, a multiple regression model was engaged in the hypothesis testing. The model is specified as follows:

Q=f(X1, X2, X3, X4, X5, X6, X7, e)…Eq. (3)
where:
Q = poultry output (naira)
X1= poultry stocking density (square meters)
X2= poultry production labour used
X3= feeds cost (naira)
X4= vaccine cost (naira)
X5 = deep litters cost (naira)
X6 = fixed inputs cost (naira)
X7 = day-old chicks cost (naira)
e= Error term

Likert scale

The Likert scale was used to examine the severity of the challenges faced by poultry farmers.

Very severe = 4
Severe = 3
Non severe = 2
Not very severe = 1

This was added to get 10 divided by 4 to get 2.5 as the cut-off point. A variable with a mean score of 2.5 and above will be regarded as severe while less than 2.5 will be regarded as not severe.

RESULTS AND DISCUSSIONS

Socioeconomic characteristics and activities of poultry farmers

The mean age of the poultry farmers was 44 years this designates that most poultry growers were within the economically active age. This finding is in line with the observation of [2] who noted that respondents within this age group were motivated and innovative individuals who can survive challenges that may originate from poultry farming. Gender is an important factor to consider in farming activities or any other activities that demand energy, out of the respondents 300 sampled 86% were male while 14% were female. This is in contrast with goat production as reported that its production were mostly carried out by female [8]. In the distribution of marital status of respondents were singles (6%) while 88.6% were married poultry farmers. The consequence is that poultry production is encouraged due to respondents' stable homes. The respondent's family size indicates that 60% of the poultry farmers have between 6 - 10 members in the family, while 33% have family sizes from 1 - 5. Family size has a consequence on the hired labour size engaged by poultry farmers, because the higher the size of the family the lower the hired labour and vice versa which support the finding [18]. The educational status of poultry growers revealed that 24% acquired tertiary education, 1.33% without formal education, 8% had primary education and 66.67% acquired secondary education. The perimeter in Table 1 confirms that 70% respondents had poultry farming experience range of 1 - 7 years with a mean farming experience of 7 years. It has been proved that the productivity of labour with higher experience is better for the poultry business [4].

The data of the distribution of the income level of respondents indicates that income level was **(N)** 382,946.70 average and flock stock size averagely was 500 birds.

Table 1. Socioeconomic activities of poultry farmers

Socio-economic variables	Frequency	%	Mean/Mode
Age (Years)			
20 – 29	42	14.00	45 years
30 – 39	70	23.33	
40 – 49	78	26.00	
50 – 59	66	22.00	
60 – 69	32	10.67	
70 – 79	12	04.00	
Total	300	100	
Gender			
Male	258	86.00	Male
Female	42	14.00	
Total	300	100	
Marital status			
Single	18	6.00	Married
Married	264	88.00	
Widowed	14	4.67	
Divorced	04	1.33	
Total	300	100	
Household size (Persons)			
1 – 5	106	35.33	8 years
6 – 10	180	60.00	
11 – 15	14	04.67	
Total	300	100	
Educational level			
No formal education	04	1.33	Secondary education
Primary education	24	08.00	
Secondary education	200	66.67	
Tertiary education	72	24.00	
Total	300	100	
Farming experience (Years)			
1 – 7	210	70.00	7 years
8 – 14	54	18.00	
15 – 21	18	06.00	
22 – 28	14	4.67	
29 – 35	04	1.33	
Total	300	100	
Flock stock size			
101 – 200	04	1.33	
201 – 300	04	1.33	
301 – 400	06	2.00	
401 – 500	110	36.67	
501 – 600	176	58.67	
Total	300	100	
Income (N)			
101,000 – 300,000	132	44.00	**(N)** 382,946.70
301,000 – 500,000	102	34.33	
501,000 – 700,000	36	12.00	
701,000 – 900,000	20	06.67	
901,000 – 1,100,000	10	03.33	
Total	300	100	

Source: Own processing based on Field survey data.

Mean income coming from broilers production

The broiler farms generated a total mean revenue income of ₦1,559, 250.00 per production cycle. Averagely 500 birds was raised per cycle with a mean selling price per bird at ₦900 per kg as revealed in Table 2. These findings collaborated with [7] who reported that means selling price of broilers is ₦1000 per kg resulting in a high level of profit.

Table 2. Mean income coming from broilers production

Numbers of birds	500
Quantity sold per kg	1,732.50
Selling price per kg	₦ 900
Total income	₦1,559,250.00

Source: Field survey data.

Average Cost of Production

The information in Table 3 revealed the poultry farmers' mean cost of production was in the purchase of feeds, day-old chicks, Detergent/soap, Drugs/vaccine, labour and Fuel which made up the total variable cost of N1,088,809.13 while rent and feeder/drinkers made up the total fixed cost (N94,732.3) incurred in poultry production. The total expenditure (cost) incurred was N1,183,541.43 and it was observed that most expenditures were in the purchase of day-old chick (N375,249.55) and feeds (N621,116.70). Continuous increases in feed costs remain noticeable issues in the poultry sector [16].

Table 3. Average cost of production

Cost of producing 500 broilers	Amount ₦
Feeds	621, 116. 70
Chicks	375, 249. 55
Detergent / Soap	2,578.00
Drugs / Vaccines	5,698.40
Labour	61,093.00
Fuel	21, 469. 48
Miscellaneous	1, 604. 00
Total variable cost	**1,088,809.13**
Cost of renting	76,871.80
Cost of feeders and drinkers	17,860.50
Total fixed cost	**94,732.30**
Total cost	**1,183,541.43**

Source: Computed based on the field data.

The findings agreed with [20] that feed cost constituted about 70% of the total variable cost in the production of broilers. According to the author, the second largest contributor to the production cost was day-old chicks (22%), while other materials contributed the remaining 22%.

Profitability of Broiler Production

The information in Table 4 stipulates that the total revenue and total cost of poultry production was N1,559,250.00 and N1,183,541.43 respectively. The poultry production gross margin and net returns were N470,440.87 and N375,708.57 respectively. These figures reveal that poultry production was a profitable business. The business benefit-cost-ratio was 1.3 which clearly indicates 30% profitability, also shows that 30 kobos will be made for every naira committed to the business, this also indicates business profit. This agreed with [6] who reported 30% profitability in goat farming in Niger Delta. But however arbitrary increase in the cost of feed and other inputs has led to a reduction in the profit margin of poultry operations.

Table 4. Profitability of broiler production Amount (₦)

Total Revenue (TR)	1,559,250.00
Total variable cost (TVC)	1,088,809.13
Total fixed cost	94,732.30
Total cost	1,183,541.43
Gross Margin (MG) = TR- TVC	470,440.87
Net Return(NR) GM-TFC	375,708.57
Benefit-Cost-Ratio = TR/TC	1.32

Source: Computed based on the field data.

Poultry Farmer Constraints

Table 5 itemized the issues that poultry farmer entrepreneurs must deal with.

Table 5. Poultry Farmer Constraints

Challenges	Frequency	%	Rank order
Lack of finance	40	16.70	3rd
Acquisition of land	08	06.70	6th
Farming inputs	64	45.00	2nd
Technical support	99	57.50	1st
Pollution	16	10.70	4th
Environmental/ Climate change	12	10.00	5th

Source: Field Survey Data.

The result presented in Table 5 indicates that lack of Technical support from government/local authorities ranked 1st the major constraint, lack of agricultural inputs, including water, day-old chicks, equipment, and machinery ranked 2nd challenges, lack of funding ranked 3rd problem confronting poultry farming and the least.

The obstacles were land acquisition which ranked 6th. This agreed with [9] and [4] reported serious constraints such as the high cost of inputs, inadequate access to credits and diseases which affected the profitability of poultry production in Delta State.

Regression Analysis

Effects of Socioeconomic Characteristics of Poultry Farmers on Output

A study indicates that four variables in the model were significant.

These are sex, age, education and farming experience.

The sex variables have a coefficient of -4.635 with a t- value of -3.186 and are significant at the 1% level with a negative coefficient sign. This implies that the female gender decreases the output of poultry farmers while male poultry farmers were more productive.

The age of rural poultry farmers had a positive sign with a coefficient of 0.677 and a t- value of 8.216. It is significant at a 1% level. This implies that older farmers had more farming experience to produce more birds than the younger ones (Table 6).

Table 6. Regression Analysis

Variables	Coefficient	Std error.	T-value.	Significance
Constant	6.638	3.341	1.987	0.050***
Sex	-4.635	1.455	-3.186	0.002***
Age	0.677	0.082	2.216	0.000***
Marital status	-0.286	1.690	-0.169	0.866
Household size	0.163	0.487	-0.335	0.739
Education	2.519	0.642	3.922	0.000***
Farming Experience	5.726	0.645	3.481	0.000***
R^2 = 0.671				
F- Ratio = 34.056				

***, ** and * significant at 1%, 5% and 10% level respectively

Source: Own results.

The level of education had a coefficient of 2.516 and a t- value of 3.922 with a positive sign at a 10% level of significance. This implies that with higher education the farmers master all the production techniques which could enhance output.

The farming experience of poultry farmers had a coefficient of 5.726 and a t- value of 3.481, it is significant at the 1% level which implies that farming experience leads to a greater poultry output (Table 6).

CONCLUSIONS

The data analysis result reveals that poultry farmers were mostly male with 7 years averagely farming experience. Most respondents had secondary education and were married with a mean household size was 7 persons. The survey exposed that sex (0.002), age (0.000), farming experience (0.000) and education (0.000) have significant positive effect on the poultry production profitability while household size (0.739) had an insignificant positive effect on the poultry production profitability. The study recommends that poultry farmers' inputs should be subsidized by Government to reduce the cost of inputs and give technical support to poultry farmers to enhance poultry business development thereby resulting in more profit.

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REFERENCES

[1]Durojaiye, B.O., 2010, Monitoring and Evaluation of Agricultural and Rural Development Project. AdemolaIge Ventures Ogun State, Nigeria.pp45-46
[2]Ebewore, S.O., Emaziye, P.O., 2016, Level of use of organic manure by farmers in Isoko North Local Government Area of Delta State, Nigeria. International Journal of Agricultural Extension, Rural Development studies 3(1):1-11.
[3]Eke, I. C., Effiong, J. A. L., 2016, The Impact of Capital Accumulation on Livestock Production Output in Nigeria. International (3), 43 – 61.
[4]Emaziye, P. O., Okpara O., Emaziye, O., 2022, Cost Benefits Analysis of Broiler Production in Delta State, Nigeria: Implication for Livelihood Sustainability. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 22(3): 211 - 214.
[5]Emaziye, P.O., Ogisi O.D., 2021, Cost and returns analysis of small-holder pig production in Niger Delta region, Nigeria. Journal of the Austrian Society of agricultural economics Vol.17.
[6]Emaziye, P.O., 2021a, Perspective Analysis of small-scale flock Production as a tool for poverty reduction in Delta South Agricultural Zone of Delta State, Nigeria. Transylvanian Review: 29(1): 15600.
[7]Emaziye, P.O., 2020, Cost and returns analysis of small-scale cat fish farming in Isoko North Local Government Area, Delta State, Nigeria. International Journal of Agricultural Extension and Rural Development Studies Vol.7, No.4, pp.1-6.
[8]Emaziye, P.O., 2021b, Profitability and hindrance of goat production among rural households in Nigeria: Perspectives of Niger Delta Area. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 21(4): 397-401.
[9]Ezah, C.I, Anyiro C.O., Chukwu, J.A., 2012, Technical Efficiency in Poultry Broiler Production in Umuahia, Capital Territory of Abia State, Nigeria. Groomer. Journal of Agricultural Science, 2(1) 001-007.
[10]FAO, 2010, Food and agriculture organization of the United Nations statistical databases http://faostat.fao.org/, Accessed on 15 March 2023.
[11]FAO, 2013, Food and Agricultural Organisation Corporate Document Reposting Agriculture and Consumer Protection. Guide to Animal Feeding Operation, Jerffeson City.
[12]Gitonga, N.K., Mbugua, H. M., Nyandat, B., 2014, New Approach to Aquaculture Extension in Kenya. Samaki News. Department of Fisheries Nairobi Kenya. Nairobi Vol. 1(1).
[13]Mwangi, M. H., 2017, A Comparative Economic Evaluation of Farming of three important poultry and fish Species in Kenya. A Project submitted to the United Nations University Fisheries Training Programme. 65p.
[14]Nwandu, P. I., 2021, Profitability of Small-Scale Broiler Farmers Production in Okpe Local Government Area of Delta State. Dutse Journal of Pure and Applied Sciences (DUJOPAS), Vol. 7:33-41.
[15]National Population Commission (NPC), 2006, Year Book of Nigeria Population Data, National PopulationCommission, Nigeria.
[16]Hafez, H. M., 2005, Governmental regulations and concepts behind eradication and control of some important poultry diseases. World Poultry Science Journal. 61:569–82. doi: 10.1079/WPS200571
[17]Ogba, O., Ahaotu, E. O., Iheanacho, R. O., Chukwu, A. O., 2020, Challenges of Small Poultry Farms in Layer Production in Ikwuano Local Government Area of Abia State, Nigeria. Sustainability, Agriculture, Food and Environmental Research, 8 (X), 212 – 222.
[18]Okeke, D. C, Emaziye, P.O., 2017, Technical efficiency of smallholder cassava production in

Anambra State, Nigeria. A Cobb Douglas stochastic frontier production approach. Journal of Poverty, Investment and Development 11: 94-99.
[19]Pillay, T.V., Kutty, M.N., 2015, Poultry Principal and Practices. United Kingdom: Blackwell Publishing, 284-316.
[20]Ravindran, V., 2013, Poultry feed availability and nutrition in developing countries: Food and Agriculture Organization of the United Nations. Poultry development review.
[21]Stiles, W., 2017, Poultry manure management. https://www.researchgate.net/publication/321001761_Poultry_manure_management/stats. Accessed on the 15th of March 2023.
[22]United States Department of Agriculture. USDA (2013). International egg and poultry report, Vol. 18, pp. 1–3. USDA.

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INFLUENCE OF FERTILIZERS ON PHOTOSYNTHETIC AND PRODUCTION CAPABILITY OF WINTER WHEAT UNDER MODERATE HUMIDIFICATION

Alexander ESAULKO, **Elena PISMENNAYA, Evgeny GOLOSNOY, Alena OZHEREDOVA, Vladimir KLETS**

Stavropol State Agrarian University, 12, Zootechnical lane, Stavropol, Russian Federation, E-mails: aesaulko@yandex.ru, pismennaya.elena@bk.ru, golosnoi@mail.ru, alena.gurueva@mail.ru

Corresponding author: pismennaya.elena@bk.ru

Abstract

The regulation of plants mineral nutrition using complex microfertilizers makes it possible to increase the productive capacity of wheat by optimizing physiological processes. Microelements that are part of enzymatic systems improve metabolism, contribute to the normal course of physiological processes that affect photosynthesis. Under the influence of microelements, the resistance of plants to diseases and adverse environmental conditions increases, the assimilation of macroelements from the soil and fertilizers improves. The lack of minor elements leads to a violation of the physiological processes in the plant's body and, as a result, a decrease in yield and a deterioration in its quality. The combination of various minor elements forms various types of microfertilizers. The goal of this research was represented by the microfertilizers Atlantica "Raikat Development", "All Inclusive", Wuxal "Microplant", Polidon "Complex", introduced on a different agricultural background (without fertilizers, recommended –$N_{90}P_{60}$ and calculated –$N_{186}P_{95}K_{45}$). An integrated approach was used, carried out in 2020–2022 in the moderate moisture zone in the Central Ciscaucasia, based on the use of field measurements of the spectral properties of the winter wheat plants physiological state and laboratory studies of micro- and macroelements of fertilizers. A dispersion analysis of the indicators correlation reflecting the physiological state of plants, nitrogen and winter wheat yields was carried out on various agricultural backgrounds.

***Key words*:** *mineral fertilizers, microfertilizers, pigments, winter wheat, vegetation indices*

INTRODUCTION

Optimization of plant nutrition, increasing the efficiency of fertilizer application are largely associated with ensuring the optimal ratio of macro- and microelements in the soil. Moreover, the regulation of plants mineral nutrition, including the use of complex microfertilizers, is necessary to increase the productive capacity of wheat [14, 16].

Microelements are essential nutrients, without which plants cannot fully develop [7]. They are part of the most important physiologically active substances and are involved in the synthesis of proteins, carbohydrates, vitamins, and fats [5, 19].

Under the influence of microelements, plants become more resistant to adverse conditions of atmospheric and soil drought, low and high temperatures, damage by pests and diseases [10, 4].

The most important elements of mineral nutrition are nitrogen, phosphorus, sulfur and magnesium, used as a building material for the photosynthetic apparatus [5]. Iron, potassium, phosphorus, chlorine, copper and other elements that are not part of chloroplasts affect the accumulation of chlorophyll and, consequently, photosynthesis. In addition, nitrogen is an integral part of chlorophyll, which enhances its synthesis. With a lack of copper, chlorophyll is easily destroyed [21].

Potassium, changing the colloidal state of the cytoplasm, affects the photosynthesis intensity and the chlorophyll accumulation.

An excessive concentration of chemicals (for example, sodium and chlorine) leads to inhibition of the photosynthesis process and a decrease in yield [3, 6, 20]. Therefore, it is important that in certain phases of plant growth, the concentration of assimilates and formed substances be optimal for yield formation [6, 11, 17]. To do this, it is necessary to direct all agrotechnical measures (including fertilization) to create the best conditions by creating an appropriate agricultural background that ensures the growth of the photosynthetic apparatus [9, 12, 18].

Today, research is of interest that can integrate field measurements of the spectral properties of the winter wheat plants physiological state and laboratory studies of soil micro- and macroelements. This approach is useful for developing effective strategies for predicting the productivity of wheat based on the planning of agrotechnological measures [15].

The purpose of our study is to analyze the effect of various doses of mineral fertilizers and complex micronutrient fertilizers on the correlation between indicators characterizing the state of the pigment complex, nitrogen content and winter wheat productivity.

The work was carried out on the territory of the educational and experimental farm of the Stavropol State Agrarian University. The soil is leached chernozem with an average supply of organic matter (5.1–5.4%), N-NO_3(16–30 mg/kg), P_2O_5 and K_2O (respectively 20–25 mg/kg and 220–270 mg/kg), as well as mobile forms of manganese (16.1–17.0 mg/kg); low availability of zinc (0.5–0.6 mg/kg) and copper (0.12–0.18 mg/kg). The reaction of the soil solution is neutral (6.1–6.5 units).

The subject of our research was complex microfertilizers:

- Atlantica «Raikat Development» (manufactured in Spain) – liquid organomineral fertilizer (N – 6%, P_2O – 4.0%, K_2O– 3.0%, B – 0.03%, Fe – 0.1%, Zn – 0.01%, Cu – 0.01%, Mn – 0.02%);
- «All Inclusive» (manufactured in Russia) – a complex liquid fertilizer, which includes low molecular weight humic acid with active molecules in the chelate form (N – 6–9%, P_2O_5– 0.5%, K_2O– 2.0%, S – 2.0-2.5%, MgO – 1.6-2.0%, Na – 0.5-0.7%, B – 0.2%, CaO – 0.5–1.0%, Fe – 0.6–0.9%, Zn – 1.6–2.0%, Cu – 0.5–0.7%, Mn – 0.4–0.6%, Co – 0.01–0.025%, Ni – 0.08%, Li –0.01%, Ag – 0.003%);
- Wuxal «Microplant» (manufactured in Germany) – a highly concentrated suspension of microelements (N – 7.8%, K_2O– 15.7%, MgO – 4.7%, SO3 – 20.3%, B – 0.5%, in chelate form: Cu – 0.8%, Fe – 1.6%, Mn – 2.4%, Zn – 1.6%, Mo – 0.01%);
- Polidon «Complex» (manufactured in Russia) – liquid microelement fertilizer (N, P_2O_5, Fe – 4.5%, Mn – 2.5%, Cu – 1.5%, Zn – 1.5%, B – 0.5%, Mo – 0.5%, Co – 0.05%).

MATERIALS AND METHODS

The meteorological conditions of the experimental zone are characterized by moderate moisture, but uneven precipitation throughout the year. According to long-term data, the average annual precipitation is 551 mm, the sum of active temperatures is 3,000–3,200 °C.

Microfertilizers were applied in the tillering phases and the beginning of stem elongation at a dose of 1 l/ha on various agricultural backgrounds:

- control (without fertilizers);
- recommended dose of mineral fertilizers (proposed by scientists of the Stavropol State Agrarian University) –$N_{90}P_{60}$;
- estimated dose for the planned yield of 7.5 t/ha –$N_{186}P_{95}K_{45}$.

The object of research is winter wheat. The predecessor is peas.

Application of the recommended dose: when sowing ammophos 115 kg/ha ($N_{14}P_{60}$), feeding with ammonium nitrate at 109 kg/ha in the tillering phase N_{38} and stem elongationN_{38}.

The calculated dose of mineral fertilizers was applied 281 kg/ha of nitroammophoska ($N_{45}P_{45}K_{45}$) and 96 kg/ha of ammophos ($N_{11}P_{50}$) for the main tillage, fertilizing with ammonium nitrate at 186 kg/ha in the tillering phase (N_{65}), going to stem elongation (N_{65}).

To determine the pigment complex - chlorophyll a, chlorophyll b, carotenoids, and nitrogen in plants, a spectral analysis of the leaf surface was performed with a PolyPen RP 410 NIR spectroradiometer, calculating data on: chlorophyll a [1]; chlorophyll b [8]; nitrogen [13]; carotenoids [2].

The analysis of variance method was used to calculate the correlation coefficients. Statistical processing of the results was carried out using the program Statistics.

RESULTS AND DISCUSSIONS

The photosynthetic productivity of crops is of great importance in the crop formation. It depends on the state of the photosynthetic apparatus functioning throughout the entire period of plant development. The results of the research analysis indicate a very high correlation between chlorophyll a and chlorophyll b in all phases of plant development and mineral nutrition backgrounds (statistical significance 0.95%).

In the stem elongation stage, the correlation was in the range of 0.958–0.983, as shown in Table 1. The closest correlation between chlorophylls a and b was noted at the beginning of flowering (0.978–0.987). Therefore, this fact indicates the readiness of the plant for flowering. Carotenoids are present in chloroplasts, which allows us to consider them as participants in the photosynthesis process. There is an opinion that the content of carotenoids in leaves decreases during the plants flowering period [20].

Analysis of the correlation between the ratio of chlorophyll a / chlorophyll b and the content of carotenoids showed a weak correlation between the values of these indicators for all phases of crop development and agricultural backgrounds (Table 1).

Table 1. Correlation of chlorophyll a and chlorophyll b according to the experiment variants (average)

Soil preparation	**Phase correlation, r**	
	Stem elongation	Flowering
Control	0.964	0.978
Recommended	0.958	0.987
Calculated	0.983	0.986

Source: Developed by the authors.

In the stem elongation stage, the coefficient was 0.103–0.404; in the flowering phase, 0.280–0.351.

There was a tendency to decrease the strength of the correlation between the values of the indicators to the flowering phase for all options, with the exception of the recommended dose, where the strength of the correlation varies from weak to moderate.

Moreover, in the stem elongation stage, the lowest bond strength was observed according to $N_{90}P_{60}$ (0.103), and in the flowering phase, according to the calculated one (0.280) (Table 2).

Table 2. Correlation of chlorophyll a/chlorophyll b indices and carotenoids by experiment variants (average)

Soil preparation	**Phase correlation, r**	
	Stem elongation	Flowering
Control	0.404	0.351
Recommended	0.103	0.327
Calculated	0.357	0.280

Source: Developed by the authors.

Perhaps the weak dependence is due to the carotenoids instability as a result of their isoprenoid structure, which implies a variable number of conjugated double bonds. Carotenoids are metabolites of isoprenoids synthesized de novo (synthesis of complex molecules from simple ones).

Against the background of the external environment, their concentration was determined by the agricultural background and the use of microfertilizers and had little effect on the change in plants processes (including photosynthesis).

Therefore, carotenoid derivatives act only as signaling molecules, they are regulators of plant growth and crop productivity. Such conclusions are confirmed in foreign studies [4, 20].

The application of nitrogen fertilizers causes an increase in the photosynthetic activity of plants, since numerous enzyme proteins are involved in this process [20].

Correlation analysis, reflected in Table 3, shows the ratio of chlorophyll a/chlorophyll b and nitrogen content (with a statistical significance of 0.95%) in the stem elongation phase and reflected a significant correlation at $N_{186}P_{95}K_{45}$, almost no correlation in the control and $N_{90}P_{90}$, and strong (0.733–0.799) in the flowering phase for all variants.

Table 3. Correlation between chlorophyll a/chlorophyll b and nitrogen indices by experiment variants (average)

Soil preparation	**Phase correlation, r**	
	Stem elongation	Flowering
Control	0.057	0.737
Recommended	0.164	0.733
Calculated	0.581	0.799

Source: Developed by the authors.

The use of all variants of microfertilizers with full control (without macrofertilizers) and the introduction of the recommended and calculated doses of macrofertilizers increased the tightness of the correlation between the pigment complex and nitrogen. The closest correlations between them in the control were noted after the introduction of the «All Inclusive» microfertilizer and, as shown in Table 4, between the accumulation of chlorophyll a and b in the stem elongation phase – 0.981, in the flowering phase – 0.994; the ratio of chlorophylls and carotenoids, 0.667 and 0.707, respectively; the ratio of chlorophylls and nitrogen is 0.512 and 0.832.

The strength of the correlation between the ratio of chlorophyll a/chlorophyll b and nitrogen, according to our research, proved the correlation of the "chlorophyll-yield" system, since the maximum yield of winter wheat in terms of agricultural backgrounds was achieved precisely in the variants of using micronutrient fertilizers, where the tightest correlation between the pigment complex and nitrogen was noted.

Table 4. Correlation of the pigment complex indices and nitrogen according to the experiment variants (average)

Stem preparation	Microfertilizers	Phase					
		Stem elongation			Flowering		
		PSSRa and PSSRb	PSSRa/ PSSRband CRI_{500}	PSSRa PSSRb and N_{550}	PSSRa and PSSRb	PSSRa/ PSSRb And CRI_{500}	PSSRa/ PSSRb and N_{550}
Control	Control	0.960	0.359	0.268	0.970	0.447	0.548
	Atlantica «Raikat Development»	0.963	0.496	0.356	0.978	0.568	0.781
	«All Inclusive»	0.981	0.667	0.512	0.994	0.707	0.832
	Wuxal «Microplant»	0.965	0,535	0.363	0.989	0.652	0.720
	Polidon «Complex»	0.961	0.495	0.349	0.977	0.454	0.640
Recommended	Control	0.929	0.127	0.526	0.982	0.106	0.595
	Atlantica «Raikat Development»	0.933	0.225	0.574	0.990	0.392	0.664
	«All Inclusive»	0.961	0.407	0.582	0.990	0.654	0.818
	Wuxal «Microplant»	0.979	0.413	0.851	0.990	0.692	0.866
	Polidon «Complex»	0.975	0.325	0.566	0.982	0.413	0.702
Calculated	Control	0.964	0.085	0.535	0.969	0.250	0.568
	Atlantica «Raikat Development»	0.985	0.187	0.565	0.991	0.430	0.766
	«All Inclusive»	0.990	0.379	0.787	0.995	0.874	0.863
	Wuxal «Microplant»	0.986	0.205	0.777	0.993	0.550	0.828
	Polidon «Complex»	0.974	0.151	0.565	0.988	0.322	0.696

Indices: PSSRa, chlorophyll a; PSSRb index, chlorophyll b; index CRI_{500} - carotenoids; index N_{550} - nitrogen.
Source: Developed by the authors.

In particular, in the control variant (without fertilizers), the maximum yield in the experiment (3.79 t/ha) was observed with the «All Inclusive» application, which is 0.7 t/ha higher than in the variant without microfertilizers, as reflected in Table 5.

On the background of the recommended dose of macrofertilizers, the greatest increase in the experiment was provided by the application of Wuxal «Microplant» – 1.44 t/ha, in comparison with the control.

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On the soil preparation with the calculated dose, the maximum yield, as well as the tightness of the correlation between the pigment complex and nitrogen, was noted with the application of «All Inclusive» – 7.74 t/ha (increase to the control 1.4 t/ha).

Table 5. Yield of winter wheat depending on the use of microfertilizers on different soil preparation, t/ha (average)

Dose of mineral fertilizers	Microfertilizers				
	Control	Atlantica «Raikat Development»	«All Inclusive»	Wuxal «Microplant»	Polidon «Complex»
Control	3.09±0.62	3.22±0.65	3.79±0.67	3.49±0.64	3.13±0.58
Recommended	4.95±0.35	5.49±0.20	6.35±0.14	6.39±0.47	5.84±0.09
Calculated	6.34±0.52	6.96±0.28	7.74±0.42	7.45±0.34	6.84±0.30

Source: Developed by the authors.

The largest average yield deviations were noted in the control (0.59–0.67 centner/ha), the smallest - when using the recommended dose (0.10–0.47 centner/ha) in combination with all types of microfertilizers.

Consequently, their use on the recommended agricultural background led not only to an increase in the productivity of the cultivated crop, but also to the stabilization of its yield.

In general, the analysis of the correlation between chlorophyll a/chlorophyll b, nitrogen and yield showed a medium and high degree of their interaction, as shown in Table 6.

Table 6. Correlation between the indices of the pigment complex, nitrogen and yield by experimental options (average)

Soil preparation	**Phase correlation, r**	
	Stem elongation	Flowering
Control	0.907	0.777
Recommended	0.653	0.972
Calculated	0.926	0.972

Source: Developed by the authors.

In the control, the correlation from very high to the flowering phase decreased to high, and on the recommended soil preparation, it increased from noticeable to very high.

CONCLUSIONS

Through our study, it became clear that on the leached chernozem in the zone of sufficient moisture in the control, the closest correlation between the pigment complex components (chlorophyll a and chlorophyll b), the ratio of chlorophylls and carotenoids, and between the ratio of chlorophyll a / chlorophyll b to nitrogen in the stem elongation and flowering phases achieved with the use of microfertilizer «All Inclusive»: respectively 0.981 and 0.994; 0.667 and 0.707; 0.512 and 0.832.

Against the background of $N_{90}P_{60}$, the strongest correlations were observed in the variant with microfertilizer Wuxal «Microplant»: 0.979 and 0.990, respectively; 0.413 and 0.692; 0.851 and 0.866, against the background of $N_{186}P_{95}K_{45}$ – «All inclusive»: 0.990 and 0.995; 0.379 and 0.874; 0.787 and 0.863.

The maximum yield of winter wheat in terms of soil preparation was achieved in the variants of using microfertilizers, where the tightest correlation between the pigment complex and nitrogen was noted: on a zero background when applying «All Inclusive»– 3.79 t/ha (increase to control 0.7 t/ha); against the background of the recommended dose when applying Wuxal «Microplant» – 6.39 t/ha (an increase of 1.44 t/ha); on the soil preparation with the estimated dose – «All inclusive» – 7.74 t/ha (increase to control 1.4 t/ha).

Our study showed that in experiments with microfertilizers «All Inclusive» and Wuxal «Microplant» yields are higher than in control, on average 1.2 times.

Through our research, it became clear that an integrated approach of field measurements of the spectral properties of the physiological state of winter wheat plants and laboratory studies of soil micro- and macroelements can be used to calculate the planned yield.

REFERENCES

[1]Blackburn, G.A., 1998, Spectral indices for estimating photosynthetic pigment concentrations: A test using senescent tree leaves. Int. J. Remote Sens., 19: 657-675.

[2]Carter, G.A., 1994, Ratios of leaf reflectances in narrow wavebands as indicators of plant stress. Int. J. Remote Sens., 15, 697-703.

[3]Dhami, N., Cazzonelli, C.I., 2020, Environmental impacts on carotenoid metabolism in leaves. Plant Growth Regul, Vol. 92. https:// link.springer.com/article/10.1007/s10725-020- 00661-w, Accessed on 10.03.2023.

[4]Diakite, S., Pagina, E., Zargar, M., Aldaibe, A.A.D., Denis, P., Gregory, L., Behzad A., 2022, Yield losses of cereal crops by Fusarium Link: A review on the perspective of biological control practices. Res. Crop, 23:418-436.

[5]Epstein, E., Bloom, A.J., 2005, Mineral Nutrition of Plants: Principles and Perspectives, 2nd ed. Sunderland, MA: Sinauer.

[6]Erenstein, O., Jaleta, M., Mottaleb, K.A., Sonder, K., Donovan J., Braun H.J., 2022, Global trends in wheat production, consumption and trade. In Wheat Improvement; Reynolds, M.P., Braun, H.J., Eds.; Springer: Cham, Switzerland.

[7]Fakharzadeh, S., Hafizi, M., Baghae, M.A., Etesami, M., Khayamzadeh, M., Kalanaky, S., Akbar, M.E., Nazaran, M.H., 2020, Using nanochelating technology for biofortification and yield increase in rice. Sci. Rep., 10:4351.

[8]Gitelson, A.A., Keydan, G.P., Merzlyak, M.N., 2006, Three-band model for noninvasive estimation of chlorophyll, carotenoids, and anthocyanin contents in higher plant leaves. Geophys. Res. Lett. 2006, 33:L11402.

[9]Gu, J., Yin, X., Stomph, T.J., et al., 2014, Can exploiting natural genetic variation in leaf photosynthesis contribute to increasing rice productivity? A simulation analysis. Plant Cell Environ. 2014. Vol. 37(1), 22-34. doi: 10.1111/ pce.12173.

[10]Gureev, I., 2021, The use of micronutrient fertilizers in the cultivation of winter wheat. In BIO Web of Conferences; EDP Sciences: Les Ulis, France; Vol. 32.

[11]Hashimoto, H., Uragami, C., Cogdell, R.J., 2016, Carotenoids and Photosynthesis. Subcellular Biochemistry. Vol. 79:111-139. doi: 10.1007/978-3-319-39126-7_4.

[12]Long, S. P., Marshall-Colon, A., Zhu, X.G., 2015, Meeting the global food demand of the future by engineering crop photosynthesis and yield potential. Cell. Vol. 161. No. 1:56-66. doi: 10.1016/j.cell.2015.03.019.

[13]López-López, M., Calderón, R., González-Dugo, V., Zarco-Tejada, P.J., Fereres E., 2016, Early detection and quantification of almond red leaf blotch using high-resolution hyperspectral and thermal imagery. Remote Sens. 2016, 8, 276; doi:10.3390/rs8040276.

[14]Miner, G.L., Delgado, J.A., Ippolito, J.A., Johnson, J.J., Kluth, D.L., Stewart, C.E., 2022, Wheat grain micronutrients and relationships with yield and protein in the U.S. Central Great Plains. Field Crops Res., 279, 108453.

[15]Parry, M. A. J., Hawkesford, M. J., 2012, An integrated approach to crop genetic improvement. J. Integr. Plant Biol. Vol. 54*(4), 2*50-259. doi: 10.1111/j.1744- 7909.2012.01109.

[16]Pennazio, S.,2005, Mineral nutrition of plants: a short history of plant physiology. Riv Biol. 98(2):215-236. PMID: 16180194.

[17]Pennazio, S., 2017, Photosynthesis: From De Saussure To Liebig. Theor Biol Forum. 110(1-2):95-113. doi: 10.19272/201711402006. PMID: 29687833.

[18]Ping, L. I., Pute, W. U., Chen, J., 2012, Evaluation of flag leaf chlorophyll content index in 30 spring wheat genotypes under three irrigation regimes. Austr. J. Crop Sci. Vol. 6(6), 1123-1130.

[19]Saquee, F.S., Diakite, S., Kavhiza, N.J., Pakina, E., Zargar, M., 2023, The efficacy of micronutrient fertilizers on the yield formulation and quality of wheat grains. Agronomy, 13, 566. https://doi.org/10.3390/agronomy13020566.

[20]Sun, T., Li, L., 2020, Toward the ‘golden’ era: The status in uncovering the regulatory control of carotenoid accumulation in plants. Plant Sci, 290. https://pubmed.ncbi.nlm.nih.gov/31779888/Accessed on 13.02.2023.

[21]Venkatesh, U., Sharma, A., Ananthan, V.A., Subbiah, P., Durga, R., 2021, CSIR Summer Research training team. Micronutrient’s deficiency in India: A systematic review and meta-analysis. J. Nutr. Sci., 10, e110.

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ASSESSMENT OF THE LIVELIHOODS OF THE RURAL VULNERABLE GROUP IN NIGERIA

Abraham FALOLA[1*], Ridwan MUKAILA[2], Grace Oluwakemi NAFIU[1*], Adetunji Sanjo OLANREWAJU[1], Sheu-Usman Oladipo AKANBI[1*], Angela Ebere OBETTA[2], Angela Chidimma IGWEH[2]**

[1]University of Ilorin, *Department of Agricultural Economics and Farm Management, **Department of Sociology, Ilorin, Kwara State Nigeria, E-mails: falola.a@unilorin.edu.ng, akanbi.so@unilorin.edu.ng, olanrewaju.as@unilorin.edu.ng
[2]University of Nigeria, Department of Agricultural Economics, Nsukka, Enugu State, Nigeria, E-mails: ridwan.mukaila@unn.edu.ng, angela.obetta@unn.edu.ng, angela.igweh@unn.edu.ng

Corresponding author: ridwan.mukaila@unn.edu.ng

Abstract

The vulnerable group is susceptible to various economic and social challenges. Understanding their livelihood is a prerequisite to addressing these menaces. Therefore, this study assessed the livelihoods of the vulnerable group and the factors responsible for their diversification in rural southwest Nigeria. Data collected were analysed using descriptive statistics, principal component analysis, the Simpson index, and the Tobit regression model. Results revealed that food crop production, cash crop production, livestock and fishing, forest and forest products, artisanship, remittances, wages and salaries from non-agriculture, and trading were the different means of livelihood among the rural vulnerable group. All the vulnerable groups derived income from farming. Cash crops, food crops, and livestock and fishing contributed 26.1%, 22.7% and 17.9% to household income, respectively. Thus, agriculture contributed the most (66.7%) to their total household income.This is followed by wages and salaries from non-agriculture (12.1%), trading (9.3%), artisanship (8.1%), remittance (2.2%) and forest and forest products (2.0%). The vulnerable group had a low level of livelihood diversification. Educational level, farming experience, total income, access to credit, age, and distance to the market were responsible for their level of livelihood diversification. This calls for government and non-governmental intervention to support the vulnerable group by providing financial assistance (credit or grants), farming inputs, and education to improve their livelihood and enhance their livelihood diversification.

Key words: *diversification, income, livelihood strategies, rural households, vulnerable people*

INTRODUCTION

The majority of residents of developing countries live in rural areas and rely on agricultural activities for a living [30, 32, 36,39]. Rural areas contribute significantly to national development through their various economic roles such as food supply, labour, market, and raw materials [13, 20]. Despite these contributions, rural areas are typically defined by agrarian activities, strong social cohesion and control, low living standards, a lack of amenities such as clean water, electricity, quality food, good health services, adequate transportation and road network, and industries, among other things [1, 29, 38]. They are also confronted with some constraints, including institutional constraints, marketing constraints, environmental constraints, inadequate infrastructure, and technological constraints. These constraints impede rural productivity and make it increasingly difficult to secure adequate livelihoods for rural populations in developing countries such as Nigeria.

Livelihood is defined as the various resources people combine and activities they undertake to secure a means of living [1, 9]. Sustainably generated income is required for economic sustainability and development [26,35]. The sustainability of livelihood is highly dependent on its capacity to satisfy the immediate needs of people without threatening its ability to satisfy future needs. That is, a sustainable livelihood should be highly resilient and adaptable to current and future shocks without jeopardizing the natural resource base [12, 19, 25]. Achieving a sustainable rural livelihood is an important component in which human development and economic growth are deeply rooted.

Certain groups, particularly in rural society, are vulnerable and face a greater risk of achieving a sustainable livelihood, and their development needs are frequently overlooked as a result of their exclusion from decision-making processes. People who are vulnerable are those who are easily frightened by shocks. For example, they include widows, physically challenged women, the elderly, poor people, children, the homeless, smallholders, and people living with chronic health conditions [15].

For most rural communities in developing countries such as Nigeria, the main source of income is farming, which is supplemented by other activities such as weaving, arts and crafts, pottery, and petty trading [19,28]. Agriculture's reliance on weather variations causes fluctuations in income and food accessibility [1, 33]. These fluctuations destabilize the rural dwellers and increase their poverty level, which further increases their vulnerability level. An increase in income and their sources will reduce poverty, increase their access to basic needs, and consequently enhance their well-being [27]. As a result, rural households, particularly vulnerable groups, must diversify their sources of income.

Livelihood diversification is an important pathway to boost income, reduce environmental risk, and consequently reduce poverty, especially among smallholders [4, 5, 17, 23]. It is also needed for rural growth, shifting from farm to non-farm activities, and household risk management mechanisms [24]. It is thus pertinent to assess the livelihood of the vulnerable group in rural societies.

Available studies on rural livelihoods concentrated on general rural households [2, 3, 8, 17, 18, 19, 22, 24, 28, 31, 34, 40]. Thus, the present study aims to fill the gap and add to the existing knowledge on rural livelihood. Based on the foregoing, the study's objectives are to identify the rural vulnerable group's various levels of access to livelihood assets; identify the rural vulnerable group's various livelihood strategies and their contribution to income; examine the choices of their livelihood strategies; determine the vulnerable group's level of livelihood diversification; and identify the determinants of the vulnerable group's livelihood diversification strategies. The results of this study would thereby assist in formulating policy-based recommendations that would reduce poverty and improve the welfare of these vulnerable rural dwellers. This would further increase their resilience and ability to withstand shocks. It will also help to understand the livelihood strategies used by these vulnerable groups and look for ways to improve them.

MATERIALS AND METHODS

Study area

The study area is Osun State, located in southwestern Nigeria. The state is divided into three agricultural zones: Iwo, Ife, Ijesha, and Osogbo, each with its zonal headquarters in Iwo, Ilesha, and Osogbo, respectively. It has a landmass of 14,875 km^2. Agriculture is of great importance in the state, as most of its population is engaged in farming, especially rural people. Annual crops in the region include maize, yam, cassava, banana, okra, and cowpea, among others, and recently watermelon and cucumber. Tree crops include oil palm, citrus, kola nuts, and cocoa. Livestock production activities mainly involve the keeping of animals like cattle, sheep, goats, poultry, snails, and pigs.

Sampling technique and data collection

The vulnerable group in the rural area makes up the population for the study and were selected using a two-stage sampling technique. Three blocks were purposively selected from each of the three agricultural zones based on the concentration of the vulnerable group in the first stage. Iwo, Ola-Oluwa, and Isokan were selected from the Iwo Zone; Osogbo, Odo Otin, and Ede North were selected from the Osogbo Zone; Ife-North, Oriade, and Atakunmonsa West were selected from the Ife-Ijesha Zone. A random selection of 20 members from each block of the three zones was carried out in the second stage. This made up a total of 180 respondents in all. Table 1 presents the summary of the sample design.

Data were collected using structured questionnaires and scheduled interviews.

Table 1. Summary of sample design

Zone	Block	Freq.	Percent
Iwo	Iwo	20	11.11
	Ola-Oluwa	20	11.11
	Isokan	20	11.11
Osogbo	Osogbo	20	11.11
	Odo-Otin	20	11.11
	Ede north	20	11.11
Ife-Ijesha	Ife north	20	11.11
	Oriade	20	11.11
	Atakunmonsa West	20	11.11
Total		180	100

Source: Authors' computation.

Methods of data analysis

Descriptive statistics, the Simpson diversification index, Tobit regression, and the Likert scale were used to analyse the data. Descriptive statistical tools were used to describe the socioeconomic characteristics and to assess the level of access to the livelihood asset.

Principal component analysis (PCA)

The PCA is a dimension-reduction tool used to reduce a large variable set to a small variable set that retains the same information as the large set. It identifies patterns in data and expresses the data in a way to highlights their similarities and differences [21, 40]. The PCA was used to identify the major livelihood strategies adopted by the vulnerable group.

Simpson diversification index (SDI)

The SDI was used to analyse the livelihood diversification of the vulnerable group. This used eight (8) total income sources: food crops, cash crops, wages and salaries from non-agriculture, remittances, forest products, fisheries and livestock, artisanship, and trading.

Simpson index =1- $\sum_{i=1}^{n} Pj^2$....................(1)

where:= total number of income sources and Pj = percentage of j-th income source.

Both the number of income sources and the distribution of income among various sources affect the SDI.The SDI has a range of 0 to 1.An SDI of less than 0.01 indicates no diversification of sources of income, 0.01 to 0.25 indicates a low level of diversification, 0.26 to 0.50 indicates a medium level of diversification, 0.51-0.75 indicates a high level of diversification, and more than 0.75 indicates a very high level of diversification[6].

Tobit regression

The factors influencing livelihood diversification by the vulnerable group were investigated using Tobit regression. The model was explicitly stated as:

$$y_i = \begin{cases} 0 \; if \; y_i^* \leq 0, \\ y^* \; if \; y_i^* > 0. \end{cases}$$

....(2)

where:

y_i is the observed variable (livelihood diversification index), and y_i^* is the latent variable explained by:

$$y_i^* = \beta_0 + \beta_1 G + \beta_2 Ag + \beta_3 HS + \beta_4 Ed + \beta_5 MS + \beta_6 FE + \beta_7 TI + \beta_8 FS + \beta_9 C + \beta_{10} TFA + \beta_{11} DM + \mu$$

....(3)

where:

G = Gender (male = 1, female = 0), Ag = Age of the respondents in years, HS = Household size (number), Ed= Education (years spent in school), MS = Marital status (married = 1, otherwise = 0FE = Years of farming experience, TI= Total income per year in naira, FS= farm size in hectare, C = Amount of credit received in naira, TFA = Total farm asset in naira, DM = Distance to the market (km), β_0= Intercept, $\beta_1 - \beta_{11}$ = Coefficients to be estimated and μ = Error term.

RESULTS AND DISCUSSIONS

Socio-economic characteristics of the vulnerable group

Table 2 provides information about the socioeconomic features of the vulnerable group.Female domination among the vulnerable group is evident from the fact that the majority of respondents (65.6%) were female.Their average age of 52 years suggests that they are old, which could have an impact on their economic activity given the nature of their employment. A higher percentage of them (53.3%) had no formal education; indicating a high level of illiteracy among the vulnerable group. This could have a negative influence on their decision-making, productivity, and economic activities [7, 14, 16]. The majority of the respondents were married (62.2%), 23.9% were widowed, and 8.9% were divorced, while those who were single accounted for just 5% of the respondents. The vulnerable group had a larger household size of seven people. The analysis further shows that their mean farming experience was 23 years, which indicates that they are experienced farmers. The physically challenged made up a bigger share of the vulnerable category (39.5%), followed by the aged (23.9%), widowed (19.4%), the diseased (12.2%) (including those with leprosy and epilepsy), and the young (5%).Additionally, the bulk of them were women, and they were all small-scale farmers.

Table 2. Socio-economic characteristics of vulnerable group

Variable	Category	Frequency	Percentage	Mean
Gender	Male	62	34.4	
	Female	118	65.6	
Age	≤30	10	5.6	52
	31-40	39	21.7	
	41-50	38	21.1	
	50-60	48	26.7	
	>60	45	25.0	
Educational level	No formal education	96	53.3	
	Primary	51	28.3	
	Secondary	29	16.1	
	Tertiary	4	2.2	
Marital status	Single	9	5.0	
	Married	112	62.2	
	Widowed	43	23.9	
	Divorced	16	8.9	
Household size	≤5	48	26.7	7
	6-10	122	67.8	
	<10	10	5.6	
Farming experience (years)	≤10	48	26.7	
	11 – 20	42	23.3	23
	>20	90	50.0	
Nature of vulnerability	Aged	43	23.9	
	Widowed	35	19.4	
	Youth	9	5.0	
	Diseased	22	12.2	
	Physically challenged	71	39.4	

Source: Field Survey, 2022.

Household assets of the vulnerable group

Table 3 shows the distribution of the different types of assets among vulnerable groups. The distribution of the respondents based on their financial assets shows that a larger proportion of the respondents sourced capital through personal savings. This was followed by family and friends, cooperative societies, money lenders, grants from the government, and grants from NGOs. Furthermore, the majority do not have access to credit facilities.

This is an indication that the vulnerable group had low access to external funding (credit), which could further increase their susceptibility to poor livelihood and inhibit their livelihood diversification. In addition, 81.9% of those who received financial help obtained N50,000 (USD 112.40) or less from external sources, and only 18.1% obtained between N50,000 (USD 112.40) and N100,000 (USD 224.90). This indicates a low level of financial support given to the vulnerable group, which consequently indicates a low financial asset among them.

Table 3. Household assets of the respondents

Types	Variables	Category	Frequency	Percent
Financial asset	Source of capital	Self	108	60.0
		Loans from the money lender	11	6.1
		Family and friends	32	17.8
		Grants from government	8	4.4
		Grants from NGO	1	0.6
		Loan from cooperatives	20	11.1
	Access to credit	Yes	63	35.0
		No	117	65.0
	Amount obtained (₦)	≤50,000	59	81.9
		50,001-100,000	13	18.1
Physical asset	Farm size	0.1 - 1.0	116	64.4
		1.1 - 2.0	64	35.6
	Land ownership	Inheritance	119	66.1
		Rent	59	32.8
		Purchase	2	1.1
	Access to drinkable water supply	Not accessible	56	31.1
		Less accessible	49	27.2
		Moderately accessible	49	27.2
		Accessible	16	8.9
		Highly accessible	10	5.6
	Access to machinery	Yes	86	47.8
		No	94	52.2
	Expenses on inputs and implements	< 20,000	154	85.6
		20,001 – 40,000	24	13.3
		>40,000	2	1.2
Natural asset	Access to farmable land	very low	12	6.7
		moderately low	18	10.0
		Average	39	21.7
		moderately high	89	49.4
		very high	22	12.2
	Access to forest resources	Yes	101	56.1
		No	79	43.8
Social asset	Membership in a cooperative	Yes	68	37.8
		No	112	62.2
	Contacts with extension agents	Yes	30	16.7
		No	150	83.3
	Source of information	Extension agents	29	16.1
		Co-farmers	54	30
		Television	16	8.8
		Radio	81	45
	Access to market information	Yes	170	94.4
		No	10	5.6
	Agricultural training	Yes	147	81.7
		No	33	18.3
Human asset	Type of labour use	Family labour	141	78.3
		Hired labour	12	6.7
		Both	27	15

Source: Field Survey, 2022.

The results based on the respondent's physical assets show that the majority (64.4%) had a farm size of 0.1 to 2 hectares, and 35.6% had a farm size of 1.1 to 2 hectares. Their average farm size was 0.96 hectares, which indicates that the vulnerable group were smallholder farmers. The largest proportion (66.1%) of the respondents got land ownership through inheritance, 32.8% through rent, and only 1.1% through purchase. Regarding portable water access, 31.1% and 27.2% had no access or less access to a drinkable water supply, respectively. This indicates that the lack of a portable water supply is a serious threat to the vulnerable group. The result further shows that the majority (52.2%) of them did not have access to farm machinery. The majority (85.6%) spent less than N20,000 on farm inputs per season, 13.3% spent between N20,000 (USD 44.96) and N40,000 (USD 89.92), and only 1.2% spent above N40,000 (USD 89.92).

The result based on their natural assets shows that 49.4% had moderately high access to farmable land, 21.7% had average access to farmable land, and 12.2% had very high access to farmable land. However, 10% and 6.7% had very low and moderately low access to farmable land, respectively. The results further show that 56.1% had access to forest resources, while 43.9% did not.

The result from the distribution of respondents based on their social assets shows that the majority (62.2%) were not members of a cooperative society, while only 37.8% were members of an association. Access to extension services was very low among the vulnerable group, as only 16.7% had contact with extension agents. Furthermore, a larger proportion (45%) of the respondents sourced for information through radio, 30% sourced for information through co-farmers, 16.1% sourced for information through extension agents, and 8.8% sourced for information through television. Regarding access to market information, the majority (94.4%) had access to market information, and a larger percentage (81.7%) did not receive formal training in agriculture.

The distribution of respondents based on their human assets shows that the majority (78.3%) used family labour, 15% used both families and hired labour, and just 6.7% used hired labour in their agricultural activities. This implies that the vulnerable rural group had human assets used as family labour for their farming activities. This is a result of their large family size.

Livelihoods activities engaged in by the vulnerable group and their contribution to income

The result in Table 4 shows that all the vulnerable group derived income from farming, which contributed the most (66.7%) to total household income. Crop production, which is by far the single largest source of income, provides 48.8% of total income. Thus, agriculture is the major means of livelihood and source of income among the vulnerable group. This supports the finding of [15] that vulnerable groups are mostly engaged in farming activities as their means of livelihood. About 19.6% of the total household's income comes from off-farm sources. The main components of these off-farm sources are selling agricultural and non-agricultural items, remittances, handicrafts, and local services. About 12.1 percent of total income is derived from non-agricultural wages and salary activities.Manufacturing, construction, administration, and other services provided non-agricultural wages.

Table 4. Livelihoods activities engaged in by the vulnerable members and their contribution to income

Diversification	Household income	Percentage of total income
Food crop	55,488.88	22.7
Cash crop	63,597.76	26.1
Livestock and fishing	43,679.78	17.9
Total on-farm income	162,766.4	66.7
Forest and forest product	4,855.56	2.0
Artisanship	19,854.74	8.1
Remittance	5,474.86	2.2
Wages and salaries from non-agriculture	29,519.66	12.1
Trading	22,765.36	9.3
Total income in naira	243,966.8	

Source: Field Survey, 2022.

Additionally, 9.3%, 8.1%, 2.2%, and 2% of the total income within the vulnerable category came from trading, artisanship, remittances, and forest and forest products, respectively.

Choices of the livelihood strategies among the vulnerable group

The result in Table 5 shows that PCA extracted five principal component factors with eigenvalues greater than 1. Component 1 from the table includes salaries and wages from non-agricultural activities, which are negative, and artisanship, which is positive. Therefore, the first extracted component from PCA for this study is artisanship and wages and salaries from non-agricultural activities. This suggests that households involved in artisanship like carpentry, shoemaking, fashion designing, barbing, and black smiting are less likely to engage in non-agricultural activities like teaching, corporate jobs, and clerk jobs. This could be a result of the time factor, as those engaged in artisanship may not have time for wages and salary work.

Component 2 consists of negative livestock and fisheries as a livelihood strategy, positive cash crops as a strategy, and positive food crop production as a livelihood strategy employed by the respondent. This implies that households that were involved in cash crop production (like cocoa, cashew, palm, mango, etc.) and food crop production (like cassava, maize, yam, vegetables, etc.) were likely not to be involved in livestock and fishing as means of livelihood.

The third component includes highly positive remittance income and lowly positive food crop production. This suggests that households that survive on remittance income may be involved in small food crop production to complement the remittance income. Some members of an elderly, vulnerable group embarked on small-scale food crop production to supplement the income received from remittances from their family members.

Component 4 is made up of three livelihood strategies: negative wages and salaries from non-agriculture, negative artisanship, and positive trading. This suggests that those households that were into trading as their major source of livelihood were likely to be less or not involved in wages and salaries from non-agriculture and artisanship. This could be because of the time required for trading in rural areas, which does not leave time for salary work in the non-agricultural sector.

The fifth component is made up of negative wages and salaries from non-agriculture, negative artisanship, positive cash crops, and positive forest and forestry. This implies that households earning income from cash crops and forest products were less or not likely to be involved in non-agricultural jobs and artisanship-based income.

Table 5. Choices of the Livelihood Strategies among the Vulnerable Group

	Component				
	1	2	3	4	5
Wages and salaries from non-agriculture	-.802			-.285	-.338
Artisanship	.791			-.350	-.270
Livestock and fishing		-.766			
Cash crop		.742			.353
Remittance			.809		
Food crop		.275	.675		
Trading				.963	
Forest and forest product					.858

Source: Field survey, 2022.

Livelihood diversification level by the vulnerable group

Table 6 shows the degree of the vulnerable group's diversification of sources of income. Almost all of them (98.9%) diversified their livelihoods and, thus, received income from multiple sources. However, the majority (75.6%) had a low level of income diversification. This was followed by a medium level (16.7%), a high level (6.7%)

and zero level (1.1%) of livelihood diversification among the vulnerable group. These results imply that the majority of the vulnerable group diversified their livelihoods at a low level. This supports [28], who found a low level of income diversification among rural households. Thus, there is still room for the vulnerable group to increase their level of livelihood diversity by engaging in several more income-generating activities. For instance, they can combine food crops, cash crops, livestock and fishing, artisanship, and forest and forest products to increase their level of livelihood diversification.

Table 6. Livelihood diversification Index

Level	Livelihood diversification index	Frequency	Percentage
No	<0.01	2	1.1
Low	0.01 - 0.25	136	75.6
Medium	0.26 - 0.50	30	16.7
High	0.51 - 0.75	12	6.7
	Total	180	100

Source: Field survey, 2022.

Driving factors of the extent of livelihood diversification

Table 7 shows the factors influencing the level of livelihood diversification among the vulnerable group. The regression result shows that educational level, farming experience, total income, and credit were the positive and significant factors contributing to livelihood diversification, while age and distance to the market were negatively significant.

Age was negatively related to involvement in numerous livelihood activities (P<0.05). This suggests that as their age increases, their level of livelihood diversification reduces. This is becausethe human strength needed to engage in several income activities reduces as age increases. This is in line with the finding of [22]who reported that farmers' level of income sources reduced as their age increased.

Education was positively related to vulnerable group livelihood diversification (P<0.01). This indicates a strong relationship with the livelihood diversification drive. This implies that vulnerable groups with higher education are more likely to seek more sources of income generation than those with less education. This is similar to [10], [11], and [18], who found that education positively influenced livelihood diversification.

Farming experience also influenced vulnerable groups' livelihood diversification (P<0.01). This implies that as the farm experience of the vulnerable group increases, it leads to an increase in the diversification of their livelihoods. This may be more important, especially for those who are mainly engaged in agricultural-related activities among them.

Household income was positively related to livelihood diversification (P<0.05). This implies that the vulnerable group with the higher income is much more likely to engage in other sources of income, most likely due to the abundance of capital for business ventures. As a result, vulnerable groups with higher incomes diversified into more livelihoods than their counterparts. [4] and [37] also reported that income enhanced livelihood diversification.

Furthermore, the credit had a positive influence on the vulnerable group's level of livelihood diversification (P<0.05). This implies that the vulnerable group having more access to credit is more likely to diversify their livelihood sources. This could be because credit provides the needed capital for people to invest in both farm and non-farm activities, which consequently boosts their income. This supports [6], [10], and [37], who reported that credit enhances livelihood diversification.

In addition, distance to the market negatively influenced the livelihood diversification of vulnerable groups (P<0.1). This indicates that the vulnerable groups that live farther away from the market are less likely to diversify their income sources. This could be because travelling a long distance to the market lowers their likelihood of seeking non-farm employment.

Table 7. Factors affecting the extent of livelihood diversification

Variables	Coefficient	Standard error	T value	p>t
Gender	0.0005	0.0211	0.02	0.980
Age	-0.0022**	0.0011	-2.00	0.047
Household size	0.0024	0.0041	0.58	0.564
Education	0.0079***	0.0021	3.99	0.000
Marital status	0.0228	0.0149	1.54	0.127
Farming experience	0.0031***	0.0009	3.20	0.002
Total income	3.97e-07**	1.55e-07	2.56	0.011
Farm size	-0.0051	0.0055	-0.92	0.361
Credit	1.98 e-07**	1.01e-07	2.06	0.039
Total farm asset	-5.21 e-07	5.90e-07	-0.88	0.379
Distance to market	-0.0041*	0.0022	-1.89	0.061
Constant	0.1272	0.0561	2.27	0.024
Sigma	0.1023	0.0072		
LR chi^2 (11)	47.59			
Prob > chi2	0.0000			
Log-likelihood	127.47036			
Pseudo R^2	0.2295			

***, **, * significant at 1%, 5% and 10%, respectively
Source: Field Survey, 2022.

CONCLUSIONS

This study assesses the livelihood diversification strategies of rural vulnerable groups. The study shows that the vulnerable group derived income from farming, where crop production is the single largest source of income. It can therefore be concluded that crop production is a major strategy employed by the vulnerable rural group.The vulnerable group’s level of livelihood diversification is low. However,few of them have a medium and a high level of livelihood diversification. The major factors that determine their level of livelihood diversification are the amount of credit received, age, educational level, total income, farm experience, and distance to market. This study recommends the following to improve the livelihood of rural vulnerable groups. Formal and informal financial institutions, including governmental and non-governmental organizations as well as donor agencies, should give credit facilities to the rural vulnerable group to improve their livelihood. This can be done by linking farmers to credit through reduced interest rates. Extensive awareness of the importance of formal education should be made to enhance vulnerable groups' level of livelihood diversification. The government should help subsidize agrochemicals, farm inputs, and farm machinery, which should be made readily available to farmers at a very affordable price. In addition, people should be educated on how to relate to vulnerable groups, especially the diseased and physically challenged. The vulnerable group should not be deprived of their basic human rights and other amenities.

REFERENCES

[1]Aderinoye-Abdulwahab, S.A., Nwachukwu, S.C., Salawu, O.L., Poopola, P.O., 2015, Assessment of livelihood activities of rural farmers in Kwara State, Nigeria. Ethiopian Journal of Environmental Studies & Management, 8(2), 120 – 129. http://dx.doi.org/10.4314/ejesm.v8i2.2
[2]Adeomi, D.T., Fadoju, D.T., Oseni, R.O., Ogunya, L., 2022, Socioeconomic factors influencing livelihood diversification among rural farming households in Southwest Nigeria: A fractional response model approach. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(4), 21-30.
[3]Adeyemo, T.A., Oni, O.A., 2013, A functioning approach to well-being analysis in rural Nigeria. Sustainable Agriculture Research, 2(1), 149-163. http://dx.doi.org/10.5539/sar.v2n1p149
[4]Admasu, T.T., Damtie, Y.A., Taye, M.A., 2022, Determinants of Livelihood Diversification among Households in the Sub-Saharan Town of Merawi, Ethiopia. Advances in Agriculture, 2022, 6600178, 1-9. https://doi.org/10.1155/2022/6600178

[5]Agarwalla, S., Saha, D., 2022, Livelihood Diversification of Forest Dwellers – A Necessity or Choice? Journal of Asian and African Studies, 57(3), 543–558. https://doi.org/10.1177/00219096211024676
[6]Ahmed, M., Bhandari, H., Gordoncillo, P., Quicoy, C., Carnaje, G., 2018, Factors affecting extent of rural livelihood diversification in selected areas of Bangladesh. *SAARC* Journal of Agriculture, 16(1), 7–21. https://doi.org/10.3329/sja.v16i1.37419
[7]Akanbi, S.O., Mukaila, R., Adebisi, A., 2022, Analysis of rice production and the impacts of the usage of certified seeds on yield and income in Cote d'Ivoire. Journal of Agribusiness in Developing and Emerging Economies,https://doi.org/10.1108/JADEE-04-2022-0066
[8]Akintunde, O., Ajayi, F., Bamiwuye, O., Olanrewaju, K., 2022, Factors influencing livelihood diversification among farming households in Ejigbo Local Governemnt Area of Osun State, Nigeria. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(3), 15-22.
[9]Amurtiya, M., Tashikalma, A.K., Kolawole, A.A., Akintunde, M.O., 2021, Rural livelihood improvement: An assessment of household strategies and activities in Adamawa State, Nigeria. The Journal of Rural and Community Development, 16(1), 1–22.
[10]Asmah, E.E., 2011, Rural livelihood diversification and agricultural household welfare in Ghana. Journal of Development and Agricultural Economics, 3(7), 325–334.
[11]Babatunde, R.O., Qaim, M., 2009, Patterns of income diversification in rural Nigeria: Determinants and impacts. Quarterly Journal of International Agriculture, 48(4), 305- 320.
[12]Carney, D. 1998, Sustainable rural livelihoods: what contribution can we make? Conference proceedings of the International Development's National Resources advisers' conference, July 1998, pp.428.
[13]Falola, A., Mukaila, R., 2022, Organic maize farming practices in Nigeria: Drivers and barriers.Mediterranean Agricultural Sciences, 35(3), 147-154.
https://doi.org/10.29136/mediterranean.1086107
[14]Falola, A., Mukaila, R., Mahmud, M.M., 2022, Are small-scale organic maize farmers technically efficient? evidence from Nigeria. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(4), 217-224. https://managementjournal.usamv.ro/pdf/vol.22_4/Art24.pdf
[15]Falola, A., Mukaila, R., Adetipe, A.E., 2023, Food Insecurity and Dietary Diversity of the Vulnerable Group in Nigeria: Drivers and Coping Strategies. KSÜ Journal of Agriculture and Nature, 26(1), 000-000. https://doi.org/10.18016/ksutarimdoga.vi.1102888
[16]Falola, A., Obalola, T.O., Mukaila, R., Abidoye, S.T., 2023, Comparative analysis of marketing of branded and unbranded local rice in Bida, Niger state, Nigeria. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 23(1), 203-210. https://managementjournal.usamv.ro/pdf/vol.23_1/Art25.pdf, Accessed on July 10, 2023.
[17]Guite, S., Sharma, H.I., Thoudam, L., 2022, Determinants of livelihood diversification among the Thadou-Kukis of Manipur, India. Economic Affairs, 67(01 Spl.), 79-86.
[18]Habib, N., Alauddin, M., Cramb, R., Rankin, P., 2022, A differential analysis for men and women's determinants of livelihood diversification in rural rain-fed region of Pakistan: An ordered logit model (OLOGIT) approach. Social Sciences & Humanities Open, *5*, 100257.https://doi.org/10.1016/j.ssaho.2022.100257
[19]Ifeanyi-Obi, C.C., Njoku, M.E.C., 2014, Socio-economic factors affecting choice of livelihood activities among rural dwellers in southeast Nigeria. *IOSR* Journal of Agriculture and Veterinary Science, 7(4), 52-56.
[20]Israr, M., Yaseen, A., Ahmad, S., 2017, Land degradation a threat to sustainable rural development in northern highlands of Pakistan. Proceeding of International Conference on Rural Development Conference 2017 9-11 July 2017 Bangkok Thailand. Pp. 124-136.
[21]Jolliffe, I.T., 2002, Principal Component Analysis, 2nd Ed. Springer: New York.
[22]Lemi, A., 2006, The Dynamics of Income Diversification in Ethiopia: Evidence from Panel data. Economics Faculty Publication Series. Paper 10. http://scholarworks.umb.edu/econ_faculty_pubs/10, Accessed on July 10, 2023.
[23]Loison, S.A., 2015, Rural livelihood diversification in Sub-Saharan Africa: A literature review. The Journal of Development Studies 51(9): 1125–1138.
[24]Loison, S.A, 2019, Household livelihood diversification and gender: Panel evidence from rural Kenya. Journal of Rural Studies, 69, 156-172.
[25]Mengistu, N.A., 2022, Rural livelihood vulnerabilities, contributing factors and coping strategies in Takusa Woreda, North Western Ethiopia. Cogent Social Sciences, 8, 2095746. https://doi.org/10.1080/23311886.2022.2095746
[26]Mianis, A.M., Darwish, M.O., 2022, Sustainable rural livelihood challenges in Afghanistan's Ghazni province: using ATLAS.ti software.European Journal of Agricultural and Rural Education, 3(6), 1-9.
[27]Mukaila, R., Falola, A., Akanbi, S.O., 2021, Socioeconomic determinants of income among rural women in Enugu state, Nigeria: implication for achieving first sustainable development goal. Journal of Agribusiness and Rural Development, 4(62), 363–370.
[28]Mukaila, R., Falola, A., Egwue, L.O., 2021, Income diversification and drivers of rural smallholder farmers' income in Enugu State, Nigeria. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 21(3), 585-592.
[29]Mukaila, R., Falola, A., Akanbi, S.O., Aboaba, K.O., Obetta, A.E., 2022, Drivers of poverty among rural women in Nigeria: Implications for poverty

alleviation and rural development. The Journal of Rural and Community Development, 17(1), 32–48.
[30]Mukaila, R., Egwue, L.O., 2022, Analysis of rural income inequality in Nigeria: before and during democratic era. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(4), 443-452. https://managementjournal.usamv.ro/pdf/vol.22_4/Art49.pdf, Accessed on July 10, 2023.
[31]Oke, F.O., Akerele, D., 2022, Effect of income diversification strategies on smallholder cassava farmers' household food security in Southwest Nigeria. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(4), 477-486.
[32]Olomola, A.S., Nwafor, M., 2018,Nigeria agriculture sector performance review.A background report for the Nigeria 2017 agriculture joint sector review. Ibadan, Nigeria: International Institute of Tropical Agriculture (IITA).
[33]Omonona, B.T., 2009, Quantitative analysis of rural poverty in Nigeria, Nigeria Strategy Support Program (NSSP), NSSP Report 9, International Food Policy Research Institute, Washington DC.
[34]Oni, O.A., Adepoju T.A., 2011, A capability approach to the analysis of rural households' wellbeing in Nigeria. Munich Personal RePEc Archive (MPRA) Paper No. 34508.
[35]Pandey, R., Alatalo, J.M., Thapliyal, K., Chauhan, K., Archie, K.M., Gupta, A.K., Jha, S.K., Kumar, M., 2018, Climate change vulnerability in urban slum communities: investigating household adaptation and decision-making capacity in the Indian Himalaya. Ecol. Ind. 90, 379–391. https://doi.org/10.1016/j.ecolind.2018.03.031
[36]Sakiyo, D.C., Musa, A., Badgal, E.B., 2020, Impact of deforestation on some selected rural communities in Jada, Ganye and Toungo local government areas, Adamawa State Nigeria. International Journal of Agriculture and Forestry, 10(3), 63-70. https://doi.org/10.5923/j.ijaf.20201003.01
[37]Sallawu, H., Nmadu, J.N., Coker, A.A.A., Mohammed, U.S., 2022, Dynamic Relationship between Vulnerability to Climate Change, Livelihood Diversification, Perception on Climate Change and Income of the Farmers in North Central Nigeria. Asian Research Journal of Agriculture, 15(3). 1-8. https://doi.org/10.9734/ARJA/2022/v15i330156
[38]Sitko, N., Knowles M., Viberti, F., Bordi, D., 2022,Assessing the impacts of the COVID-19 pandemic on the livelihoods of rural people – A review of the evidence. Rome, FAO. https://doi.org/10.4060/cb7672en
[39]Udu, L.E., Onwe, S.O., 2016, Approaches to Community Development in Nigeria, Issues and Challenges: A Study of Ebonyi State Community and Social Development Agency (EB-CSDA) Journal of Sustainable Development, 9(1) 296-307.
[40]Yograj, G., Andersen, A., 2016, Rural livelihood diversification and household wellbeing: insights from Humla. NepalJournal of Rural Studies. 24, 239-249.

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USING INFRARED THERMOGRAPHY FOR DETAILED MONITORING OF CABBAGE WATER AND HEAT STRESS

Tarek FOUDA[1], Eltaher MADY[2], Nouri AL BAY[2], Ashraf SWIDAN[2], Shaimaa SALAH[1]

[1]Tanta University, Faculty of Agriculture, Agriculture Engineering Department, Egypt, Emails: tfouda628@gmail.com, Shimaa2010atia@yahoo.com
[2]Higher Institute of Agricultural Technologies in Al-Ghiran, Tripoli, Libya, E-mails: tahermady312@gmail.com, n.albay60@gmail.com, Swidanashraf349@gmail.com

Corresponding author: tfouda628@gmail.com

Abstract

The research was conducted on the farm of the agricultural research station, Agricultural Research Center, Tripoli, Libya (latitude of 32° 12` 25`` and longitude of 13° 62` 16``) during the season of 2021-2022. Cabbage and lettuce crops were planted at greenhouse condition in November 2021. The objective of this study was using alternate representations of infrared thermography IR to detect the vegetative indicators addition to continuously monitor cabbage and lettuce plants growing conditions for discrimination plants stresses under the shortage of nitrogen and irrigation water, using four levels of nitrogen fertilization (0, 50, 100 and 150% of Nitrogen recommended). Also four levels of water regime (50%, 75%, 100% and 125% of ETc) . The leaf-to-air temperature difference (ΔT), The relationship between the temperature of the canopy (Tc) and temperature of soil (Ts), pair is best suited to find the plant under water stress. Water stress index (CWSI) and stomatal conductance index (Ig) using various reference and non-reference thresholding techniques were tested. In this research a thermal imaging system was used to measure the leaf-temperature changes of several crops according to plant stresses. Results showed by applying 100% fertilization and 100% ETc to cabbage. The heat stress was the highest as MTD, maximum temperature difference, normalized relative canopy temperature were 8 and 0.32 C when the water stress as CWSI, IG index of stomatal conductance were 0.5 and 4.15 for cabbage in100% ETC and 150%F. Finally, possibility of using infrared thermography for detailed and continuous monitoring showed its ability to distinguish and show the thermal and water stress of plants under nitrogen and water deficiency.

Key words*: *cabbage, infrared, thermography, monitoring, heat, water, stress

INTRODUCTION

The United Nations estimated that by 2050 the world population is expected to reach 9.8 billion people. This leads to an increase in the demand for food, and the agricultural sector faces many obstacles, such as risky temperatures, soil degradation and expected drought. So agricultural practices are needed to ensure that high yields in 2020, world production of cabbages were 71 million tons, led by China with 48% of the world total [8].

The most productive agricultural lands in Libya are limited to a strip along the Mediterranean Sea, where most of the rain falls. Agriculture contributed about 2% to the gross domestic product of Libya in FAO 2011 These challenges can be addressed by integrating Libyan soil resources it will lead Using of the greenhouse is one of the fast solutions to meet the demand for vegetables in light of climate changes and the lack of arable land in Libya. The ideal conditions Plants need air, light, warmth, water and nutrients to be healthy. If a plant doesn't have one of these requirements it could affect its growth **[7].**

Climate change presents a major challenge for developing countries that lack adequate resources. Climate change will lead to severe weather events for Libya, affecting both the intensity and frequency of extreme temperature, precipitation, rainfall, and drought. The global mean temperature has increased gradually by 0.74 ± 0.18 ˚C during the 100 years from 1906 to 2005, and can be expected to reach an increase up to 1.5 to 2.0 ˚C by the year 2100 [6].

The Cruciferous vegetables included cabbage are considered to be excellent source of some bioactive phytochemicals such as glucosenolates, folate, myricetin, selenium, vitamins (A, B1, B2, B6, C, and E), minerals (Mn, Ca, K and Mg) and protein. All of these compounds are important in human diet in order to protect against cancer of prostate, lung and breast [15].

The quantity of water needed by plants and the timing of irrigation are managed by predominant climatic conditions, crop type and its growth stage, holding capacity of soil moisture and the intensity of root system as determined by crop variety, growth stage and soil type. Water deficit stress is considered one of the most critical abiotic stresses for cabbage productivity. Cabbage has been categorized as moderately susceptible to irrigation water deficit stress and it is more sensitive especially in the period of head formation, therefore insufficient available water limits the yield and quality of cabbage [14].

The plant stress is one of the most significant factors affecting plant fitness and, consequently, food production. However, plant stress may also be profitable since it behaves hormetically; at low doses, it stimulates positive traits in crops, such as the synthesis of specialized metabolites and additional stress tolerance. The controlled exposure of crops to low doses of stressors is therefore called hormesis management, and it is a promising method to increase crop productivity and quality. Nevertheless, hormesis management has severe limitations derived from the complexity of plant physiological responses to stress [19].

Plant monitoring data help characterize ecosystem responses to weather and climate, land plant changes, and abiotic stresses. the farmers and breeders aim to improve crop responses to abiotic stresses and secure yield under adverse environmental conditions [3]. To achieve this goal and select the most resilient genotypes, plant breeders and researchers rely on phenotyping to quantify crop responses to abiotic stress. Recent advances in imaging technologies allow researchers to collect physiological data non-destructively and throughout time, making it possible to dissect complex plant responses into quantifiable traits. The use of image-based technologies enables the quantification of crop responses to stress in both controlled environmental conditions and field trials [16].

Abiotic stresses such as temperature, insolation, drought, flooding, salinity, agricultural practices, and the use of machinery and other agricultural equipment. These are both physical and chemical factors. subtle changes in canopy temperature, which is a function of the temperatures of the leaves of a plant canopy, can be measured with a thermal imaging camera, also known as an infrared camera or infrared thermography, which forms a temperature image using emitted long wave radiation. For decades, satellite-based thermal imaging cameras have been extensively used to monitor vegetation and crop conditions on a regional scale, estimate energy fluxes and soil moisture, detect plant water stress, predict yield, and monitor regional drought. However, their usefulness in precision agriculture and small area phenotyping has been mixed due to the fact that their spatial resolution and the homogeneity of data with large pixels is typically not suitable for precision agriculture. cabbage is one of the vegetables that are most susceptible to heat, water and nitrogen stress.

Reducing stress on plants is one of the major tasks in maintaining crop quality and profitability [4].

These studies proposed that drip irrigation and fertilization can achieve higher water and fertilizer use efficiency and recommended improved water and fertilization management schemes for these crops compared with standard practices. But may also cause soil environmental deterioration. To improve the efficiency of water and fertilizer use and determine the appropriate amount of water and fertilizer for crop growth, some authors have studied winter wheat, potato, tomato, broccoli, onion and areca nut, among other crop species. Doing this sustainably is an even bigger challenge. So the continuous monitoring of plants stresses to make data informed assessments and more accurately provide direct support to their plants. Decoding the Language of Plants and

Vegetables to understanding our plants and vegetables is that it is easier to control crop yield quantities throughout the growing season [23].

Plant growth monitoring is an important aspect of precision agriculture implementation. The monitoring can be performed by estimating the volume by the result of Three-dimensional reconstruction by using Close-range Photogrammetry. For the validation purposes and its functionality for modelling and estimating volumetric objects, Chinese cabbage with four size variations at different ages was used (14, 21, 28, and 35 Days After Transplant). As the result, the developed system could observe and generate the plant in a three-dimensional manner resemble the actual plant model. Further improvements in accuracy need to be made for precise measurements as well as validation for other crop types. There are several options to monitor vegetables, one of them is by Infrared thermography is the process of using a thermal imager to detect radiation from an object. Infrared thermography is the process of using a thermal imager to detect radiation (heat) coming from an object, converting it to temperature and displaying an image of the temperature distribution [17].

Infrared thermal imaging is a non-destructive testing technology that can be used to determine the superficial temperature of objects. This technology has an increasing use in detecting diseases and distress in animal husbandry within the poultry, pig and dairy production. The process can identify changes in peripheral blood flow from the resulting changes in heat loss and; therefore, have been a useful tool for evaluating the presence of disease, edema, and stress in animals. also detect plants heat stress [20].

Optical sensors have been used to study (a) the response of plants to pathogens, pests and abiotic stressors; (b) to identify primary disease foci; (c) to monitor resistance or susceptibility of different plant genotypes to specific stress factors; (d) to evaluate the severity of symptoms; (e) and to assess plant biomass and yield. Stomatal activity is one of the most important physiological traits for plant growth and development. It plays a crucial role in the carbon and water balance by controlling photosynthesis and transpiration. Hence, stomatal conductance to water (gs) is related to yield and to the tolerance of environmental stresses and correlates strongly with leaf temperature [12].

Studied water and nitrogen productivity for cabbage under the shortage of nitrogen and irrigation water during growing cabbage (Saturn) plants. Mass production, nitrogen productivity, water productivity, chlorophyll A, chlorophyll B and total chlorophyll, respectively were test under using four levels of nitrogen fertilization (0, 50, 100 and 150% of Nitrogen recommended) and also four levels of water regime (50%, 75%, 100% and 125% of ETc) in Libya conditions. The optimum conditions in drip irrigation greenhouse for crops grow were provided to give us high yield, quality production for cabbage crops. Applying 100% N fertilization and 125% ETc to cabbage was the highest nitrogen productivity of 1,132.3 kg yield /kg N, water productivity 17.32 kg/m^3 and mass production of 17.57 Mg/ha. The highest value of chlorophyll A, chlorophyll B and total chlorophyll obtained with 100%N and 100% ETc applied water for cabbage were (0.505, 0.753 and 1.258 mg/100gm), respectively [11].

Radiation is a form of heat loss through infrared rays involving the transfer of heat from one object to another without physical contact. Skin emissivity is an important factor in determining the true skin temperature, and through the assessment of surface temperature, it is possible to acquired knowledge regarding physical and healthy status of humans and other living creatures [2].

Because numerous aspects might influence thermal imaging, it is vital to evaluate the likely impact of the measurement environment on the information to be collected from the picture when operating at a certain observation scale. Thermal imaging cameras, like conventional imaging cameras, are built with a lens that focuses infrared light onto a detector. The radiation that strikes a thermal camera originates from three sources. The camera picks up radiation Wobj from the target item as well as radiation Wamb from its surroundings, which has been reflected onto the object's surface [5].

Thermal long-wave infrared (TIR) cameras (or simply thermal cameras) are calibrated sensors able to record emitted radiation in the thermal images representing temperature values per pixel. Thus, conventional, timeconsuming ground-based measurements can be feasibly replaced by thermal images evaluating plant physiological status at different scales in short periods of time. Additionally, highly sensitive thermal cameras with a relatively simple operational procedure have become more available to research groups, at a lower cost and at higher spatial resolution [13].

In this study the main objectives of this research were the possibility of using infrared thermography for detailed and continuous monitoring of plant. Display the temperature difference, crop water stress and stomatal conductance index changes under greenhouse condition

MATERIALS AND METHODS

The study was conducted at agriculture greenhouse, Agricultural Research center, Tripoli, Libya (latitude of 32° 12` 25`` and longitude of 13° 62` 16``) during the winter season of 2021-2022. Cabbage plants were planted in November 2021. Different agricultural practices were performed as recommended. Plants monitoring data collecting to express about heat, water, and nitrogen stresses. Using a new technique application of digital and thermal imaging to detect plants heat stress

Cabbage and greenhouse, soil, and water, Phosphoric, Nitrogen fertilizer, Thermal camera with testo 865 and IR soft program, as a materials were used under this study.

Cabbage

The Cabbage seed was obtained from private company, Tripoli Governorate, Libya. Cabbage and lettuce nurseries were made for healthy seed growth. Coming from Jebal Atias Co. Street NO. 9, Ghout Alshaal, Tripoli, Lybia. Orgin USA standard seed from SAKATA with 94% Germination product date 9/2020 Cabbage, cultivars of *(Brassica Oleracea*), is a leafy green, as showed in Photo 1.

Photo 1. *Brassica Oleracea Capitate* – Cabbage .
Source: Original photo taken by authors.

Agricultural greenhouse

Plastic film greenhouse were used dimensions were 60 × 30 = 1,800 m^2 The materials covered by flexible plastic films, polyethylene and polyester material. Steel framing as vertical support structure. which supports the weight of the roof? There are number of structural parts of a greenhouse roof which include bar caps, gutters, purlins, trusses, ridge cap, sash bar, and side posts as shown in Figure 1.

Fig. 1. Isometric of greenhouse frame
Source: drawing by authors.

Soil physical and chemical properties

The physical and chemical analysis of soil for this experiment were tested at Tripoli Center for Agricultural Research laboratories. Soil mechanical analysis was sandy loam

The drip irrigation system

An irrigation system has been installed under a drip system consisting of main and laterals line (24 lines) the length of each line was (21 meters) with a diameter of (12 mm) and GR long path flow emitter type building In-line discharge (4 liters/hour) at a pressure of (0.5 bar) and was connected to each line with a stopcock to control the amount of irrigation water and connected with a branch line of diameter (32 mm) and the water source (a water tank with a capacity of 8 m^3 and a suction pump of 1.5 bar).

Nitrogen, Phosphorous and potassium

Phosphorous and potassium fertilizers were applied in liquid form during irrigation. Phosphate and potassium fertilizer were added in the form of Phosphoric Acid H_3PO_4 85%(3.600L) and JOSPA K50. Nitrogen fertilizer was added in the form of nitrate (3.88 kg) and applied in four equal doses: The first one at 20 days after transplanting on 29/11/2021 and the other on 29/12/2021 and the other on 9/1/2022, while the last dose from potassium only on 4/2/2022.

The thermal monitoring system

Infrared thermography and thermal camera with testo 865 and IR soft program to monitor the level of stress in plants by the thermal imager testo 865s. MATLAP software package was used to analysed the digital images. Figure 2 showing in Thermal monitoring system.

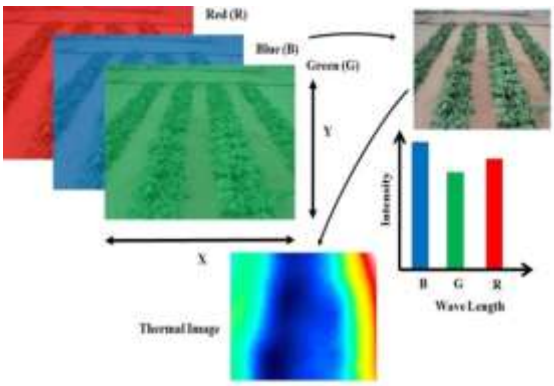

Fig. 2. The digital and thermal monitoring system component
Source: drawing by authors.

The Thermal camera

The thermal imager testo 865s is the ideal entry into the world of thermography. It impresses with the best image quality in its class and intuitive operation in a modern tile look. The testo 865s fits comfortably in the hand and is robust enough to withstand the rigours of everyday use. Helpful functions such as IFOV-Warner and Scale Assist ensure even better thermal images. All that combined with an unbeatable price-performance ratio. Switch on point, know more.

Image quality with IR resolution of 160 x 120 pixels (with testo Super Resolution technology 320 × 240 pixels). Thermal sensitivity of 0.1 °C., automatic detection of hot and cold spots, free analytical software for creating professional reports. fast measurement with fixed focus and measuring accuracy of ±2 °C Photo 2 and Table 1, which shows and explain the Thermal imaging camera and Technical Data of Thermal imaging camera- testo 865s.

Photo 2. Thermal imaging camera- testo 865s
Source: Original photo taken by authors.

Table 1. Technical Data of Thermal imaging camera- testo 865s

Infrared image output		Image presentation	
Infrared resolution	160 x 120 pixels	Display type	8.9 cm (3.5") TFT, QVGA (320 x 240 pixels)
Thermal sensitivity	<0.1 °C (100 mK)	Display option	IR image only
Field of view	31° x 23°	Colors	4 (iron, rainbow, cold-hot, grey)
Minimum focus distance	<0.5 m	Measurement	
Geometric resolution (IFOV)	3.4 mrad	Measuring range	-20 to +280 °C
Super Resolution (Pixel)	320 x 240 pixels	Accuracy	±2 °C, ±2 % of mv

Source: Camera- testo 865s Catalogue.

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IRSoft · PC-Software

The IRSoft software is used for the analysis, processing and archiving of the images recorded by a testo thermal imager. It also has integrated reporting for the clear presentation of the data. The settings can be performed on the connected thermal imager via the instrument control.

System requirements: Operating system, the software run on the following operating systems: Windows 8 (32 bit / 64 bit) Windows 10 (32 bit / 64 bit). Computer The computer have the requirements of the corresponding operating system. Interface USB 2.0 or higher. Internet Explorer 6.0. Intel Core i3-2310M 2.1 GHz, Intel Pentium Dual Core E2220 2.4 GHz 2.4 GHz 4 GB RAM. 500 GB available hard drive capacity. DirectX 9c graphics device.

User interface: Interface have three items ribbon, work space and status bar to detect thermal image (Photo 3).

Photo 3 present IRSoft software interface.

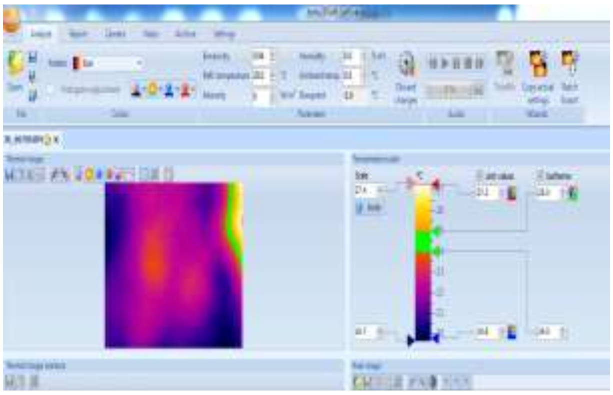
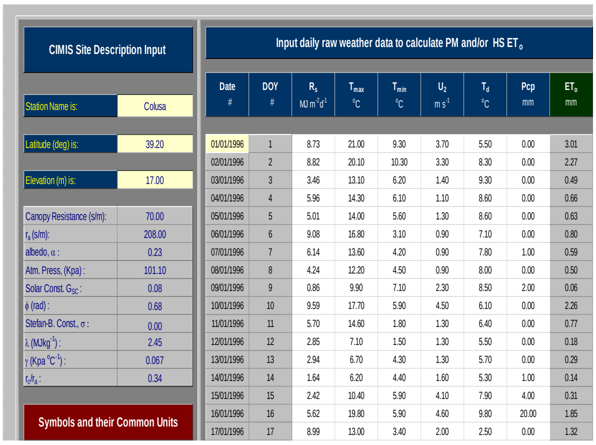


Photo 3. IR soft interface, ribbon, work space and status bar
Source: Authors' determination.

CUP plus model

CUP plus model application of Cabbage and lettuce under Libyan conditions. This worksheet, CUP plus program, has been developed and created by California Department of Water Resources and Department Land, Air and Water Resources, University of California, USA [21]. To estimate the reference evapotranspiration (ETo) CUP plus model application Interface of monthly climate input worksheet is showed in Photo 4.



CIMIS Site Description Input	
Station Name is:	Colusa
Latitude (deg) is:	39.20
Elevation (m) is:	17.00
Canopy Resistance (s/m):	70.00
r_a (s/m):	208.00
albedo, α :	0.23
Atm. Press, (Kpa) :	101.10
Solar Const. G_{SC} :	0.08
ϕ (rad) :	0.68
Stefan-B. Const., σ :	0.00
λ ($MJkg^{-1}$) :	2.45
γ (Kpa $^oC^{-1}$) :	0.067
r_c/r_a :	0.34
Symbols and their Common Units	

Input daily raw weather data to calculate PM and/or HS ET_o								
Date #	DOY #	R_s $MJ\,m^{-2}d^{-1}$	T_{max} ^oC	T_{min} ^oC	U_2 $m\,s^{-1}$	T_d ^oC	Pcp mm	ET_o mm
01/01/1996	1	8.73	21.00	9.30	3.70	5.50	0.00	3.01
02/01/1996	2	8.82	20.10	10.30	3.30	8.30	0.00	2.27
03/01/1996	3	3.46	13.10	6.20	1.40	9.30	0.00	0.49
04/01/1996	4	5.96	14.30	6.10	1.10	8.60	0.00	0.66
05/01/1996	5	5.01	14.00	5.60	1.30	8.60	0.00	0.63
06/01/1996	6	9.08	16.80	3.10	0.90	7.10	0.00	0.80
07/01/1996	7	6.14	13.60	4.20	0.90	7.80	1.00	0.59
08/01/1996	8	4.24	12.20	4.50	0.90	8.00	0.00	0.50
09/01/1996	9	0.86	9.90	7.10	2.30	8.50	2.00	0.06
10/01/1996	10	9.59	17.70	5.90	4.50	6.10	0.00	2.26
11/01/1996	11	5.70	14.60	1.80	1.30	6.40	0.00	0.77
12/01/1996	12	2.85	7.10	1.50	1.30	5.50	0.00	0.18
13/01/1996	13	2.94	6.70	4.30	1.30	5.70	0.00	0.29
14/01/1996	14	1.64	6.20	4.40	1.60	5.30	1.00	0.14
15/01/1996	15	2.42	10.40	5.90	4.10	7.90	4.00	0.31
16/01/1996	16	5.62	19.80	5.90	4.60	9.80	20.00	1.85
17/01/1996	17	8.99	13.00	3.40	2.00	2.50	0.00	1.32

Photo 4. CUP plus model application Interface of monthly climate input worksheet
Source: Authors' determination.

Experimental design

The experimental design was set up as a spilt, spilt plot design with three replicates. The treatments were applied under the shortage of nitrogen and irrigation water, using four levels of nitrogen fertilization (0, 50, 100 and 150% of Nitrogen recommended) and four levels of water regime (50%, 75%, 100% and 125% of ETc) (Figure 3).

The leaf-to-air temperature difference (ΔT), The relationship between the temperature of the canopy (Tc) and temperature of soil (Ts), pair is best suited to find the plant under plant stresses. Also determining reference evapotranspiration (ETo), crop coefficient (Kc) values, crop evapotranspiration (ETc), and evapotranspiration of applied water (ETaw), water stress index (CWSI) and stomatal conductance index (Ig) using various reference and non-reference thresholding techniques were estimations.

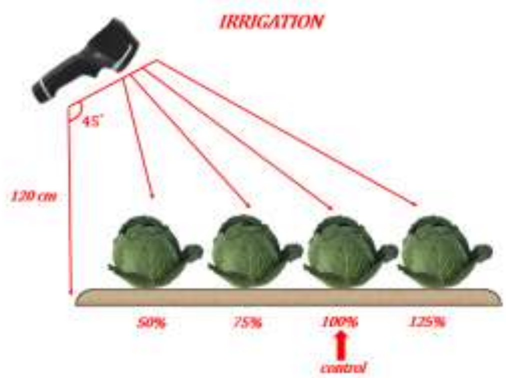


Fig. 3. Photographing transactions with thermal images for Cabbage
Source: Own results.

Irrigation water requirements

Irrigation water requirements for the drip irrigation system was calculated based on the meteorological data collected from Tripoli weather station which is next to the experiment. Irrigation water requirements were based on the calculation of potential evapotranspiration using CUP plus model application.

Reference Crop Evapotranspiration

Because of the extra high aerodynamic resistance induced by low wind velocity (0.01–0.3 m s^{-1}), ETo will be underestimated in greenhouse under low wind velocity situations [9]. Therefore, the ETo inside greenhouse, referred to $ETo_{,GH}$, was computed using a modified Penman–Monteith method established in greenhouse [10], in which a constant aerodynamic resistance of 295 s m^{-1} was utilized to counterbalance the effect of the low wind speed on ETo.

$$ETO_{GH} = \frac{0.408\Delta(R-G)+Y(\frac{628}{(T+273)})VPD}{\Delta+1.24Y} \text{..........(1)}$$

where:

$ETo_{,GH}$ is the reference evapotranspiration (mm d^{-1}); Rn is the net radiation (MJ m^{-2} d^{-1}); G is the soil heat flux density (MJ m^{-2} d^{-1}); T is the mean air temperature (◦C);Δ is the saturation slope of the saturation vapor pressure curve at T (kPa $◦C^{-1}$); γ is the psychometric constant (kPa $◦C^{-1}$); and VPD is the vapor pressure deficit (kPa).

Cabbage Crop Coefficient

The Cabbage and lettuce crop coefficient (K_{cb}) was defined as the ratio of crop transpiration (T_r) to reference crop evapotranspiration ETo when the average soil water content of the root zone was adequate to sustain full plant transpiration [1].

At the daily base, the crop transpiration amount can be regarded as the daily sap flow when the water storage in plant tissue is negligible. Then, K_{cb} is calculated as the ratio of plant sap flow (SF) to $ETo_{,GH:}$

$$K_{cb} = SF/ETo_{,GH} \quad \text{.....................(2)}$$

where:

K_{cb} is the Cabbage and lettuce crop coefficient; SF is the daily sap flow amount (mm d^{-1}); and $ETo_{,GH}$ is the daily reference evapotranspiration (mm d^{-1}) in greenhouse.

Crop Water Stress Index (CWSI)

The measurement of canopy temperature as an indicator of stress was put on a sound footing by [18] who defined a 'Crop Water Stress Index' (CWSI). The index IG was proportional to the leaf conductance to water vapor transfer which was calculated from leaf temperatures according to the formula 3.

$$IG = (T_{dry}–T_{leaf})/ (T_{leaf}–T_{wet}) \text{..........(3)}$$

This index is theoretically proportional to stomatal conductance (gs). An index analogous to [18] crop water stress index (CWSI) was also calculated, using Formula 4.

$$CWSI= (T_{dry}–T_{leaf})/ (T_{dry}–T_{wet}) \text{..........(4)}$$

Heat Indices Basics IR

To consistently compare plant temperature across the plant age, we calculated the deviation of Tp from ambient temperature (dTp=Tp - Ta), a measure often used in field phenotyping studies of heat tolerance.

Canopy Temperature CT

[22] affirmed that Canopy temperature measured with the infra-red can be utilized successfully to indicate water stress in grapevines by comparing them to well-irrigated reference vines.

ΔT normalized canopy or leaf temperature

$$= T_{canopy}-T_{air} \text{ or } T_{leaf} - T_{air} \text{..........................(5)}$$

MTD, maximum temperature difference = $T_{leaf\_max}-T_{leaf-min}$..(6)

NRCT, normalized relative canopy temperature =

$$\frac{(T\ leaf-Tminimum)}{(Tmaximum-Tminimum)} \text{.................................(7)}$$

Index (CWSI) program mode for plant greenhouses.

RESULTS AND DISCUSSIONS

The results were revealed by using a new technique application of digital and thermal imaging for showing plants monitoring data collecting to express about heat, water, nitrogen and heavy metal stresses during Cabbage plants growth periods.

Detects Heat Stress by thermal images for Cabbage Crops

The temperature of air, soil, canopy, and leaf were measured by IR image affected by different irrigation and fertilization levels of Cabbage crop at different fertilization levels. The interaction between the water regime and nitrogen fertilization levels has an effect on Cabbage temperature indices. The results were discussed during irrigation levels 50% ETC, 75% ETC, 100% ETC and 125% ETC. Also, they are shown in Photos 5 and 6 at different levels of nitrogen fertilization: 0, 50, 100 and 150% at average temperature for growth periods.

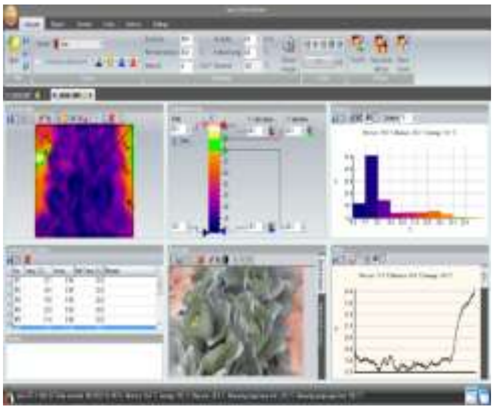


Photo 5. IR soft interface, ribbon, work space and status bar for Cabbage Crop.
Source: Own results.

With the control level of fertilization (0%), Fig. 4 showed the maximum value of Cabbage temperature of air, soil, canopy, and leaf were 31, 26.5, 32, and 21 °C, recorded with 100 % ETC. also showed the minimum value were 28, 26, 22 and 20 °C. at 50% ETC.

With the control level of irrigation (100% ETC), Fig. 5 showed the maximum value of Cabbage temperature of air, soil, canopy, and leaf were 24.5, 23, 20.5, and 18 °C, recorded with 100 % nitrogen fertilization also showed the minimum value were 25, 24.5, 20.5 and 19.5 °C recorded with 0 % nitrogen fertilization level.

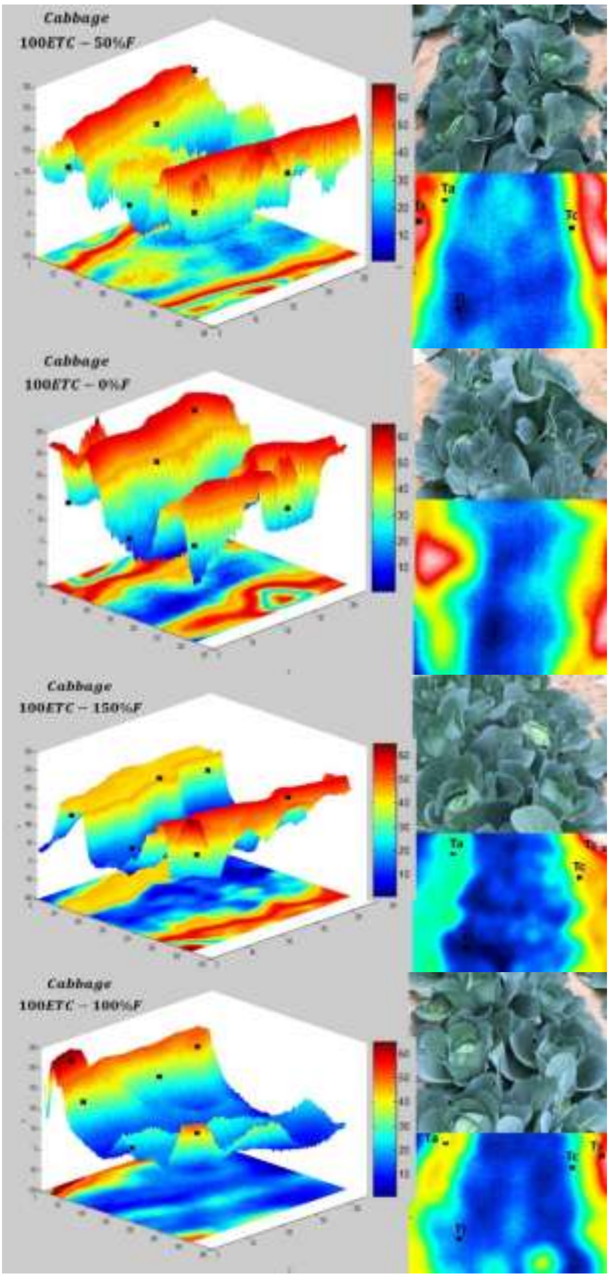


Photo 6. Cabbage temperature recorded under different fertilization at 100% ETC irrigation levels.
Source: Own results.

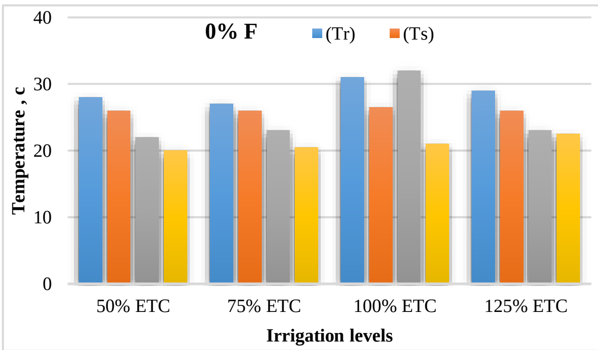


Fig. 4. Relationship between heat stress indices and irrigation levels of cabbage crop
Source: Own results.

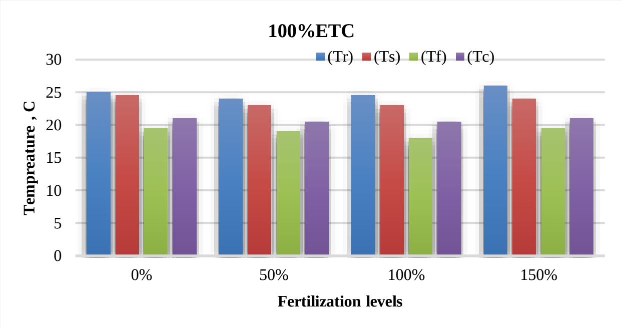


Fig. 5. Relationship between heat stress indices and fertilization levels of cabbage crop
Source: Own results.

With the levels of irrigation the maximum value of cabbage temperature of maximum temperature differences and normalized relative canopy temperature were 7.23 and 0.87 °C, also showed the minimum value for the same indices were 2.58 and 0.78 °C. Also, in Figures 6 and 7, where the levels of fertilization showed the maximum value of maximum temperature difference, and normalized relative canopy temperature were 6.63. and 0.84 °C, also showed the minimum value for the same indices were 2.29 and 0.45 °C.

Linear regression analysis was performed to predict the MTD and NRCT at different irrigation and fertilization levels. The following equation represents the relationship.

MTD:

$y = 1.5621x + 1.0424$ $R^2 = 0.9988$

$y = 1.463x + 1.1475$ $R^2 = 0.9575$

NRCT:

$y = 0.0311x + 0.749$ $R^2 = 0.9978$

$y = 0.1253x + 0.3291$ $R^2 = 0.9904$

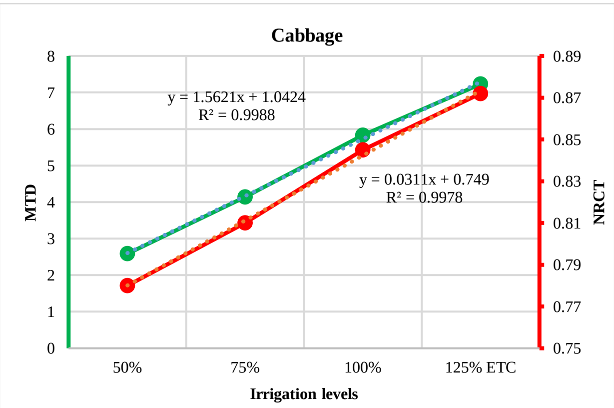


Fig. 6. Maximum temperature difference and normalized relative canopy temperature with irrigation levels of cabbage crop
Source: Own results.

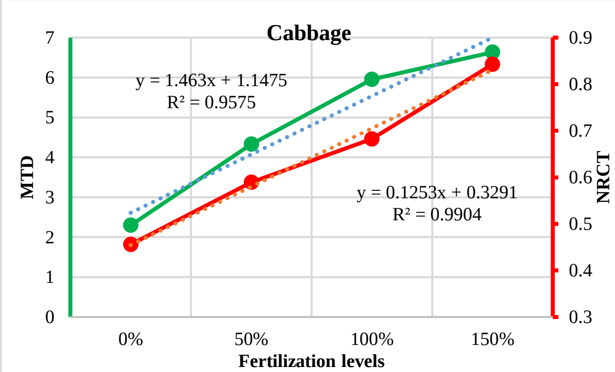


Fig. 7. Maximum temperature difference and normalized relative canopy temperature with fertilization levels of cabbage crop
Source: Own results.

Cabbage Plant Water Stress With Water Regime Levels

As it is presented in Figure 8, with the levels of irrigation showed the maximum value of that the crop water stress index, and the index of stomatal conductance were 0.62. and 2.77, also showed the minimum value for the same indices were 0.36 and 1.8.

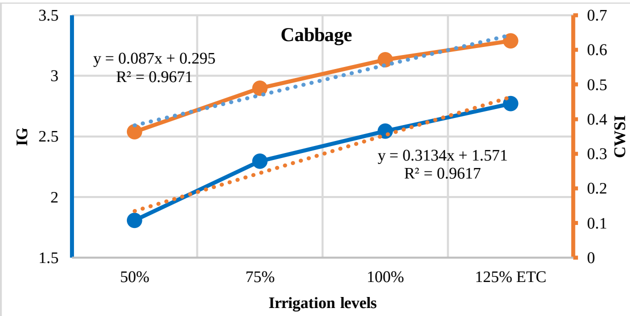


Fig. 8. Crop water stress index, and the index of stomatal conductance with irrigation levels of cabbage crop
Source: Own results.

Linear regression analysis was performed to predict the CWSI and IG at different irrigation levels.

The following equations represent the relationship.

CWSI:

$y = 0.087x + 0.295$ $R^2 = 0.9671$

IG:

$y = 0.3134x + 1.571$ $R^2 = 0.9617$

Detecting Water Stress Indices with Fertilization Levels For Cabbage Crop

Cabbage vegetative measurements such as crop water stress index and index of stomatal conductance were affected by four levels of nitrogen fertilization (0, 50, 100 and 150%) during growth periods, the initial stage, rapid stage, mid-season stage, and late season stage were discussed at constant 100 % ETC water regime level.

Figure 9 with the levels of fertilization showed the maximum value of that the crop water stress index, and the index of stomatal conductance were 0.57 and 2.87.

Also, it was shown the minimum value for the same indices were 0.41and 1.9.

Linear regression analysis was performed to predict the CWSI and IG at different irrigation levels.

The following equations represent the relationship.

CWSI:

$y = 0.0547x + 0.367$ $R^2 = 0.9809$

IG:

$y = 0.3231x + 1.1536$ $R^2 = 0.984$

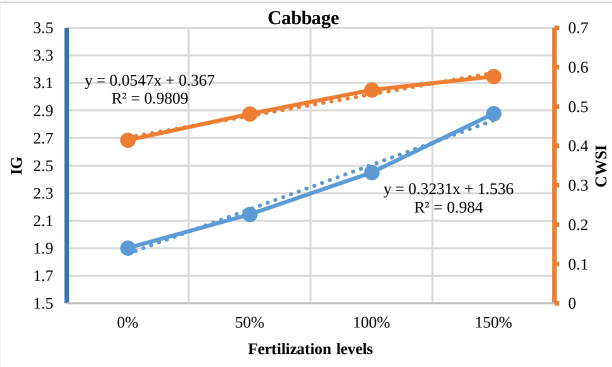


Fig. 9. Crop water stress index, and the index of stomatal conductance with fertilization levels of cabbage crop
Source: Own results.

CONCLUSIONS

The use of infrared thermography for detailed and continuous monitoring showed its ability to distinguish and show the thermal stress of plants under nitrogen deficiency and irrigation water, and to distinguish the percentages of plant contamination with heavy elements and their impact on vegetative characteristics, and to detect the heat water stress under protected greenhouse conditions in Libya.

REFERENCES

[1]Allen, R.G., Pereira, L.S., Raes, D., Smith, M., 1998, Crop evapotranspiration: guidelines for computing crop water requirements. FAO irrigation and drainage paper 56. FAO, Rome. Accessed on 8/10/2023.

[2]Alsaaod, C., Syring, J., Dietrich, J., Doherr, M.G., Gujan, T., Steiner, A., 2014, A field trial of infrared thermography as a non-invasive diagnostic tool for early detection of digital dermatitis in dairy cows. The Veterinary Journal 199(2):281–285. Accessed on 8 October, 2023.

[3]Al-Tamimi, N., Langan, P., Bernád, V., Walsh, J., Mangina, E., Negrão, S., 2022, Capturing crop adaptation to abiotic stress using image-based technologies. Open Biology, 12(6), 210353. Accessed on 8 October, 2023.

[4]Araus, J.L., Kefauver, S.C., Zaman-Allah, M., Olsen, M.S., Cairns, J.E., 2018, Translating High-Throughput Phenotyping into Genetic Gain. Trends Plant Sci. 23, 451–466. Accessed on 8 October, 2023.

[5]Belin, E., Rousseau, D., Landry, B., Demilly, D., Ducournau, S., Chapeau-Blondeau, F., Durr, C., 2015, Thermal imaging for evaluation of seedling growth. Accessed on 8 October, 2023.

[6]Change, C., 2007, IPCC fourth assessment report. The physical science basis, 2, 580-595. Accessed on 8 October, 2023.

[7]FAO, 2011, Food and Agriculture Organization of the United Nations, FAOSTAT, FAO Statistic Division. Accessed on 8 October, 2023.

[8]FAO, 2020, Food and Agriculture Organization Corporate Statistical Database. http://www.fao.org/faostat/en/#data/QC. Accessed on 8 October, 2023.

[9]Fernández, M.D., Bonachela, S., Orgaz, F., Thompson, R., López, J.C., Granados, M.R., Gallardo, M., Fereres, E., 2010, Measurement and estimation of plastic greenhouse reference evapotranspiration in a Mediterranean climate. Irrig. Sci., 28, 497–509. [CrossRef]. Accessed on 8 October, 2023.

[10]Fernández, M.D., Bonachela, S., Orgaz, F.; Thompson, R., López, J.C., Granados, M.R., Gallardo, M. 2011, Fereres, E., Erratum to: Measurement and estimation of plastic greenhouse reference evapotranspiration in a Mediterranean climate. Irrig. Sci. 29, 91–92. [CrossRef]. Accessed on 8 Oct. 2023.

[11]Fouda, T., El-Babi, N., Ali, E., Salah, S., 2022, Assessment of Water and Nitrogen Productivity of Cabbage and Lettuce Planting Under Greenhouse J. of Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 13 (8), August, 2022. Accessed on 8 October, 2023.

[12]Jones, H., 2014, Plants and Microclimate: A Quantitative Approach to Environmental Plant Physiology, 3rd ed. Cambridge University Press: Cambridge, UK, Volume 56. Accessed on 8 October, 2023.

[13]Khanal, S., Fulton, J., Shearer, S., 2017, An overview of current and potential applications of thermal remote sensing in precision agriculture. Comput. Electron. Agric. 2017, 139, 22–32. [CrossRef]. Accessed on 8 October, 2023.

[14]Larteh, I. T., 2011, Response of drip-irrigated cabbage (*Brassica oleracea L. var capitata*) to levels of

applied water. MPhil. Thesis, University of Ghana, Legon, p. 91. Accessed on 8 October, 2023.

[15]Maynard, D. N., Hochmuth, G.J., 2007, Knott's handbook for vegetable growers: Vegetables and the vegetable industry. Nutritional composition of vegetables. pp. 46-53. 5th Ed., John Wiley and Sons, Inc. 621 pp. Accessed on 8 October, 2023.

[16]Patil, G., Patil, A., Pathmudi, S., 2021, Plant Monitoring System. International Journal of Engineering Research & Technology (IJERT). Vol. 10(9). http://www.ijert.org,. Accessed on 8 October, 2023.

[17]Putro, A. W., Nugroho, A. P., Sutiarso, L., Okayasu, T., 2022 (June), Application of 3D reconstruction system based on close-range photogrammetry method for plant growth estimation. In IOP Conference Series: Earth and Environmental Science, Vol. 1038(1), p. 012051. IOP Publishing. Accessed on 8 October, 2023.

[18]Reginato, R. J., 1983, Field quantification of crop water stress. Transactions of the ASAE, 26(3), 772-0775. Accessed on 8 October, 2023.

[19]Rico-Chávez, A. K., Franco, J. A., Fernandez-Jaramillo, A. A., Contreras-Medina, L. M., Guevara-González, R. G., Hernandez-Escobedo, Q., 2022, Machine Learning for Plant Stress Modeling: A Perspective towards Hormesis Management. Plants, 11(7), 970. Accessed on 8 October, 2023.

[20]Sagan, V., Maimaitiyiming, M., Fishman, J., 2018, Effects of Ambient Ozone on Soybean Biophysical Variables and Mineral Nutrient Accumulation. Remote Sens. 10, 562. [CrossRef]. Accessed on 8 October, 2023.

[21]University of California, California Department of Water Resources and Department Land, Air and Water Resources, USA, https://www.fws.gov/lodi/, Accessed on October 8, 2023.

[22]Van Zyl, J.L., 1986, Canopy Temperature as a Water Stress Indicator in Vines. S. Afr. J. Enol. Vitic., Vol. 7(2), 53-60. Accessed on 8 October, 2023.

[23]Zhang, X., Wang, Y., Chen, J., Chen, A., Wang, L., Guo, X., Niu, Y., Liu, S., Mi, G., Gao, Q., 2019, Reducing basal nitrogen rate to improve maize seedling growth, water and nitrogen use efficiencies under drought stress by optimizing root morphology and distribution. Agric. Water Management, 212, 328-337. Accessed on 8/10/2023.

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MONITORING WATER AND HEAT STRESS OF LETTUCE CROP BY USING INFRARED THERMOGRAPHY TECHNIQUE

Tarek FOUDA[1], Eltaher MADY[2], Nouri AL BAY[2], Ashraf SWIDAN[2], Shaimaa SALAH[1]

[1]Tanta University, Faculty of Agriculture, Agriculture Engineering Department, Egypt, Emails: tfouda628@gmail.com, Shimaa2010atia@yahoo.com
[2]Higher Institute of Agricultural Technologies in Al-Ghiran, Tripoli, Libya, E-mails:tahermady312@gmail.com, n.albay60@gmail.com,Swidanashraf349@gmail.com

Corresponding author: tfouda628@gmail.com

Abstract

The objective of this study was the possibility of using infrared thermography IR to detect and continuously monitor for lettuce plants growing conditions. Also, discernment plants stresses under the shortage of nitrogen and irrigation water. The results showed for Lettuce plants, At the level of fertilization (0%), the maximum values of lettuce the lowest values for MTD maximum temperature difference, and normalized relative canopy temperature NRCT were 0.673 and 0.1 °C at irrigation systems ETC 100% and ETC 50% and nitrogen fertilization systems at 0% level.. And ETC 50% and systems and nitrogen fertilization level 100%. In the fourth level of fertilization (150%), the maximum value of leaf temperature was 24, 23, 22.5, and 23 °C and NRCT was 5.5 and 3.5 °C, and the lowest values for MTD and NRCT were 0.82, 0.28 °C, and 0.018 °C at 0.018 °C. Irrigation ETC 100% and ETC 50% and systems and nitrogen fertilization standard 150%. Also crop water stress index increased from 0.18. at the initial stage to 0.4. and at rapid stage, mid-season stage, and late season stage increased from 0.28 to 0.45, from 0.3 to 0.5, and from 0.31 to 0.59 respectively at constant irrigation level (0%) and the fertilization level from 0 % to 100%, also the index of stomatal conductance with the same trend the crop water stress index increased from 0.51. at the initial stage to 1.26. and at rapid stage, mid-season stage, and late season stage increased from 0.36 to 2.14, from 0.93 to 3.52, and from 0.95 to 5.52 respectively at constant irrigation level (0%) and the fertilization level from 0 % to 50%

Key words**:** *Lettuce, temperature , thermography, monitoring, heat, water, stress*

INTRODUCTION

Lettuce (*Lactucasativa* L.) is a green leafy vegetable belonging to the Asteraceae family. It is a cool-season vegetable which thrives in temperatures ranging from 7 to 24 ◦C and is commonly consumed in salad mixes. Among different vegetables grown in the United States, lettuce surpasses all others except potato in terms of land devoted to production and crop value. Lettuce is very nutritious and a rich source of vitamin C, minerals and fiber. Lettuce has been used as a medicine for different ailments including stomach problems, inflammation, pain and urinary tract infections from ancient times due to the presence of secondary metabolites such as terpenoids, flavonoids and phenols. Nowadays, consumption of organic vegetables, including lettuce, is surging because of the fast-growing human population, rapid urbanization and increased health concerns. However, one significant factor that limits vegetable cultivation is inadequate land space [24].

In Libya, food demand is expected to increase significantly in the upcoming decades due to rapid population growth, expected to be nearly 1% annually. Libya imports approximately 80% of its total food [5].

The water released from the leaf stomata (transpiration) consumes energy and reduces the leaf temperature. Sunlit leaves receive more direct radiation than shaded leaves of the canopy, and sunlit leaves are therefore assumed to have higher temperature than that of shaded leaves. When non transpiration occurred (no transpiration cooling effect), the temperature difference between sunlit and shaded leaves is maximum. When water is available for the plant to transpire, the transpiration rate in sunlit portions of the canopy would be higher than the transpiration rate in shaded portions [11].

Leaf lettuce belongs to Lactucacompositae and originated on the Mediterranean coast. Leaf lettuce is one kind of high nutrition vegetable, which contains vitamins (A, B1, B2), calcium, iron and other nutrients [23].

lettuce plants were divided into below- and aboveground parts. The belowground part consisted of the roots, and the aboveground part included the stems, leaves and heads. The biomass per fraction, distribution ratio and total biomass under different water and fertilizer coupling treatments are presented in previous studies. Different treatments had significant effects on the head biomass; specifically, the head biomass of spring Lettuce in HWLF was significantly higher than that in MWMF and LWHF, and the head biomasses of autumn Lettuce in HWLF and MWMF were significantly higher than that in LWHF [4].

Vegetable planting area accounts for approximately 13% of the grain crop planting area, but vegetable water consumption accounts for approximately 20% of the grain crop water consumption. At present, the greenhouse vegetable planting area accounts for 58.7% of the vegetable planting area in the Beijing–Tianjin–Hebei region, and the planting area of greenhouse vegetables, water consumption and fertilization amount are increasing annually. It has been reported that the amount of nitrogen (N) fertilizer used in greenhouse vegetable production in this area is 1.3–5.8 times higher than the recommended value, and the nitrate content in groundwater of vegetable fields in some areas exceeds 37.5%–44.8% [28].

Both irrigation and fertilization had significant effects on the root, leaf and total biomass of Chinese Lettuce, but the effects of the different water and fertilizer treatments on root, leaf and total biomass were not significant. The irrigation and fertilization had no significant effect on the head biomass of broccoli but had a significant effect on the biomass of leave [9].

Among many factors affecting crop growth, water and fertilizer are key factors that can be adjusted and controlled. In actual agricultural production, to obtain higher yields, excessive water use and fertilization have become standard practices, and these practices not only leach nutrients from surface soil to deep soil, reducing water and nutrient use efficiency [15].

Compost as an organic source of fertilizers is a valuable product that manipulates soil properties, via improving organic matter content, nutrient availability, aeration and water holding capacity and reducing soil bulk density. Moreover, the use of biochar for soil restoration and bio fertilization has increasingly received interest as low-cost and eco-friendly amendment. Biochar caused a positive impact on soil stability by altering the size of aggregates and regulating soil water, actions that may promote plant growth. In addition, vermicompost as an organic fertilizer plays a role in enhancing soil fertility, increasing soil–water holding capacity and soil aggregates [16].

Since plants cannot move, they face many environmental stresses. Plants have to deal with changes in light, humidity, drought, or cold. And if that was not enough, they still have to fight against all kinds of pathogens. The stress in plants can be categorized as abiotic (originated by drought, cold, high light) and biotic (originated by the attack of bacteria, fungi, herbivores). For those reasons, plants have developed an arsenal of enzymes, metabolites, and signaling pathways to face all kinds of environmental stresses. But even though a lot of research has been done in this sense, there are still some important gaps in understanding how plants interact and defend themselves [26].

Plants have had to develop different mechanisms to face those stresses. The stress not only affects the plant's productivity but also their survival. Depending on the type of stress, plants can dry out, freeze, burn or even die. Plant stress obviously matters to the plants, but also to all of humanity because plants are the primary source of food for human consumption. The findings conclude that plants have many strategies: such as protein and metabolite production, activation of the gene expression, and signaling cascades (or transduction pathways) to face abiotic and biotic stress. Also, plants use similar strategies to respond to different types of stresses [29].

When crops are experiencing water shortage, transpiration from the leaves decreases that is expected to reduce both stomata conductance and water potential of leaves. A decrease in transpiration can also cause insufficient cooling of leaf surface which will ultimately lead to an increase in leaf temperature. Although there are a number of factors which affect actual level of water stress in a plant, leaf temperature is considered as one of the most important factors [12].

Water use is also important to the irrigator from the point of view of gaining maximum return from a limited resource. Irrigation scheduling is a farmer level decision process which includes when to irrigate and how much water to apply to a crop field. suggested that greater precision in the application of irrigation can potentially be obtained by the using ‘plant stress sensing’. The most established method for detecting crop water stress remotely is through the measurement of a crop’s surface temperature [13].

Water stress is one of the most critical abiotic stressors limiting crop development. The main imaging and non-imaging remote sensing based techniques for the detection of plant stress (water stress and other types of stress) are thermography, visible (VIS), near- and shortwave infrared (NIR/SWIR) reflectance, and fluorescence. Just very recently, in addition to broadband thermography, narrowband (hyperspectral) thermal imaging has become available, which even facilitates the retrieval of spectral emissivity as an additional measure of plant stress. It is, however, still unclear at what stage plant stress is detectable with the various techniques [10].

The levels of water stress are not harmful to the development of the crop and affect its productivity, its detection and monitoring are necessary, and it can occur in different ways. One of them is through the Crop Water Stress Index (CWSI). This index quantifies water stress through the normalization of leaf temperature between the maximum and minimum plant temperatures as a function of evaporation conditions. The responses of a low-cost infrared (IR) sensor were crossed with image processing through segmentation by the Excess Green model to develop a water stress detection system using CWSI. A soil/plant temperature map was generated through a point-to-point scan of the IR sensor. And when it overlaid with a segmented image of the experimental area, only points identified as plants had their temperature values maintained. The Non-Water-Stressed Baseline (NWSB) equation was parameterized for the same conditions of the experiment and external environmental. The experimental area was divided into three different treatments, maintained under stable water conditions throughout the experiment and the system was able to identify stably different stress values between treatments. Although the relationship between crop and environment affected the results, this work showed that using an irrigation system based on CWSI is possible [3].

To satisfy crop needs, farmers combine several irrigation water sources, such as brackish groundwater, desalinated water, reclaimed water, and desalinated water. Good agricultural and irrigation practices are essential for preventing soil salinization and production losses, and remote sensing might be used to evaluate these practices. The thermal camera did not operate well within the greenhouse, but it performed in the commercial plot, where the canopy temperature was linearly correlated, with an R2 value of 0.50. The second analyzed vegetative metric, the Normalized Difference Plants Index (NDVI), was exclusively applied to the vegetation and showed minimal relationships with the soil salinity [17].

Plant growth monitoring is an important aspect of precision agriculture implementation. The monitoring can be performed by estimating the volume by the result of Three-dimensional (3D) reconstruction by using Close-range Photogrammetry. However, to present the functionality of the system for plant growth behavior, it is necessary to evaluate its accuracy and performance. The objective of this study was to apply a 3D reconstruction system using the CRP method for validating volume variation and estimate the rate of growth of Chinese Lettuce. This system consists of Canon 700D's DSLR camera and camera stabilizer. The stage of image processing using 3DF's Zephyr Pro photogrammetric software for generating 3D models. For the validation purposes and its functionality for modelling and estimating volumetric objects[19].

Many technological advances assist plant stress science in overcoming such limitations, which results in extensive datasets originating from the multiple layers of the plant defensive response. For that reason, artificial intelligence tools, particularly Machine Learning (ML) and Deep Learning (DL), have become crucial for processing and interpreting data to accurately model plant stress responses such as genomic variation, gene and protein expression, and metabolite biosynthesis. In this review, we discuss the most recent ML and DL applications in plant stress science, focusing on their potential for improving the development of hormesis management protocols [21].

Studied water and nitrogen productivity for lettuce under the shortage of nitrogen and irrigation water during growing lettuce (Babura) plants. Mass production, nitrogen productivity, water productivity, chlorophyll A, chlorophyll B and total chlorophyll, respectively were test under using four levels of nitrogen fertilization (0, 50, 100 and 150% of Nitrogen recommended) and also four levels of water regime (50%, 75%, 100% and 125% of ETc) in Libya conditions. The optimum conditions in drip irrigation greenhouse for crops grow were provided to give us high yield, quality production for lettuce crops. The highest value of chlorophyll A, chlorophyll B and total chlorophyll obtained with 100%N and 100% ETc applied water for lettuce were (0.382, 0.299 and 0.681 mg/100 gm), respectively [8].

Infrared thermal imaging is a non-destructive testing technology that can be used to determine the superficial temperature of objects. This technology has an increasing use in detecting diseases and distress in animal husbandry within the poultry, pig and dairy production. The process can identify changes in peripheral blood flow from the resulting changes in heat loss and; therefore, have been a useful tool for evaluating the presence of disease, edema, and stress in animals. also detect plants heat stress. [22].

The results confirmed the possibility of pre-symptomatic detection of P. carotovorum subsp. carotovorum in lettuce at the canopy level. With respect to identifying healthy and infected lettuce plants by supervised classification, the best results were obtained at 4 and 8 DAI, especially when using the subsets derived from the Mapir Survey3W camera (RGN sensor), for both classifiers. The subsets obtained with the conventional visible sensor (RGB sensor) produced the best results at 20 and 24 days [2].

Pinter. et.al., (2003) stated that green plant leaves typically display very low reflectance and transmittance in visible regions of the spectrum (0.4 to 0.7 μm) due to strong absorbance by photosynthetic and accessory plant pigments since controlling factors for this region are leaves pigments (Chlorophyll and anthocyanins) [18].

Infrared radiation is energy emitted by the mobility of atoms and molecules on the surface of an object at temperatures greater than absolute zero. The strength of the emittance varies with the material's temperature. In other words, the higher the temperature, the more intense the infrared energy released. Materials not only emit infrared radiation, but they also reflect it, absorb it, and, in certain situations, transfer it. When the material's temperature equals the temperature of its surroundings, the amount of thermal radiation absorbed by the item equals the amount emitted by the object [27].

Thermal image allows the visualization of differences in surface temperature by detecting emitted infrared radiation [long-wave infrared (8–14 μm)]. Computer software transforms these radiation data into thermal images in which temperature levels are indicated by a false-colour gradient. Infrared thermography can give frequency distributions of leaf temperature over the target area. A one-shot thermograph has more than 70,000 pixels, each pixel with visual temperature information of sensitivity < 0.1°C. The canopy temperature difference of approximately 8°C in this study is large enough to visually detect transpiration changes in foliage of the genotypes and instantly monitor the soil water stress of plant growth. The frequency distributions ranged from 18°C to 26°C which were clearly different with some genotypes under salinity to have a greater variance of temperature. Thus, infrared thermography has great potential as a tool to instantly monitor water stress in fields [14].

The main objectives of this research were the possibility of using infrared thermography for detailed and continuous monitoring of plant. Display the temperature difference, crop water stress and stomatal conductance index changes under greenhouse condition

MATERIALS AND METHODS

The experimental design was set up as a spilt, spilt plot design with three replicates. The treatments were applied under the shortage of nitrogen and irrigation water, using four levels of nitrogen fertilization (0, 50, 100 and 150% of Nitrogen recommended) and four levels of water regime (50%, 75%, 100% and 125% of ETc). The leaf-to-air temperature difference (ΔT), The relationship between the temperature of the canopy (Tc) and temperature of soil (Ts), pair is best suited to find the plant under plant stresses. Also determining reference evapotranspiration (ETo), crop coefficient (Kc) values, crop evapotranspiration (ETc), and evapotranspiration of applied water (ETaw), water stress index (CWSI) and stomatal conductance index (Ig) using various reference and non-reference thresholding techniques were estimations. Mass production, nitrogen productivity, water productivity, chlorophyll A, chlorophyll B and total chlorophyll, respectively were tested at the season is separated into initial, rapid, midseason, and late season growth periods.

Experiment statements

Different agricultural practices were performed such as the greenhouse preparing, **Lettuce** planting, watering fertilizer and plants protection during plants growth using an application of thermal imaging to detect plants stresses.

The greenhouse preparing

The field work began on Saturday 10/10/2021 for cleaning operations, removing all existing obstacles, and preparing the greenhouse land from the inside on which the experiment is based .Greenhouse preparation stages. The soil of the experimental study wasn't planted five years ago so the land was reclamation to preparing it for planting and then put drip irrigation system. The soil samples were collected from the study area and chosen randomly from surface at 10 cm. Ten soil samples were collected covering most of the study area a soil sample was Collected and put in a sealed plastic bag to determine the soil chemical analysis was done in the lab to determine some soil chemical properties.

Lettuce planting

Lettuce crop were planted in plant nursery. 6 week-old seedlings were transplanted in the greenhouse in 4 November 2021. The distance between rows and plants on the same furrow was 100 and 30 cm respectively. A two-meter distance was left between different treatments to avoid overlapping between different treatments.

Lettuce watering

As for the first irrigation after transplanted, the amount of water added was 3.5 m^3 every four days from 4/11 to 28/11/2021. Most of the irrigations were in the morning with a network pressure of 1.45 bar. The field experiment was divided into sixteen combinations treatments. Four irrigation schedules (50%, 75%, 100% and 125% ETc). Water was added about 24 twenty-four times during four stage, I from 29/11, 3/12,7/12, 11/12 and15/12/2021, stage, II from 19/12/2021 to 8/1/2022, stage, III from

13/1/2022 to 3/2/2022 and stage, IIII from 8/2/2022 to 28/2/2022, the amount of water added after seeding was 4.2 $m^3.h^{-1}$. The irrigation treatments were according to the program prepared for irrigation. The amount of water distributed with the initial stage (Init. (Lini), rapid stage (Dev. (Ldev), mid-season stage (Mid (Lmid)), and late season stage (Late (Llate) growth periods as shown in Table 1.

Table 1. Lettuce growth periods with crop coefficient

Crops	Init. (L_{ini})	Dev. (L_{dev})	Mid (L_{mid})	Late (L_{late})
Lettuce	40	60	50	15
Lettuce Kc	Kc_{ini}=0.7	Kc_{mid}=1.05		Kc_{end}=0.95

Source: Authors' determination.

Lettuce fertilizer

Phosphorous and potassium fertilizers were applied in liquid form during irrigation. Phosphate and potassium fertilizer were added in the form of Phosphoric Acid H_3PO_4 85%(w/v) and JOSPA K50. Nitrogen fertilizer was added in the form of nitrate (3.88 kg) and applied in four equal doses: The first one at 20 days after planting on 29/11/2021 after planting and the other on 29/12/2021 and the other on 9/1/2022.while the last dose from potassium only on 4/2/2022. Four nitrogen nutrient levels distributed with (0, 50, 100 and 150%N).Irrigation and fertilization scheduling in one program to distribute of irrigation and fertilization prepared the replicates of the experiment**.**

The IR soft steps

Interface have three items ribbon, work space and status bar to detect thermal image.The ribbon helps you to carry out modifications and settings and to find the relevant functions and commands quickly. The functions are divided into different groups on four tabs: Analysis, Report, Imager and Settings. The functions/commands vary depending on the tab selected, the sequence of digital and thermal image analysis processes as showed inFigure 1.

Experimental measurements

Many measurements were taken to include meteorological and microclimatic measurements of temperature and humidity, water measurements, vegetative measurements of lettuce and Lettuce, thermal measurements, and measurement indicators of plant stress.

Meteorological and microclimatic

The meteorological data comes from a meteorological station in, Agricultural Research center, Tripoli, Libya (latitude of 32°12`25`` and longitude of 13°62`16``) during the winter season of 2021-2022. Lettuceand lettuce plants were planted in November 2021. Agriculture greenhouse microclimatic measurements It comes with a small and portable weather station.

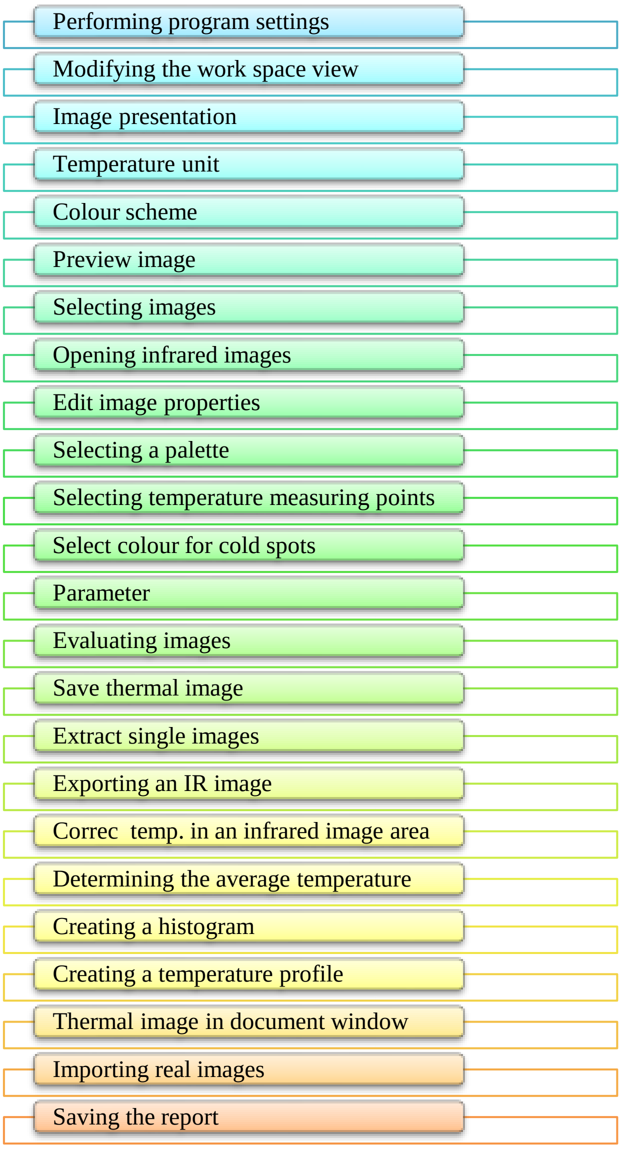

Fig. 1. The sequence of digital and thermal image analysis processes
Source: Authors' determination.

Irrigation water requirements

Irrigation water requirements for the drip irrigation system was calculated based on the meteorological data collected from Tripoli weather station which is next to the experiment. Irrigation water requirements were based on the calculation of potential evapotranspiration using CUP plus model application.

Reference Crop Evapotranspiration

Because of the extra high aerodynamic resistance induced by low wind velocity (0.01–0.3 m s^{-1}), ETo will be underestimated in greenhouse under low wind velocity situations [6]. Therefore, the ETo inside greenhouse, referred to $ETo_{,GH}$, was computed using a modified Penman–Monteith method established in greenhouse [9], where a constant aerodynamic resistance of 295 s m^{-1} was utilized to counterbalance the effect of the low wind speed on ETo.

$$\mathbf{ETO}_{GH} = \frac{0.408\Delta(R-G)+Y(\frac{628}{(T+273)})VPD}{\Delta+1.24Y} \quad ..(1)$$

where:

$ETo_{,GH}$ is the reference evapotranspiration (mm d^{-1}); Rn is the net radiation (MJ m^{-2} d^{-1}); G is the soil heat flux density (MJ m^{-2} d^{-1}); T is the mean air temperature (◦C);

Δ is the saturation slope of the saturation vapor pressure curve at T (kPa $◦C^{-1}$); γ is the psychometric constant (kPa $◦C^{-1}$); and VPD is the vapor pressure deficit (kPa).

Lettuce and lettuce Crop Coefficient

The Lettuce and lettuce crop coefficient (K_{cb}) was defined as the ratio of crop transpiration (T_r) to reference crop evapotranspiration ETo when the average soil water content of the root zone was adequate to sustain full plant transpiration [1]. In this study, the soil surface was covered by a plastic sheet, and the total water use was from crop transpiration. At the daily base, the crop transpiration amount can be regarded as the daily sap flow when the water storage in plant tissue is negligible. Then, K_{cb} is calculated as the ratio of plant sap flow (SF) to $ETo_{,GH:}$

$$\mathbf{K_{cb} = SF/ETo_{,GH}} \quad ....(2)$$

where:

K_{cb} is the Lettuce and lettuce crop coefficient; SF is the daily sap flow amount (mm d^{-1}); and $ETo_{,GH}$ is the daily reference evapotranspiration (mm d^{-1}) in greenhouse.

Crop Water Stress Index (CWSI)

The measurement of canopy temperature as an indicator of stress was put on a sound footing by [20] who defined a 'Crop Water Stress Index' (CWSI).Natural references were actual vine leaves (either detached in their natural position within the canopy, or detached and hung on a frame) The index IG was proportional to the leaf conductance to water vapor transfer which was calculated from leaf temperatures as follows:

$$\mathbf{IG = (T_{dry}–T_{leaf})/ (T_{leaf}–T_{wet})} \quad ....(3)$$

This index is theoretically proportional to stomatal conductance (gs) . An index analogous to [18] crop water stress index (CWSI) was also calculated, where in this case:

$$\mathbf{CWSI= (T_{dry}–T_{leaf})/ (T_{dry}–T_{wet})} \quad ....(4)$$

Heat Indices Basics IR

To consistently compare plant temperature across the plant age, we calculated the deviation of Tp from ambient temperature (dTp=Tp - Ta), a measure often used in field phenotyping studies of heat tolerance.

Canopy Temperature CT

[25]affirmed that canopy temperature measured with the infra-red can be utilized successfully to indicate water stress in grapevines by comparing them to well-irrigated reference vines.

ΔT normalized canopy or leaf temperature=

$$T_{canopy}-T_{air} \text{ or } T_{leaf} - T_{air} \quad ....(5)$$

MTD, maximum temperature difference=

$$T_{leaf\_max}-T_{leaf-min} \quad ....(6)$$

NRCT, normalized relative canopy temperature=

$$\frac{(T\ leaf-Tminimum)}{(Tmaximum-Tminimum)} \quad ....(7)$$

C++ plus model

The C++ programming language was used to build a set of algorithms to determine and predict the colorimetric and thermal indicators and to study the effect of thermal, water and fertilization stress. The simulation and predicting programs model written by C++

Program mode Crop Stress Index (CWSI)

To estimate the Color Vegetation indices (CVI) program model I, and Crop Stress Index (CWSI) program mode for plant greenhouses as presented in Figure 2.

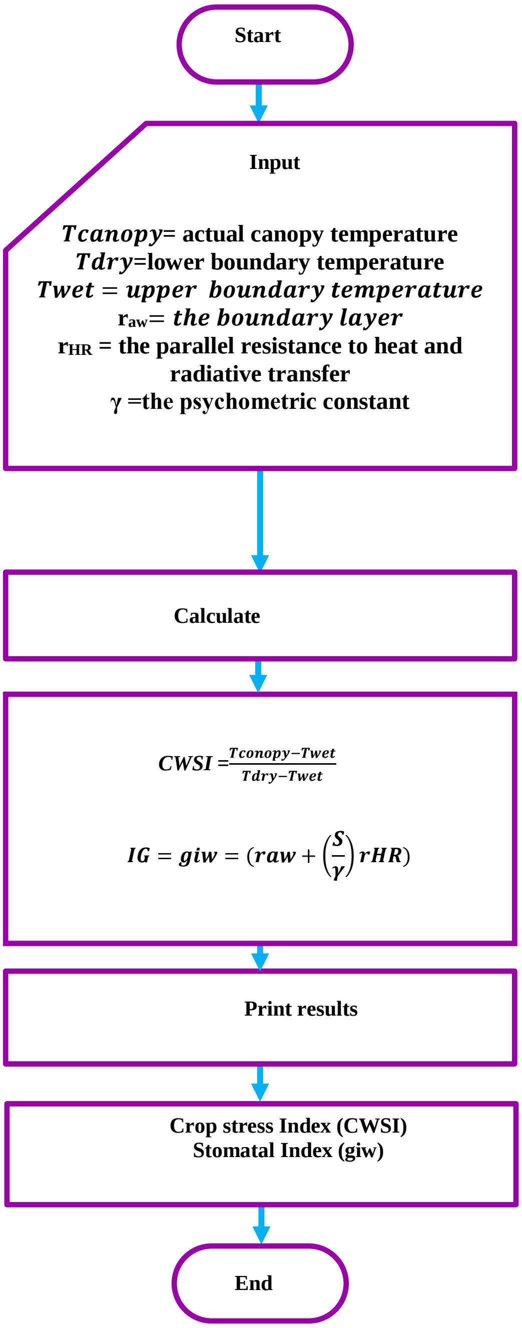

Fig. 2. Flowchart of Crop Stress Index (CWSI) program mode
Source: Authors' drawing.

RESULTS AND DISCUSSIONS

The temperature of air, soil, canopy, and leaf were measured by IR image affected by different irrigation and fertilization levels of lettuce crops at different fertilization levels.The interaction between the water regime and nitrogen fertilization levels has an effect on Lettuce temperature indices. The results were discussed during irrigation levels 50% ETC, 75% ETC, 100% ETC and 125% ETC. Also at different levels of nitrogen fertilization 0, 50, 100 and 150% at average temperature for growth periods are shown in Figures3 and 4 .

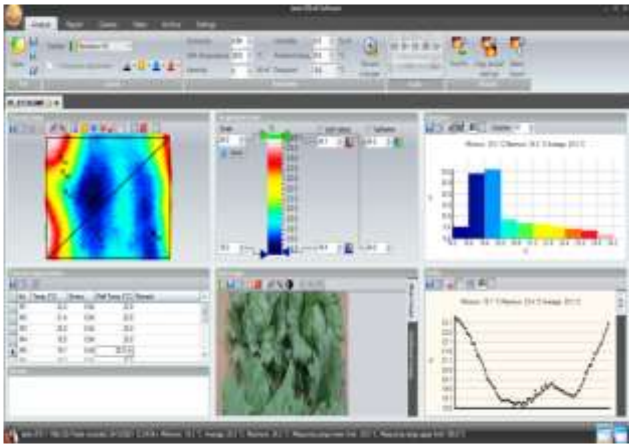

Fig. 3. IR soft interface, ribbon, work space and status bar for Lettuce Crop
Source: Authors' determination

Monitoring temperature of lettuce crop under different fertilization and irrigation levels

With the control level of fertilization (0%), Figure (5)showed the maximum value of lettuce temperature of air, soil, canopy, and leaf were 27, 25, 27, and 24 °C, recorded with 100 % ETC also showed the minimum value for the same indices were 23, 23, 22and 21 °C at 50%ETC. With the control level of irrigation (100%ETC), Figure (6)showed the maximum value of lettuce temperature of air, soil, canopy, and leaf were 24, 22.5, 18.5, and 17.3 °C, recorded with 125 % fertilization, also showed the minimum value for the same indices were 19, 18.3, 16.2 and 15.3 °C recorded with 0 % fertilization level.

With the levels of fertilization, Figure (7)showed the maximum value of maximum temperature difference, andnormalized relative canopy temperature were 6.24. and 0.56 °C, alsoFigure (8) showed the minimum value for the same indices were 4.44 and 0.33 °C. Linear regression analysis was performed to predict the MTD and NRCT at different irrigation and fertilization levels. The following equation represents the relationship. MTD:

$y = 0.6091x + 3.9119 \quad R^2 = 0.9804$

$y=0.5535x+3.9729 \quad R^2=0.943$

NRCT:

$y = o.0779x + 0.2444 \quad R^2 = 0.9861$

$y = 0.1004x + 0.1155 \quad R^2 = 0.9351$

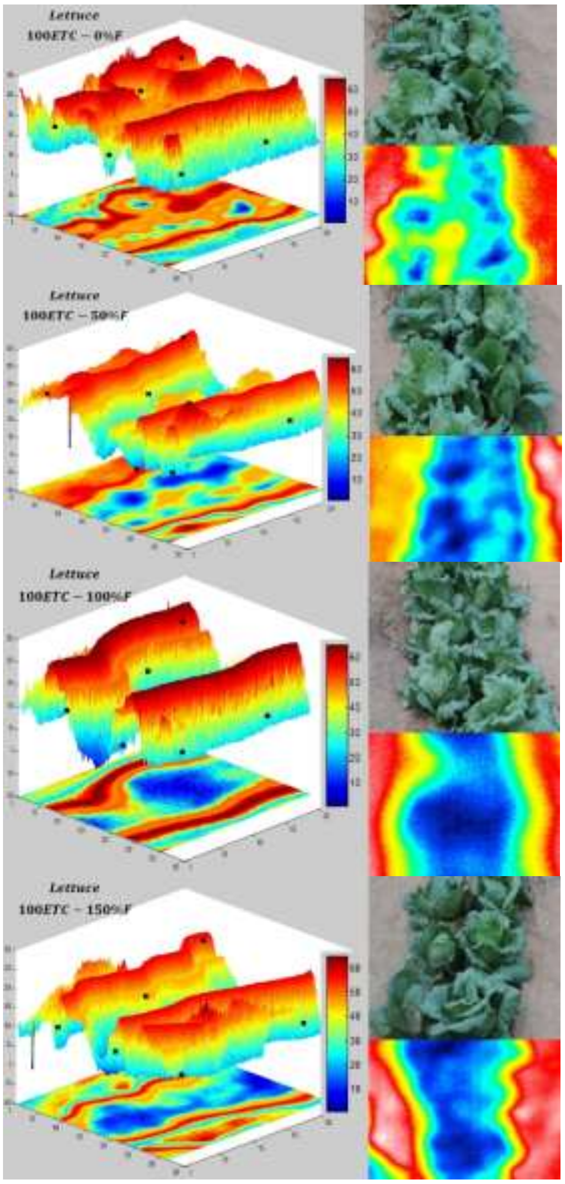

Fig. 4. Lettuce temperature recorded under different fertilization at 100% ETC irrigation levels
Source: Authors' determination.

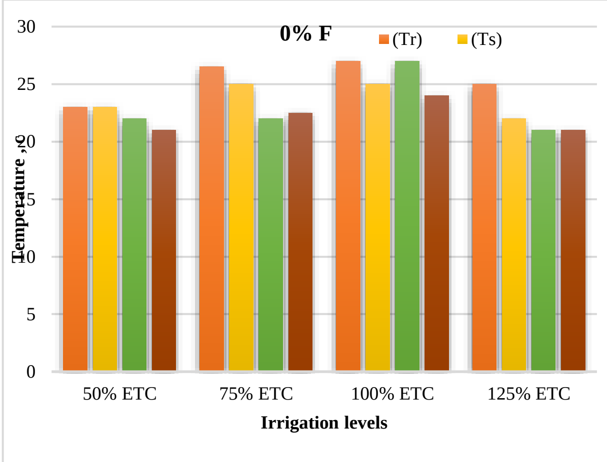

Fig. 5. Relationship between heat stress indicators and irrigation levels of lettuce crop
Source: Authors' determination.

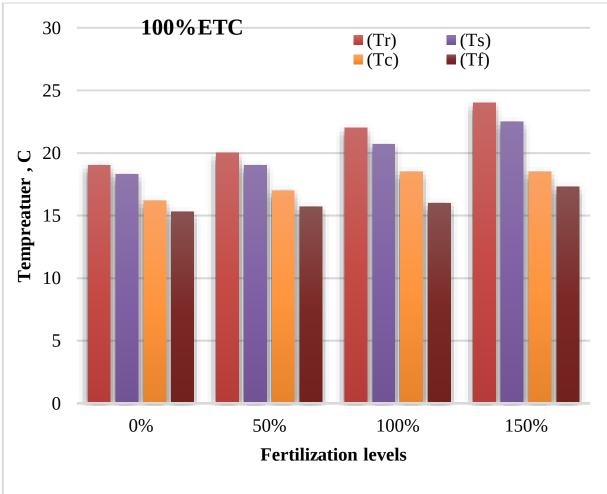

Fig. 6. Relationship between heat stress indicators and fertilization levels of lettuce crop
Source: Authors' determination.

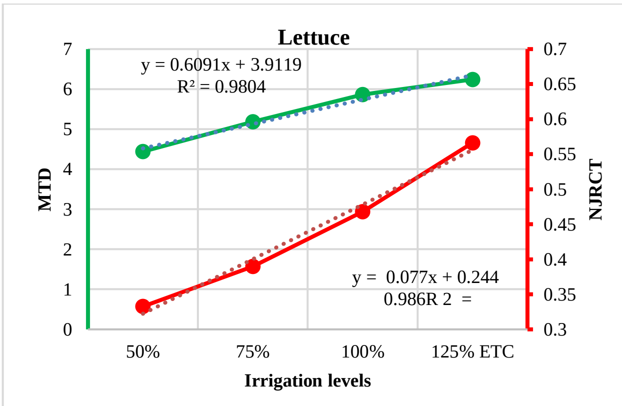

Fig. 7. Maximum temperature difference and normalized relative canopy temperature with irrigation levels of lettuce crop
Source: Authors' determination.

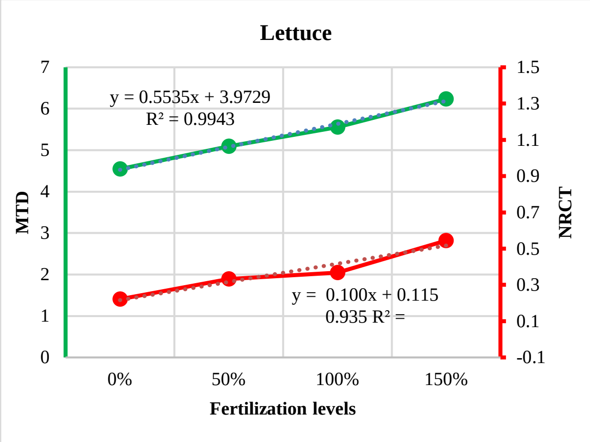

Fig. 8. Maximum temperature difference and normalized relative canopy temperature with fertilization levels of lettuce crop
Source: Authors' determination.

CONCLUSIONS

In greenhouse production systems often crop growth monitoring involving accurate quantification of plant physiological properties. plant becomes stressed when any biological or environmental factor inhibit growth and development. Stressed plants express their symptoms in many ways. It is difficult to detect and rapid accurate quantification of early symptoms with conventional measurement methods. For Lettuce plants, the results showed: At the level of fertilization (0%), the maximum values of lettuce the lowest values for MTD and NRCT were 0.673 and 0.1 °C at irrigation systems ETC 100% and ETC 50% and nitrogen fertilization systems at 0% level.. And ETC 50% and systems and nitrogen fertilization level 100%. In the fourth level of fertilization (150%), the maximum value of leaf temperature was 24, 23, 22.5, and 23 °C and NRCT was 5.5 and 3.5 °C, and the lowest values for MTD and NRCT were 0.82, 0.28 °C, and 0.018 °C at 0.018 °C. Irrigation ETC 100% and ETC 50% and systems and nitrogen fertilization standard 150%.

REFERENCES

[1]Allen, R.G., Pereira, L.S., Raes, D., Smith, M., 1998, Crop evapotranspiration: guidelines for computing crop water requirements. FAO irrigation and drainage paper 56. FAO, Rome. Accessed on 8 October, 2023..

[2]Carmo, G. J. D. S., Castoldi, R., Martins, G. D., Jacinto, A. C. P., Tebaldi, N. D., Charlo, H. C. D. O., Zampiroli, R., 2022, Detection of Lesions in Lettuce Caused by Pectobacteriumcarotovorum Subsp. carotovorum by Supervised Classification Using Multispectral Images. Canadian Journal of Remote Sensing, 48(2), 144-157. Accessed on 8 October, 2023.

[3]De Paulo, R. L., Garcia, A. P., Umezu, C. K., Camargo, A. P. D., Soares, F. T., Albiero, D., 2022, Water Stress Index Detection Using a Low-Cost Infrared Sensor and Excess Green Image Processing. Available at SSRN 4176692. Accessed on 8 October, 2023.

[4]Erdem, T., Arın, L., Erdem, Y., Polat, S., Deveci, M. Okursoy, H., Gülta¸S, H.T. , 2010, Yield and quality response of drip irrigated broccoli (*Brassica oleracea* L. var. italica) under different irrigation regimes, nitrogen applications and cultivation periods. Agric. Water Manag. 2010, 97, 681–688. [CrossRef] Accessed on 8 October 8, 2023.

[5]FAOSTAT., 2016, Food and Agriculture Organization Corporate Statistical Database. http://www.fao.org/faostat/en/#data/QC. Accessed on 8 October, 2023.

[6]Fernández, M.D., Bonachela, S., Orgaz, F., Thompson, R., López, J.C., Granados, M.R., Gallardo, M.,Fereres, E., 2010, Measurement and estimation of plastic greenhouse reference evapotranspiration in a Mediterranean climate. Irrig. Sci., 28, 497–509. [CrossRef]. Accessed on 8 October, 2023.

[7]Fernández, M.D., Bonachela, S., Orgaz, F.; Thompson, R., López, J.C., Granados, M.R., Gallardo, M. 2011,Fereres, E., Erratum to: Measurement and estimation of plastic greenhouse reference evapotranspiration in a Mediterranean climate. Irrig. Sci. 29, 91–92. [CrossRef]. Accessed on 8 Oct. 2023.

[8]Fouda, T., El-Babi, N., Ali, E., Salah, S., 2022, Assessment of Water and Nitrogen Productivity of Cabbage and Lettuce Planting Under Greenhouse J. of Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 13 (8), August, 2022. Accessed on 8 October, 2023.

[9]Gao, N., Liu, Y., Wu, H., Zhang, P.,Yu, N., Zhang, Y., Zou, H., Fan, Q., Zhang, Y., 2017, Interactive effects of irrigation and nitrogen fertilizer on yield, nitrogen uptake, and recovery of two successive Chinese Lettuce crops as assessed using 15N isotope. Sci. Hortic. 215, 117–125. Accessed on 8/10/2023.

[10]Gerhards, M., Rock, G., Schlerf, M., Udelhoven, T., 2016, Water stress detection in potato plants using leaf temperature, emissivity, and reflectance. International journal of applied Earth observation and geoinformation, 53, 27-39. Accessed on 8/10/2023.

[11]Irmak, S., Mutiibwa, D., Irmak, A., Akebauer, T.J., Weiss, A., Martin, D.L., Eisenhauer, D.E., 2008, On the scaling up leaf stomatal resistance to canopy resistance using photosynthetic photon flux density. Agric. For. Meteorol. 148 (6–7), 1034–1044

[12]Jackson, R. D., 1982, Canopy temperature and crop water stress. Adv. Irrig., 1, 43-85. Accessed on 8 October, 2023.

[13]Jones, H. G., 1990, Plant water relations and implications for irrigation scheduling.

ActaHorticulturae, 278, 67-76. Accessed on 8 Oct. 2023.
[14]Jones, H.G., 2004, Application of thermal imaging and infrared sensing in plant physiology and ecophysiology. In Advances in Botanical Research; Academic Press: Cambridge, MA, USA, 2004; Vol. 41, pp. 107–163. Accessed on 8 Oct. 2023.
[15]Li, Y., Sun, Y., Liao, S., Zou, G., Zhao, T., Chen, Y., Yang, J., Zhang, L., 2017, Effects of two slow-release nitrogen fertilizers and irrigation on yield, quality, and water-fertilizer productivity of greenhouse tomato. Agric. Water Manag. 2017, 186, 139–146. Accessed on 8 Oct. 2023.
[16]Mostafa, H.H.A., Hefzy, M., Zahran, M.M.A.A., Refai, E.F.S., 2019, Response of lettuce (Lactucasativa L.) plants to application of compost levels under various irrigation regimes. Mid East J Agric Res 8:662–674. Accessed on 8 Oct. 2023.
[17]PedreroSalcedo, F., Pérez Cutillas, P., Aziz, F., LlobetEscabias, M., Boesveld, H., Bartholomeus, H., Tallou, A., 2022, Soil Salinity Prediction Using Remotely Piloted Aircraft Systems under Semi-Arid Environments Irrigated with Salty Non-Conventional Water Resources. Agronomy, 12(9). Accessed on 8 Oct. 2023.
[18]Pinter, P., Hatfield, J., Schepers, J., Barnes, E., Moran, M.S., Daughtry, C., et al., 2003, Remote Sensing for Crop Management. Photogrammetric Engineering and Remote Sensing, 69, 647-664. Accessed on 8 Oct. 2023.
[19]Putro, A. W., Nugroho, A. P., Sutiarso, L., Okayasu, T., 2022 (June), Application of 3D reconstruction system based on close-range photogrammetry method for plant growth estimation. In IOP Conference Series: Earth and Environmental Science, Vol. 1038(1), p. 012051. IOP Publishing. Accessed on 8 Oct. 2023.
[20]Reginato, R. J., 1983, Field quantification of crop water stress. Transactions of the ASAE, 26(3), 772-0775. Accessed on 8 October, 2023.
[21]Rico-Chávez, A. K., Franco, J. A., Fernandez-Jaramillo, A. A., Contreras-Medina, L. M., Guevara-González, R. G., Hernandez-Escobedo, Q., 2022, Machine Learning for Plant Stress Modeling: A Perspective towards Hormesis Management. Plants, 11(7), 970. Accessed on 8 October, 2023.
[22]Sagan, V., Maimaitiyiming, M., Fishman, J., 2018, Effects of Ambient Ozone on Soybean Biophysical Variables and Mineral Nutrient Accumulation. Remote Sens. 10, 562. [CrossRef]. Accessed on 8 October, 2023.
[23]Shao, W., Zhao, Y., 2008, Study on effects of storage conditions on preservation of leaf-used lettuce. J. Changjiang Veg. 2009, 18, 40–42. Accessed on 8 Oct. 2023.
[24]Sublett, W., Barickman, T.,Sams, C., 2018, The effect of environment and nutrients on hydroponic lettuce yield, quality, and phytonutrients. Horticulturae 2018, 4, 48. [CrossRef]. Accessed on 8 Oct. 2023.
[25]Van Zyl, J.L., 1986, Canopy Temperature as a Water Stress Indicator in Vines. S. Afr. J. Enol. Vitic., Vol. 7(2), 53-60. Accessed on 8 October, 2023.
[26]Verma, S., Nizam, S., Verma, P. K., 2013, Biotic and abiotic stress signaling in plants. Stress Signaling in Plants: Genomics and Proteomics Perspective, Volume 1, 25-49. Accessed on 8 Oct. 2023.
[27]Wang, W., Vinocur, B., Altman, A., 2003, Plant responses to drought, salinity and extreme temperatures: towards genetic engineering for stress tolerance. Planta, 218(1), 1-14. Accessed on 8 Oct. 2023.
[28]Yuan, L., Ju, X., Zhang, L., Wang, J., Yang, Z., N.P.K, 2010, Accumulation in greenhouse soil and its effect on groundwater. Chin. J. Eco Agric., 18, 14–19. (In Chinese) [CrossRef]. Accessed on 8 Oct. 2023.
[29]Zhu, J. K., 2016, Abiotic stress signaling and responses in plants. Cell, 167(2), 313-324. Accessed on 8 Oct. 2023.

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DETECTING LEAD TOXICITY OF CABBAGE AND LETTUCE CROPS BY USING INFRARED IMAGES

Tarek FOUDA[1], Eltaher MADY[2], Nouri AL BAY[2], Ashraf SWIDAN[2], Shimaa SALAH[1]

[1]Tanta University, Faculty of Agriculture, Agriculture Engineering Department, Egypt, E-mails: tfouda628@gmail.com, Shimaa2010atia@yahoo.com
[2]Higher Institute of Agricultural Technologies in Al-Ghiran, Tripoli, Libya, E-mails: tahermady312@gmail.com, n.albay60@gmail.com, Swidanashraf349@gmail.com

Corresponding author: tfouda628@gmail.com

Abstract

The objective of this study was the possibility of using IR images to detect lead toxicity for Cabbage and lettuce crops. Lead Pb-contaminated were watered with 3 levels of (2, 4,and 6 mg/lit). To distinguish the heavy metal contamination and their impact on vegetative characteristics. For plants, the results showed a poisoning level (2mg/liter). The maximum MTD and NRCT values were 6.3 and 4, respectively. The lowest values under the same level of poisoning were 0.89 and 0.01. The greatest MTD and NRCT values at the poisoning level (4 mg/liter) were 5.3 and 2.5, respectively. The lowest values at the same level of poisoning were 0.19 and 0.07. Additionally, at the same time period with the same poisoning level (6 mg/liter), the maximum values for MTD and NRCT were 5.8 and 0.24, and the lowest values were 1.5 and 0.1. C. For lettuce plants, at a toxic dose of 2 mg/liter. The MTD and NRCT values ranged from 6.2 and 1.5 to 0.2 and 0.09 at the same amount of poisoning, respectively. Intoxication (4 mg/liter). In poisoning level (4mg/liter) the highest values for MTD and NRCT were 3.2 and 1.87 also the minimum value in the same level of poisoning were 0.2 and 0.08. And in the same period with poisoning level (6mg/liter) the highest values for MTD and NRCT were 2.88 and 1.55 also the minimum value in the same level of poisoning were 0.22 and 0.05. Linear regression analysis was performed to predict MTD and NRCT at different days were done .The maximum value of cabbage temperature of air, soil, canopy, and leaf was 35, 30, 27, and 23 °C, also showed the minimum value for the same indices were 17.4, 16.2, 15.5 and 14.5 °C, in poisoning level (2mg/liter). In poisoning level (4mg/liter) the maximum value of cabbage temperature of air, soil, canopy, and leaf were 40, 35, 28, and 31 C, also showed the minimum value for the same indices were 14, 15, 16. and 17.9 °C. While the maximum value of lettuce temperature of air, soil, canopy, and leaf was 33.6, 30.6, 28.6, and 26 °C, also showed the minimum value for the same indices were 18.9, 17.8, 15.4 and 13.6 °C, in poisoning level (2mg/liter). In poisoning level (4mg/liter) the maximum value of Lettuce temperature of air, soil, canopy, and leaf were 40, 32.7, 28.6, and 26 °C, also showed the minimum value for the same indices were 24, 21, 18. and 13.7 °C.

Key words**:** *cabbage and lettuce, Lead Pb-contaminated,, thermography, detect, heat, water, stress*

INTRODUCTION

Detection of Pb toxicity in food has long been in demand.We deliberate that infrared discriminant analysis is an effective method to accurately and quickly conduct qualitative analyses of lead toxicity for Cabbage and lettuce. This method may have applications in other crops and other pesticide residues. According to world vegetable production data, cabbage is the 4th most grown product (70,997,938 and 70,459,086 tons) in 2014 and 2015. However, according to Bursa and Turkey fresh vegetable production of cabbage is the most grown 8th (34,761- 33,476 tons and 733,081-766,675 tons) product [6].

Lettuce (*Lactucasativa* L.) is a leafy vegetable crop regarded as one of the major greenhouse-grown plants, owing to its high productivity and economic value [7].

The majority of the world's food and sustenance comes from plants. Heavy metal poisoning is a severe problem that not only affects the physiology of plants and has negative consequences that can lead to considerable production loss; it also has an impact on consumers of these diseased plants and moves up the food chain [4].

Reduced root lengths, chlorosis, and stunted growth are the non-specific signs of Pb toxicity.

Once within the cell, Pb alters the permeability of the cell membrane, hormonal changes, inhibition of several enzymes with sulfhydryl groups, decrease in water content, and altered mineral feeding. Pb poisoning slows down the growth of seedlings and prevents germination. Because lead toxicity alters the ultrastructure of the chloroplast and prevents the synthesis of vital pigments like chlorophyll and carotenoids in addition to plastoquinone, plants exposed to lead toxicity experience negative effects on their photosynthetic processes. In addition, by shutting down the Calvin cycle and electron transport chain, it also hinders the production of carbon dioxide by closing stomatal pores [11].

Heavy metal pollution, particularly in mining regions, is a serious environmental issue. Using wastewater from the Nagodi mining site as irrigation, the study compared the accumulation of heavy metals in the stems, leaves, and roots of Lactucasativa (lettuce), Brassica oleracea L. varcapitata (cabbage), and Daucuscarrotavarsativa (carrot). A pot experiment was carried out utilizing topsoil (0–20 cm). Using an atomic absorption spectrophotometer, it was determined how differently copper (Cu), lead (Pb), iron (Fe), manganese (Mn), cadmium (Cd), and zinc (Zn) accumulated and translocated in vegetable roots, stems, and leaves. The amount of Cd in D. carrota's various sections ranged from 0.070 to 0.090 mg/Kg. The stem of L. sativa has the highest content of Mn (17.30 mg/Kg). The roots of B. oleracea absorbed Fe at a high rate (139.6 mg/Kg). D. carrota roots had the highest content of copper (0.221 mg/kg), and Brassica roots had the highest concentration of zinc (35.35 mg/kg). The amount of cadmium in L. sativa and B. oleracea was less than the detection threshold (0.002 mg/Kg). The three genotypes' Pb absorption was below the detection threshold (0.005 mg/Kg). Vegetables grown with such effluent may be regarded safe for food even if heavy metals were absorbed, their quantities were below WHO/FAO approved limits [1].

Water hyacinths were used as test subjects for the effects of lead toxicity, and it was discovered that high lead concentrations severely impede plant growth. It was shown that the lead mostly builds up in the tissues of the roots, petiole, and leaves. It can be argued that water hyacinths have effective defenses against lead toxicity because the activity of antioxidant enzymes likewise rises with increased lead stress [8].

Water, soil, and plant samples were taken from the El-Khashab canal (polluted water), the Al-Bagoria canal (Nile water), and the cultivated land locations nearby in order to evaluate the effects of wastewater irrigation on soil and plants. In wastewater samples and soil under wastewater irrigation, the values of EC, SAR, available N, OM, and the majority of heavy metals (Fe, Mn, Zn, Cu, Co, Cr, and Pb) were considerably higher than in control. In order to be employed as phytoextractors, the cabbage, lettuce, and turnip acquired significant concentrations of metals in their various organs, particularly in their shoot. Most of the examined plants had heavy metal concentrations that were over the allowable range. According to this study, the El-Khashab Canal's effluent increased the OM content and soil fertility. but with dangers, as high metals can endanger organic farming. Vegetables, especially leafy ones, have a strong capacity to absorb, translocate, and accumulate large quantities of heavy metals in their edible sections, making the agricultural soils in this region unsuitable for cultivating them. However, at this location, other plants might be grown [5].

The potential human health risks of zinc (Zn), copper (Cu) and iron (Fe) contamination to native inhabitants through the food chain were assessed in Pinetown, Durban, where their irrigation processes are from the Umgeni River passing through the highly industrialised Pinetown area. River water, vegetables (cabbage and lettuce) and soil were analysed for Zn, Cu and Fe; transfer factor, health risk index anddaily intake of metals were also calculated. The concentrations of heavy metals indicated the pattern trend as Fe Zn Cu for both cabbage and lettuce. The levels of transfer factors for heavy metals ranged from 0.02 mg/kg to 1.89 mg/kg. The health risk index (0.0002–01430) was found to be within the recommended range [9]. As a practice to maintain the quality of the water, all plant-based N monitoring methods have the same essential drawback. They can give a hint as to the crop's current N status. A suitable tissue N value, however, does not predict future N fertilization needs and so cannot precisely identify locations where in-season N application can be minimized or postponed because plant diagnostics are insensitive to soil NO3-N availability. In conclusion, the average annual N uptake in commercial lettuce fields was 145 kg•ha-1, with an average daily uptake of 4 kilogram N/ha/d. Without affecting crop production, current commercial N fertilization rates can be significantly reduced [2].

Under various source-sink manipulation treatments, such as defoliation (DF), spike shading (SS), and half spikelets removal (SR), the photosynthetic properties of flag leaves as well as the accumulation and remobilization of pre-anthesis dry mass (DM) and nitrogen (N) in vegetable organs in nine wheat cultivars were investigated. The SS treatment, according to the results, boosted the flag leaf's photosynthetic rate (Pn) in source-limited cultivars, but had no appreciable impact on sink-limited cultivars. The Pn of flag leaf reduced after the SR treatment. In certain cultivars, grain DM buildup was constrained by the source, while in others, it was constrained by the sink. The source supply was the key factor limiting grain N buildup [12].

Developing an array of sensors and innovative technologies is important in meeting agricultural demands of a larger population. Current technology for measuring plant health or diagnosing disease is expensive, invasive, and often requires sending samples to central facilities for processing [10].

Canopy temperature variability (CTV) as the range (maximum minus minimum) of CT sensed with the infrared thermometer during a particular measurement period [3].

The objective of this study was the possibility of using IR images to detect Lead Pb-contaminated for Cabbage and lettuce crops.

MATERIALS AND METHODS

A greenhouse pot experiment was conducted to investigate the effect of lead Pb [heavy metals (HMs)] toxicity and availability for lettuce and cabbage. The soil was contaminated with lead by 9 doses of Pb were given with irrigation water during the period from 8/1/2021 to 11/2/2021 Pb-contaminated soil was watered with 4 levels of (0, 165, 250 and 500 mg/lit). The plants were irrigated with water contaminated with heavy metals and plant leaves for this experiment and then they were tested at Central Laboratory Tanta University laboratories. The results regarding heavy metals analysis in plant leaves are presented in Table 1.

Table 1. Heavy metals analysis for Plant leaves samples

Sample ID	Analyte	Mean
Cabbage R1	Pb 217.000	0.709 mg/L
Cabbage R2	Pb 217.000	0.647 mg/L
Cabbage R3	Pb 217.000	0.516 mg/L
Lettuce R2	Pb 217.000	26.16 mg/L
Lettuce R3	Pb 217.000	36.34 mg/L

Source: Central Laboratory Tanta University laboratories. Own determination.

Poisoning treatments Pb-contaminated

Nine doses of Lead Pb were given with irrigation water during the growth period. Pb-contaminated plant was watered with 4 levels of (0, 165, 250 and 500 mg/lit). The plants were irrigated with water contaminated with heavy metals and plant leaves with 4 levels of (0, 165, 250 and 500 mg/lit). Plant poisoning program with lead nitrate with 5 dose start on, Sunday 8/1/2021, end at 26/1/2021 Lettuce and cabbage crops were sprayed with three concentrations of lead nitrate as a control treatment only as follows: - Dose No. (1) on Sunday 8/1/2021
Dose No. (2) on Thursday 12/1/2021
Dose No. (3) on Tuesday 17/1/2021
Dose No. (4) on Saturday 21/1/2021
Dose No. (5) on Thursday 26/1/2021.

Heat Indices Basics IR

To consistently compare plant temperature across the plant age, we calculated the deviation of Tp from ambient temperature (dTp=Tp - Ta), a measure often used in field.

Canopy Temperature CT

Van Zyl J.L. (1986) Canopy temperature measured with the infra-red can be utilized successfully to indicate water stress in grapevines by comparing them to well-irrigated reference vines.

ΔT normalized canopy or leaf temperature = T_{canopy}-T_{air}orT_{leaf} - T_{air}............................(1)

MTD, maximum temperature difference= T_{leaf_max}-$T_{leaf-min}$.....................................(2)

NRCT, normalized relative canopy temperature=
$\frac{(T\ leaf - Tminimum)}{(Tmaximum - Tminimum)}$...........................(3)

RESULTS AND DISCUSSIONS

Detecting Heat Stress at different poisoning levels for Cabbage and Lettuce Crops

Using IR image to measure the temperature of air, soil, canopy, and leaf shower in Figures 1, 2 and 3) were affected by different poisoning levels for Cabbage and lettuce crops. The collaboration between the irrigation days and lead nitrate poisoning levels has an effect on cabbage and lettuce temperature indices. the results were discussed during poisoning levels 2, 4, and 6 mg/liter. During the period from 28/1/2022 to 9/2/2022, with the control level of fertilization (0%) and irrigation (100% ETC),

Detecting Heat Stress at different poisoning levels for Cabbage Crops

Figure 4 showed the maximum value of cabbage temperature of air, soil, canopy, and leaf was 35, 30, 27, and 23 °C, also showed the minimum value for the same indices were 17.4, 16.2, 15.5 and 14.5 °C, in poisoning level (2mg/liter). In poisoning level (4mg/liter) the maximum value of cabbage temperature of air, soil, canopy, and leaf were 40, 35, 28, and 31 C, also showed the minimum value for the same indices were 14, 15, 16. and 17.9 °C as showed in Figure 5, And in the same period with poisoning level (6 mg/liter) as showed in Figure 6 the maximum value of cabbage temperature of air, soil, canopy, and leaf were 35, 31.8, 27.6, and 23 °C, also showed the minimum value for the same indices were 13.8, 15, 16. and 17 °C. As showed in Figure 7 and with the poisoning level (2mg/lit)**,** showed the maximum value of maximum temperature difference, and normalized relative canopy temperature were 6.43. and 0.2 °C, also showed the minimum value for the same indices were 1.5 and 0.2 °C. Linear regression analysis was performed to predict MTD and NRCT at different days. The following equation represents the relationship.

MTD: y = 0.4167x -18577 $R^2 = 0.92$
NRCT: y = 0.009x-401.21 $R^2 = 0.9959$

As showed in Figure 8 and with the poisoning level (4mg/lit)**,** showed the maximum value of maximum temperature difference, and normalized relative canopy temperature were 6.43. and 0.2 °C, also showed the minimum value for the same indices were 1.5 and 0.2 °C.

Linear regression analysis was performed to predict MTD and NRCT at different days. The following equation represents the relationship.

MTD: y = 0.112x -04992.2 $R^2 = 0.9473$
NRCT: y = 0.0097x-430.95 $R^2 = 0.9917$

As showed in Figure 9 and with the poisoning level (6 mg/lit)**,** showed the maximum value of maximum temperature difference, and normalized relative canopy temperature were 6.43. and 0.2 °C, also showed the minimum value for the same indices were 1.5 and 0.2 °C.

Linear regression analysis was performed to predict MTD and NRCT at different days. The following equation represents the relationship.

MTD: y = 0.1x -4457.3 $R^2 = 0.9321$
NRCT: y = 0.0147x-653.92 $R^2 = 0.9938$

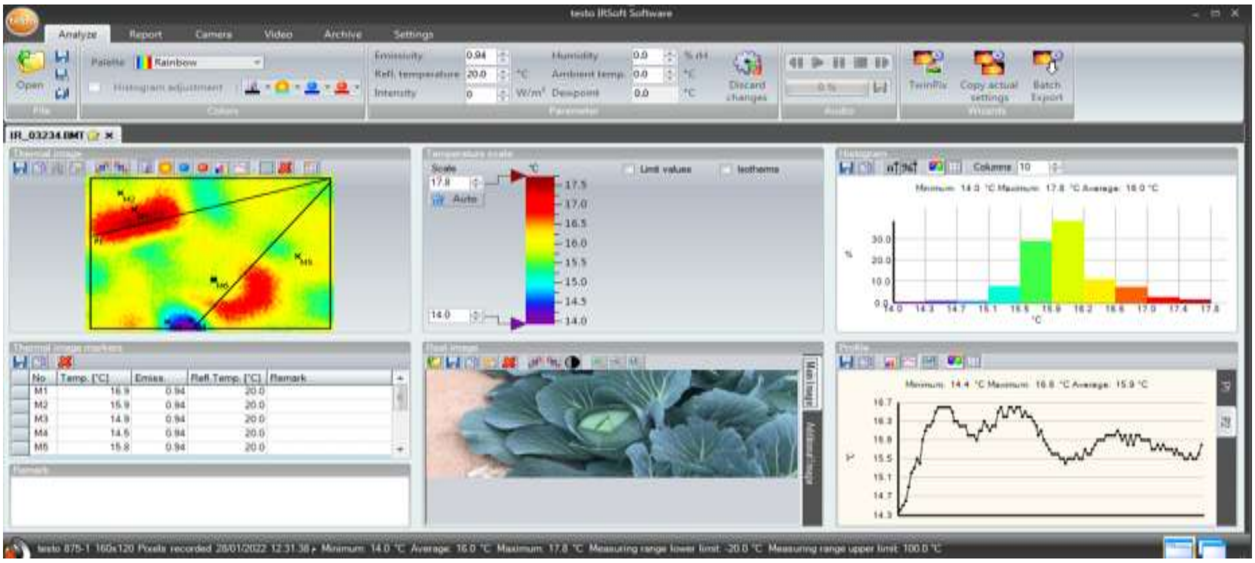

Fig. 1. IR soft interface, ribbon, work space and status bar for poisoning Cabbage Crop
Source: Own determination.

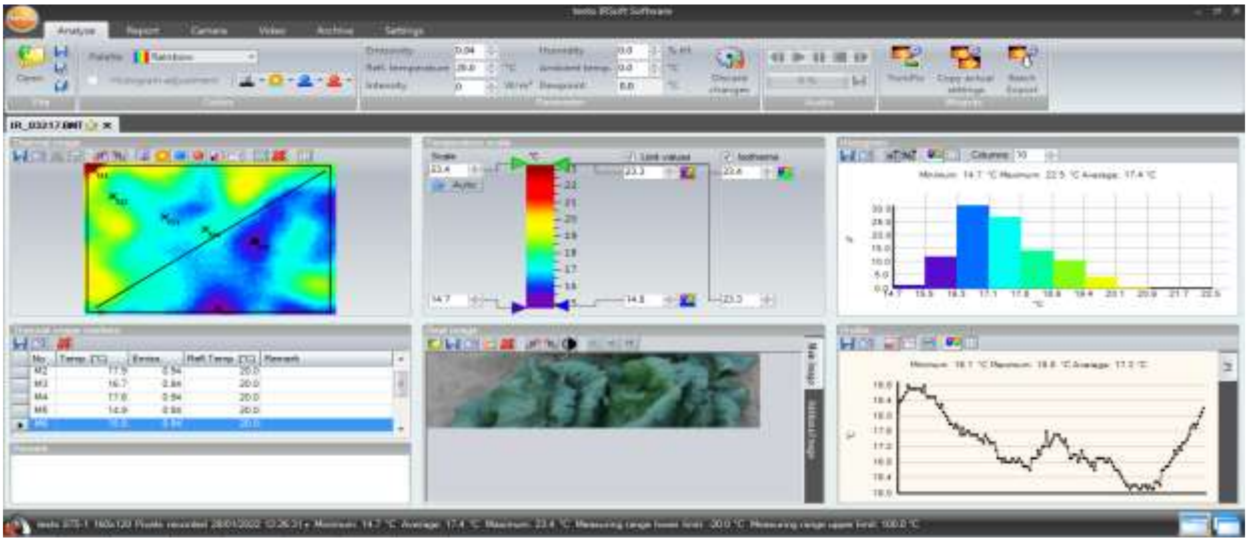

Fig. 2. IR soft interface, ribbon, work space and status bar for poisoning Lettuce Crop
Source: Own determination.

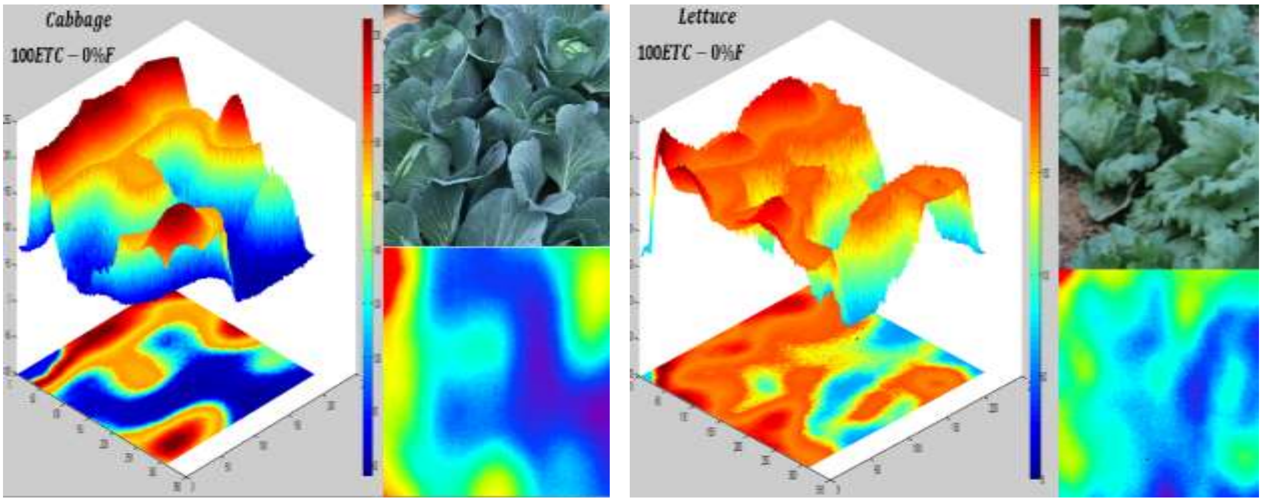

Fig. 3. Cabbage and Lettuce temperature recorded under different levels of poisoning
Source: Own determination.

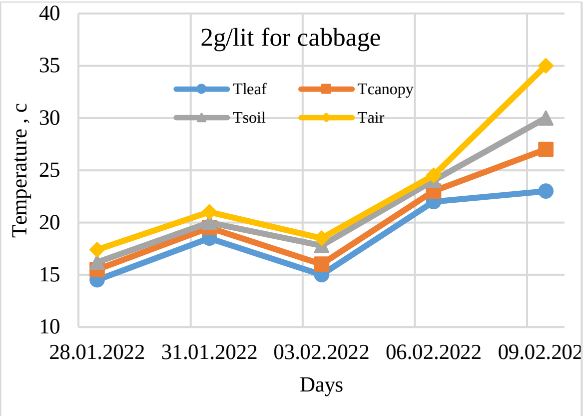

Fig. 4. Effect of poisoning level (2mg/lit) of cabbage crop on maximum temperature difference at different days
Source: Own determination.

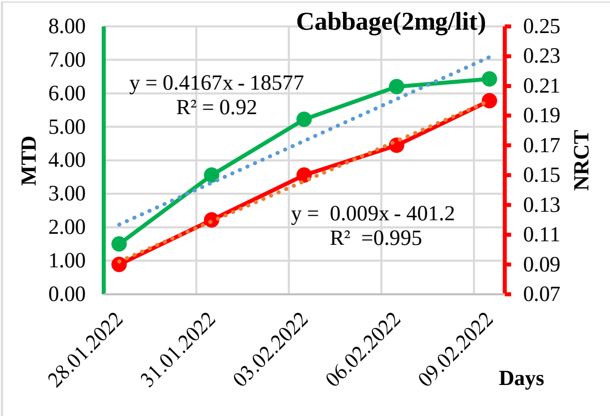

Fig. 7. Maximum temperature difference and normalized relative canopy temperature at different days of cabbage crop atpoisoning treatment(2mg/lit).
Source: Own determination.

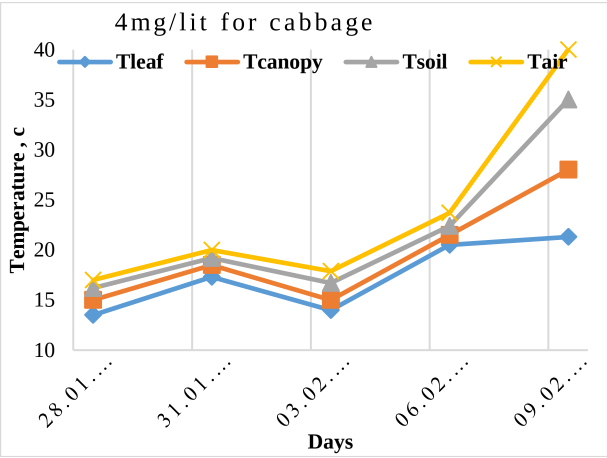

Fig. 5. Effect of poisoning level (4mg/lit) of cabbage crop on temperatures at different days
Source: Own determination.

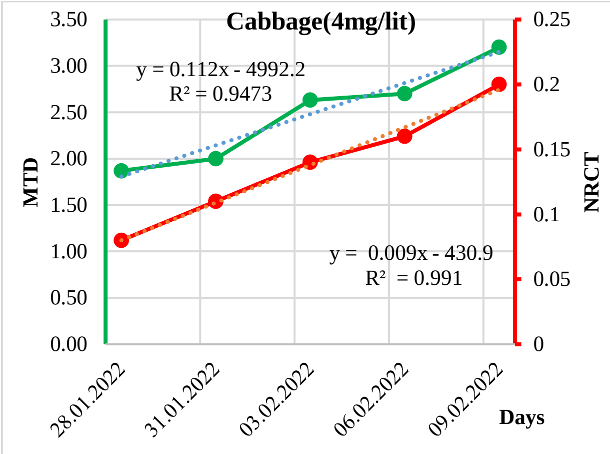

Fig. 8. Maximum temperature difference and normalized relative canopy temperature at different days of cabbage crop at poisoning treatment(4mg/lit).
Source: Own determination.

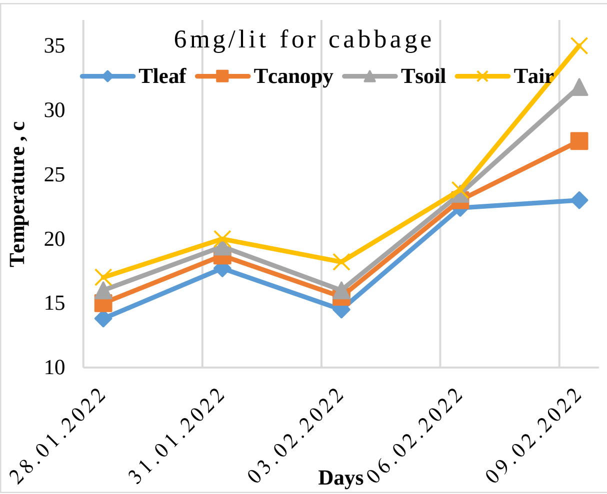

Fig. 6. Effect of poisoning level (6mg/lit) of cabbage crop on temperatures at different days
Source: Own determination.

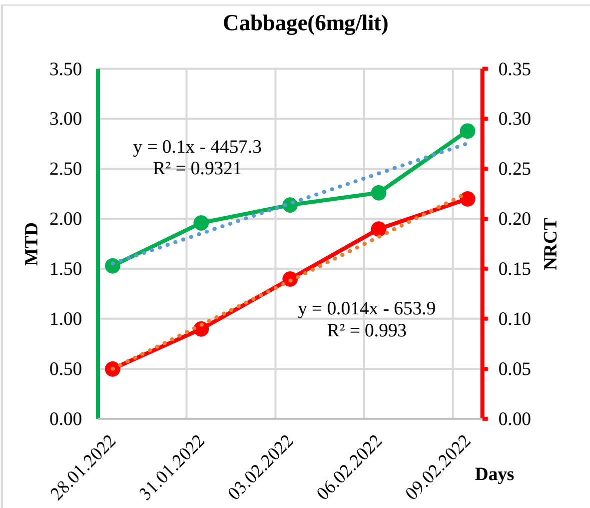

Fig. 9. Maximum temperature difference and normalized relative canopy temperature at different days of cabbage crop at poisoning treatment (6mg/lit)
Source: Own determination.

Detecting Heat Stress at different poisoning levels for Lettuce Crops

During the period from 28/1/2022 to 9/2/2022, with the control level of fertilization (0%) and irrigation (100% ETC).

Figure 10 showed the maximum value of lettuce temperature of air, soil, canopy, and leaf was 33.6, 30.6, 28.6, and 26 °C, also showed the minimum value for the same indices were 18.9, 17.8, 15.4 and 13.6 °C, in poisoning level (2 mg/liter).

In poisoning level (4 mg/liter) the maximum value of Lettuce temperature of air, soil, canopy, and leaf were 40, 32.7, 28.6, and 26 °C, also showed the minimum value for the same indices were 24, 21, 18. and 13.7 C as showed in Figure 11, And in the same period with poisoning level (6 mg/liter) as showed in Figure 12 the maximum value of lettuce temperature of air, soil, canopy, and leaf were 36, 33, 30, and 27 °C, also showed the minimum value for the same indices were 14.2, 15, 15.8. and 16.7 °C.

With the poisoning level (2 mg/lit), in Figure 13 showed the maximum value of maximum temperature difference, and normalized relative canopy temperature were 6, 3 and 0.89 °C, also showed the minimum value for the same indices were 4 and 0.018 °C. Linear regression analysis was performed to predict MTD and NRCT at different irrigation and fertilization levels. The following equation represents the relationship.

MTD: $y = 0.1867x - 18319$ $R^2 = 0.9526$
NRCT: $y = 0.073x - 3253.1$ $R^2 = 0.9742$

With the poisoning level (4 mg/lit), in Figure 14 showed the maximum value of maximum temperature difference, and normalized relative canopy temperature were 4.30. and 0.19 °C, also showed the minimum value for the same indices were 2.5 and 0.075 °C. Linear regression analysis was performed to predict MTD and NRCT at different irrigation and fertilization levels. The following equation represents the relationship.

MTD: $y = 0.1533x - 6834.5$ $R^2 = 0.9497$
NRCT: $y = 0.0097x - 432.55$ $R^2 = 0.9717$

With the poisoning level (6 mg/lit),in Figure 15 showed the maximum value of maximum temperature difference, and normalized relative canopy temperature were 5.8. and 0.24 °C, also showed the minimum value for the same indices were 1.5 and 0.1 °C.

Linear regression analysis was performed to predict MTD and NRCT at different irrigation and fertilization levels. The following equation represents the relationship.

MTD: $y = 0.3767x - 16794$ $R^2 = 0.9831$
NRCT: $y = 0.0127x - 568.2$ $R^2 = 0.9642$

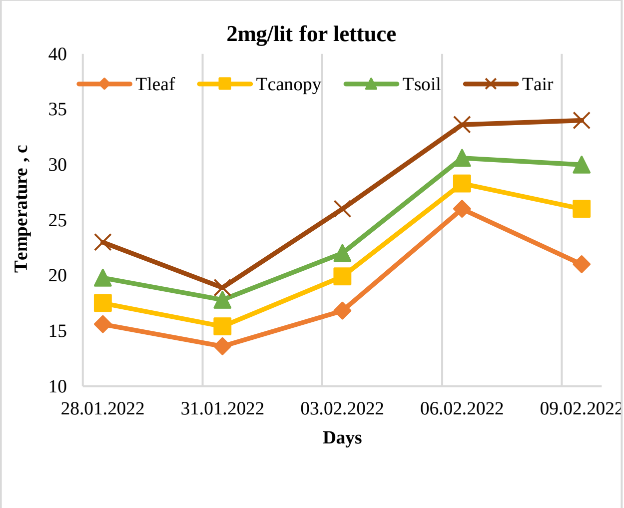

Fig. 10. Effect of poisoning level (2mg/lit) of lettuce crop on temperatures at different days
Source: Own determination.

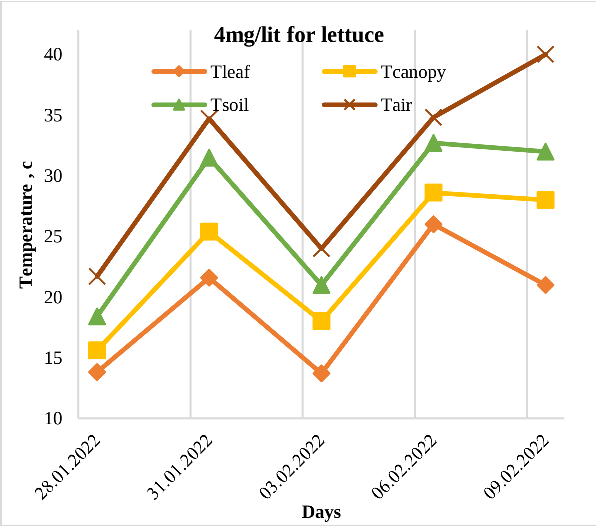

Fig. 11. Effect of poisoning level (4mg/lit) of lettuce crop on temperatures at different days
Source: Own determination.

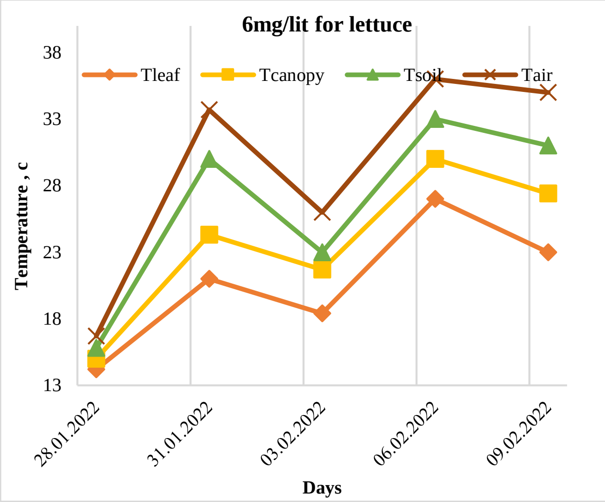

Fig. 12. Effect of poisoning level (6 mg/lit) of lettuce crop on temperatures at different days
Source: Own determination.

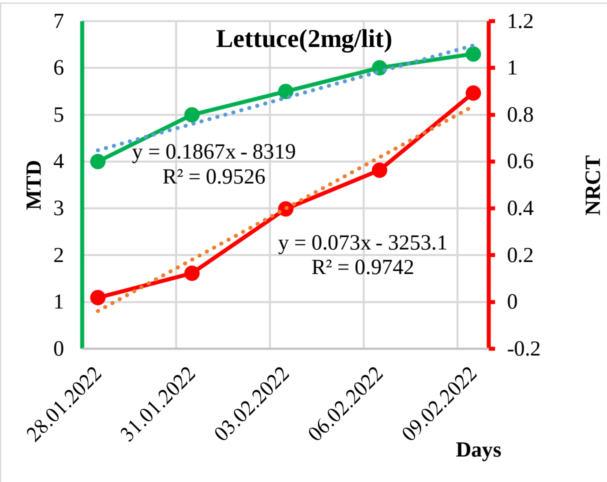

Fig. 13. Maximum temperature difference and normalized relative canopy temperature at different days of lettuce crop at poisoning treatment (2 mg/lit)
Source: Own determination.

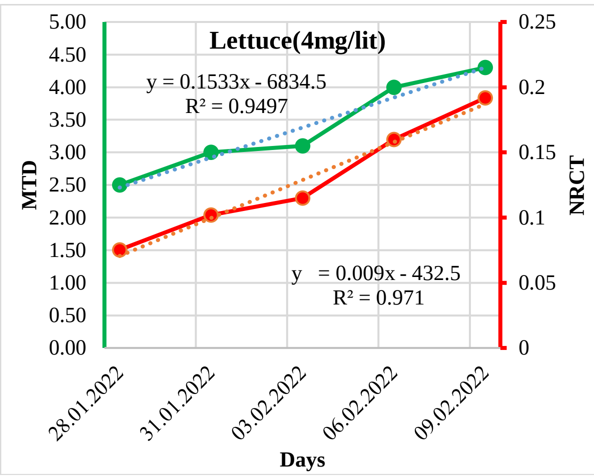

Fig. 14. Maximum temperature difference and normalized relative canopy temperature at different days of lettuce crop at poisoning treatment (4mg/lit)
Source: Own determination.

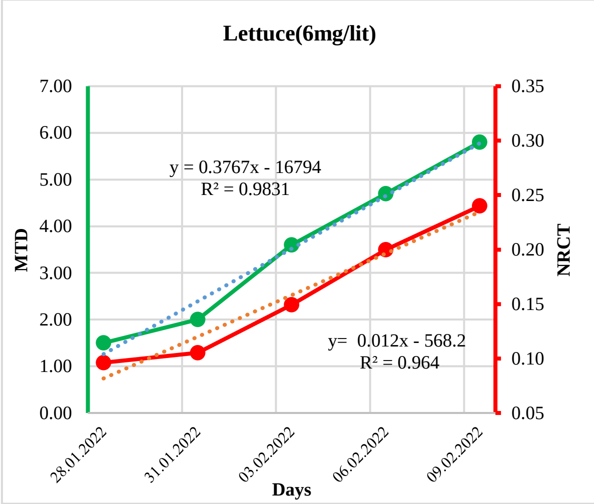

Fig. 15. Maximum temperature difference and normalized relative canopy temperature at different days of lettuce crop at poisoning treatment (6mg/lit)
Source: Own determination.

CONCLUSIONS

Infrared images can be used to detect lead contamination of cabbage and lettuce crops.

The toxicity of lead has been detected for cabbage and lettuce crops.

The results showed lead heating at different levels.

It showed a change in the temperature of leave, soil and canopy, MTD and NRCT vegetative characteristics.

As a final conclusion, the detection of heavy metal toxicity is compulsory for assuring crops growing and yield and also to deliver products of high quality ensuring food safety.

REFERENCES

[1]Boamponsem, G.A., Kumi, M., Debrah, I., 2012, Heavy Metals Accumulation In Cabbage, Lettuce And Carrot Irrigated With Wastewater From Nagodi Mining Site In Ghana. International Journal of Latest Research in Science and Technology 1(11):124-129, Accessed on 8 Oct. 2023.

[2]Bottoms, T.G., Smith, R.F., Cahn, M.D., Hartz, T.K., 2012, Nitrogen Requirements and N Status Determination of Lettuce. HortScience 47(12):1768–1774. Accessed on 8 Oct. 2023.

[3]Clawson, K.L., Blad, B.L., 1982, Infra-red thermometry for scheduling irrigation of corn. Agron. J. 74, 311-316. Accessed on 8 Oct. 2023.

[4]Elango, D., Devi, K.D., Jeyabalakrishnan, H.K., Rajendran, K., Haridass, V.K.T., Dharmaraj, D., Charuchandran, C.V., Wang, W., Fakude, M., Mishra, R., Vembu, K., Wang, X., 2022, Agronomic, breeding

and biotechnological interventions to mitigate heavy metal toxicity problems in agriculture, Journal of Agriculture and Food Research, Vol.10, 100274, https://doi.org/10.1016/j.jafr.2022.100374, Accessed on 25 August, 2023.

[5]Elliethy, M.Z., Ragab, A.A.M., Bedair, R.I., Khafagi, O.M.A., 2022, Assessment of nutrients and heavy metals content in soil and some vegetables cultivated in agricultural land around El-Khashab canal (Helwan-El Saff area). International Journal of Theoretical and Applied Research, 2022, Vol. 1(1), 27-37. Accessed on 8 Oct. 2023.

[6]Kızıloğlu, F.M., Turan, M., Sahin, U., Angin, I., Anapali, O., Okuroglu, M., 2007, Effects of wastewater irrigation on soil and cabbage plant chemical properties. J. Plant Nutr. Soil Sci. 170: 166- 172. DOI: 10.1002/jpln.200621971 Accessed on 8 Oct. 2023.

[7]Křístková, E., Doležalová, I., Lebeda, A., Vinter, V., Novotná, A., 2008, Description of morphological characters of lettuce (*Lactucasativa* L.) genetic resources. HortSci 35:113–129. https://doi.org/10. 17221/4/2008-HORTSCI, Accessed on 8 Oct. 2023.

[8]Malar, S., Manikandan, R., Favas, P. J., Sahi, S. V., Venkatachalam, P., 2014, Effect of lead on phytotoxicity, growth, biochemical alterations and its role on genomic template stability in *Sesbaniagrandiflora*: a potential plant for phytoremediation. Ecotoxicology and environmental safety, 108, 249-257. Accessed on 8 Oct. 2023.

[9]Nkosi, S.M., Msimango, N.M., 2022, Screening of zinc, copper and iron in lettuce and Chinese cabbage cultivated in Durban, South Africa, towards human health risk assessment. South African Journal of Science Volume 118| Number 11/12 November/December 2022, Accessed on 8 Oct. 2023.

[10]Roper, J. M., Garcia, J. F., Tsutsui, H., 2021, Emerging technologies for monitoring plant health in vivo. ACS omega, 6(8), 5101-5107. Accessed on 8 Oct. 2023.

[11]Sharma, P., Dubey, R. S., 2005, Lead toxicity in plants. Brazilian journal of plant physiology, 17, 35-52. Accessed on 8 Oct. 2023.

[12]Zhang, Y., Sun, N., Hong, J., Zhang, Q., Wang, C., Xue, Q., Zhou, S., Huang, Q., Wang, Z., 2014, Effect of Source-Sink Manipulation on Photosynthetic Characteristics of Flag Leaf and the Remobilization of Dry Mass and Nitrogen in Vegetative Organs of Wheat Journal of Integrative Agriculture. 2014, 13(8): 1680-1690. Accessed on 8 Oct. 2023.

RISKS ANALYSES AND CHALLENGES IN CROP MANAGEMENT IN ROMANIA

Iulian Virgil GHIULEANU, Cristiana Silvia BUZATU, Valentina Constanța TUDOR, Răzvan PANAIT, Cosmina Andreea (CARBARĂU) SMEDESCU

University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania, 59 Marasti Boulevard, District 1, 011464, Bucharest, Romania, E-mails: vghiuleanu@yahoo.com, buzatu.cristiana@managusamv.ro, tudor.valentina@managusamv.ro, panait.razvan@managusamv.ro, smedescu.cosmina@managusamv.ro

Corresponding author: cristianabuzatu@yahoo.com

Abstract

Crop management in the Romanian agriculture faces many risks and challenges that directly influence the technical and economic performance of the farms and implicitly the sustainability of the agricultural sector. These challenges range from climate change to resource issues, from plant health problems to market and regulatory issues. It is therefore essential to understand these issues in detail to develop effective crop management strategies and support Romanian agriculture in the face of a complex and changing environment. Through methods of statistical analyses and bibliographic documentation, we will identify and analyze this risks and challenges in detail in order to obtain a more comprehensive picture of the agricultural landscape in Romania in order to develop some necessary measures to reduce and, as far as possible, eliminate these risks. Data were collected from public institutions, from the official National Institute of Statistics, NIS, website Tempo-Online. The aim of crop management in Romania, as in any other country, is to ensure efficient, sustainable and profitable agricultural production. By adopting these recommendations and proactively addressing risks and challenges, agriculture in Romania can become more resilient and sustainable, further ensuring the supply of high-quality food and contributing to the country's economic development.

Key words: *climate change, adaptation to new technologies, sustainability*

INTRODUCTION

Cereals are very important at the global level to sustain population and farm animals life, and also for biofuel [15].

Crop management in Romania faces a number of risks and challenges, many of which are common to other countries, but with certain particularities. Here are some of the most significant:

-Climate change has increased the frequency and intensity of extreme weather events such as droughts, floods and temperature fluctuations. These can significantly affect agricultural production and put pressure on the irrigation system [4].

-Drought is a significant problem in Romania and water resources can become limited in dry years. Farmers face challenges in securing access to water for irrigation and crop needs. Excessive use of pesticides and chemical fertilisers can lead to pollution of soil and water resources, as well as pest resistance to pesticides. Farmers need to strike a balance between crop protection and sustainable chemical management.

-Diseases, pests and weeds can cause significant crop losses. The development of pesticide resistance and climate change can exacerbate these problems.

Sustainable soil management is a major challenge, as intensive farming can lead to soil degradation and reduced fertility. Soil conservation and the adoption of sustainable agricultural practices are becoming increasingly important.

- Today, more than ever, farmers face uncertainties related to crop prices, market demand and economic fluctuations which significantly affect the profitability and sustainability of agricultural businesses.

-Changes in agricultural policy and environmental regulations can have a significant impact on how farmers manage their crops, as they have to adapt to new legislative requirements and changing environmental standards.

-Agriculture faces a shortage of skilled labor, especially for activities such as harvesting, leading to crop losses and increased production costs.

-Romanian agriculture must face international competition and the export of agricultural products can be influenced by global factors such as tariffs and quality standards.

-Farmers need to adapt to technological developments and implement digital solutions to improve their efficiency and productivity.

Cereals business has come into a risky and uncertain situation concerning the production costs as a consequence of higher prices for farm inputs which started from 2021 fall and the situation was amplified by the conflict between Russia and Ukraine which increased fuel and energy prices with a negative effect on all the other prices in the economy [15,16].

Crop management in Romania therefore requires a strategic approach and adaptability to address these risks and challenges and to ensure sustainable and profitable agricultural production.

Cereals are raw materials of agricultural origin and are of particular importance in world agriculture, as they play an important role in human nutrition and are also a basic element in animal feed ration [3, 6, 7].

The aim of crop management in Romania, as in any other country, is to ensure efficient, sustainable and profitable agricultural production. However, there are many risks and challenges associated with crop management in the Romanian specific, and the aim of this approach is to identify them and propose solutions to manage them.

MATERIALS AND METHODS

The data that contributed to the realization of this study were collected from public institutions, from various professional websites, and from various specialized articles, and the statistical data were taken from the official National Institute of Statistics, NIS, website Tempo-Online, with the following codes:

-AGR108A - Area under main crops;
-AGR109A - Crop production of main crops;
-AGR111A - Area under vines;
-AGR114A - Number of fruit trees;
-AGR210A - Volume of agricultural labor force.

The methods used were: documentation, comparative analyses and statistical interpretation of these data.

RESULTS AND DISCUSSIONS

Risks and challenges in crop management in Romania include several issues that can affect agricultural production and the sustainability of the sector.

Here is a more detailed description of these risks and challenges:

Climate change - Romania has seen significant changes in climate patterns, with rising average temperatures and extreme weather events such as prolonged droughts and floods.

-*Drought and water management* - drought is a recurrent problem in Romania and water resources can become limited in dry years.

Protection against pests and diseases - pests and diseases can cause significant damage to crops.

-*Inefficient use of fertilisers and pesticides* - uncontrolled use of chemical fertilisers and pesticides can lead to soil and water pollution and affect the quality of agricultural products.

-*Soil sustainability and conservation* - improper use of agricultural land can lead to soil degradation and decreased soil fertility.

-*Price and demand fluctuations* - farmers face risks related to fluctuating crop prices and variable market demand.

-*Agricultural policies and regulations* - changes in agricultural policy and environmental regulations can have a significant impact on how crops are managed.

-*Lack of skilled labor* - agriculture faces a shortage of skilled labor.

The goal of crop management in Romania is to address these risks and challenges by developing sustainable production strategies, optimizing resource use, adopting advanced technologies, adapting to climate and legislative changes, and ensuring food security and profitability of the agricultural sector.

It is important that farmers, government authorities and other stakeholders work together to effectively manage these challenges and promote the sustainable development of agriculture in Romania.

Cultivated area with selected agricultural crops

The dynamics of the cultivated area with cereals for grains: common wheat, barley, grain corn and also with rape is shown for the period 2018-2022 in Table 1, based on the data collected from NIS Tempo-online.

Table 1. Areas cultivated with the main crops (total Romania) (ha)

Unit of measure: Hectare						
Crops	**Forms of ownership**	**2018**	**2019**	**2020**	**2021**	**2022**
Cereals for grains	Overall	5,257,168	5,569,090	5,338,067	5,351,547	5,183,820
	Private sector	5,237,554	5,547,499	5,313,017	5,312,011	5,144,991
	Individual farms	3,285,879	3,262,296	3,133,764	2,807,933	2,778,807
Common wheat	Overall	2,110,520	2,162,645	2,150,987	2,167,716	2,162,096
	Private sector	2,098,657	2,152,078	2,137,421	2,146,655	2,142,379
	Individual farms	1,039,689	1,022,767	1,045,415	943,076	923,894
Barley	Overall	250,797	285,065	292,079	333,007	322,730
	Private sector	249,305	283,199	289,862	330,599	320,211
	Individual farms	98,012	95,624	83,619	89,956	86,761
Grain corn	Overall	2,439,842	2,678,504	2,537,104	2,549,281	2,431,106
	Private sector	2,435,500	2,671,704	2,530,079	2,536,239	2,417,475
	Individual farms	1,779,675	1,788,167	1,720,213	1,569,108	1,579,805
Rapeseed	Overall	632,679	352,622	362,865	445,918	468,870
	Private sector	629,462	351,046	361,001	441,105	464,613
	Individual farms	145,155	120,033	97,775	105,536	90,614

Source: NIS, http://statistici.insse.ro [12].

The area under main crops is the area sown or planted in the main field in the reference agricultural year or in previous years (biennial, triennial or perennial crops) with a main crop occupying the land for most of the year.

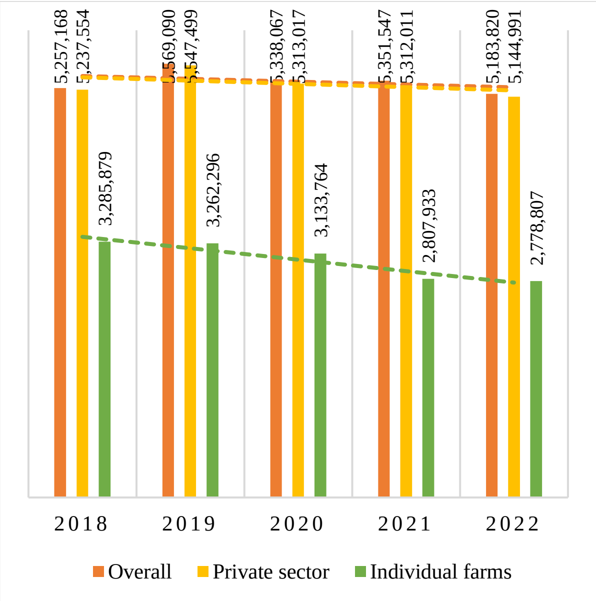

Fig. 1. Dynamics of the area with cereals for grains in Romania, 2018-2022 (ha)

Source: Own design based on the data from NIS, http://statistici.insse.ro [12].

Otherwise, we can say that grain crops are on a downward scale (especially individual crops), with percentages of -1.4% for the total number, -1.77% for the private sector and -15.43% for individual crops (between reference years 2018 - 2022) (Table 1, Fig.1).

Regarding the common wheat crop, data is presented, the scale is upward for total and private numbers, but downward for individual numbers. Expressed in percentages, these would be 2.39% for total number, 2.04% for private and -11.14% for individual (between the reference years 2018 - 2022). (Table 1, Fig. 2).

Regarding the barley culture in Romania, the total area is on an ascending scale, it is 22.29 %. In the case of the private ones there is an increase, it is 22.14 % and -11.48% in the case of the individual ones (between the reference years 2018 - 2022), (Table 1, Fig.3).

In grain maize crops, the total number is in a slight decrease of -0.36%, as well as in the case of private crops, the percentage is -0.74% and in the case of individual crops the percentages are in a much larger decrease of -11.23% (between the reference years 2018 - 2022), (Table 1, Fig.4).

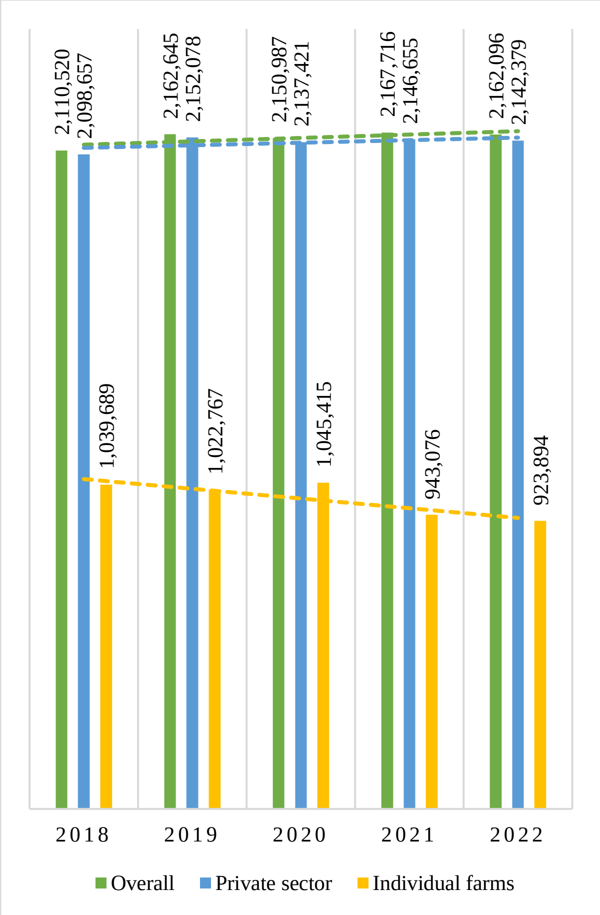

Fig. 2. Dynamics of the area with common wheat in Romania, 2018-2022 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [12].

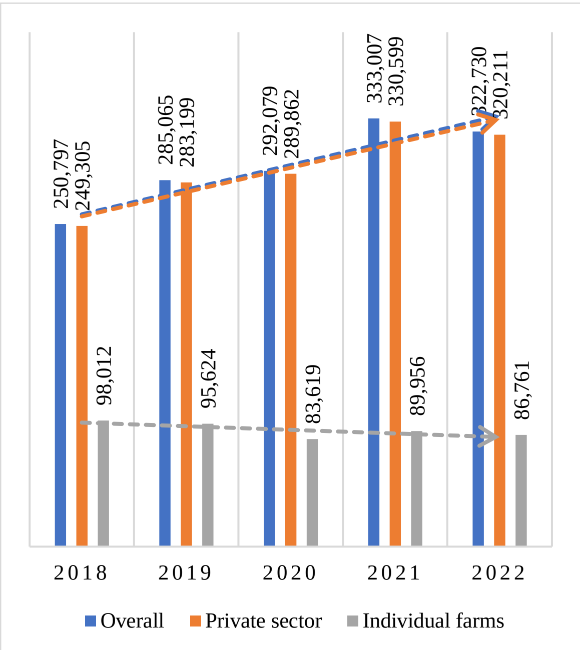

Fig. 3. Dynamics of the area with barley culture in Romania, 2018-2022 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [12].

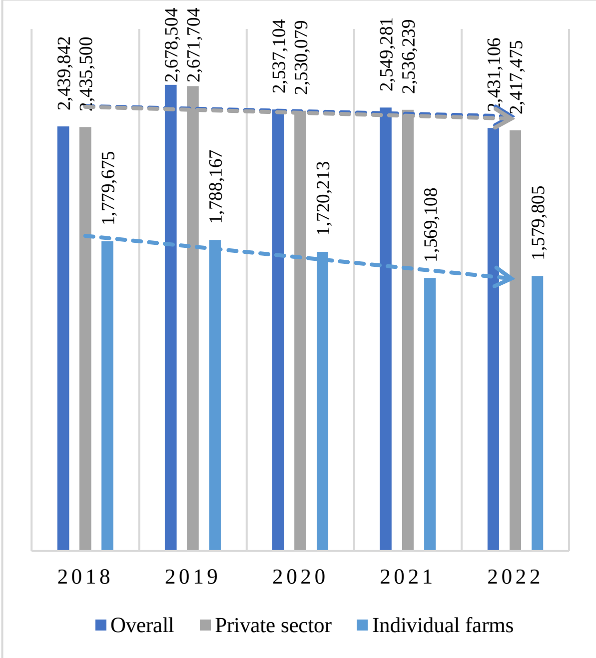

Fig. 4. Dynamics of the area with grain corn in Romania, 2018-2022 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [12].

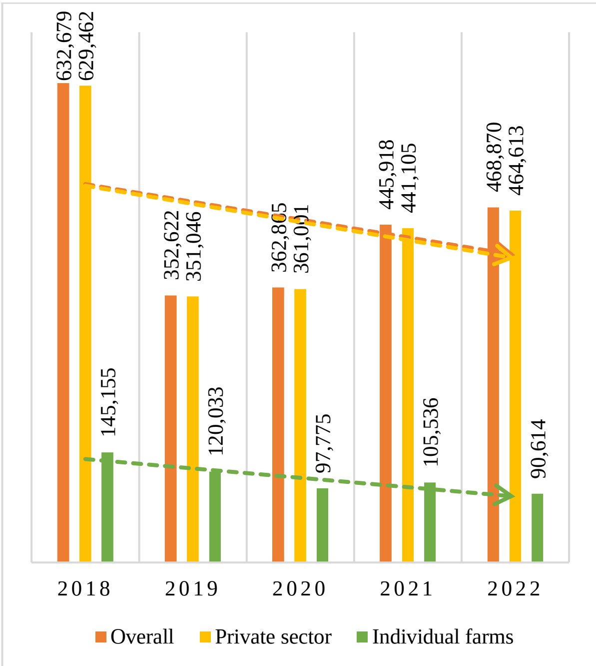

Fig. 5. Dynamics of rapeseed culture in Romania, 2018-2022 (ha)
Source: Own design based on the data from NIS, http://statistici.insse.ro [12].

The area occupied with the rape crop is founding on a descending scale, the total number being -25.89%, private -26.19% and individual -37.57% (between reference years 2018 - 2022) (Table 1, Fig.5).

Rapeseed has several advantages and benefits for both farmers and consumers. Here are some of these advantages:
-Quality oil production;
-Profitability for farmers;
-Resistance to varying climatic conditions;
-Improved crop rotation;
-Multiple uses;
-Reduced environmental impact;
-Consumer health.

It is important to note that proper management of the oilseed rape crop, including fertilization, pests and diseases, is necessary to achieve these benefits.

Agricultural crop production

The agricultural crop production in Romania by forms of ownership in 2018-2022 are shown in Table 2.

Table 2. Romania's agricultural crop production by forms of ownership (t)

Unit of measure: Tonnes						
Crops	**Forms of ownership**	**2018**	**2019**	**2020**	**2021**	**2022**
Cereals for grains	Overall	31,553,279	30,412,426	18,153,714	27,791,258	18,860,679
	Private sector	31,468,941	30,317,523	18,059,942	27,598,059	18,736,494
	Individual farms	18,801,066	16,625,966	10,476,648	12,976,951	8,952,099
Common wheat	Overall	10,122,912	10,280,578	6,381,692	10,404,076	8,661,220
	Private sector	10,074,939	10,236,235	6,333,574	10,305,391	8,589,250
	Individual farms	4,963,030	4,707,867	3,072,876	3,966,037	3,317,229
Barley	Overall	1,276,620	1,340,389	847,241	1,593,802	1,406,689
	Private sector	1,270,816	1,332,476	839,411	1,582,274	1,396,900
	Individual farms	455,169	417,640	230,594	293,735	294,228
Grain corn	Overall	18,663,939	17,432,223	10,096,689	14,820,693	8,037,134
	Private sector	18,639,932	17,397,712	10,064,743	14,748,285	8,003,334
	Individual farms	12,250,618	10,482,121	6,562,783	8,135,374	4,866,304
Rapeseed	Overall	1,610,907	798,215	780,155	1,375,067	1,229,532
	Private sector	1,605,334	794,883	776,402	1,363,116	1,220,328
	Individual farms	356,904	241,787	199,947	302,786	244,663

Source: NIS, http://statistici.insse.ro [12].

Total agricultural crop production is the physical (gross) production obtained in each period, expressed in physical units of measurement (kg, tonnes) according to the nature of the products and product groups.

Analyzing the evolution of these cultures regarding vegetable agricultural production, the expressions being in percentages, between the reference years 2018 – 2022, we observe the following:

Grain cereals = overall -40.23 %, private -40.46 %, individual -52.39.

Common wheat = overall -14.44 %, private -14.75 %, individual -33.16 %.

Barley = overall 9.25 %, private 9.03 %, individual -36.36 %.

Grain corn = overall -56.94 %, private -57.06 %, individual -60.28 %.

Rapeseed = overall -23.67 %, private -23.98 %, individual -31.45 %.

Labour force in the Romanian agriculture

The volume of labor force in Romanian agriculture, using the list of variables between 2018-2022 are shown in Table 3.

Table 3. Romania's agricultural labor force (AWU)

Unit of measurement: 1,000 annual work units (AWU)					
List of labor force variables	**2018**	**2019**	**2020**	**2021**	**2022**
Overall	1,474	1,402	1,090	1,055	1,015
Unpaid	1,314	1,243	919	879	845
Salaried	160	159	171	176	170

Source: NIS, http://statistici.insse.ro [18].

The volume of the labor force in agriculture represents the ratio of the total number of days worked by employees and self-employed persons in the agricultural industry in a year to the annual work unit expressed in days.

The annual work unit is the work done by a person in full-time equivalent in agriculture in a year (245 working days of 8 hours per day).

We observe that the total number of employees and non-employees are on a downward scale (-31.14% total, -35.69% non-employees) and the number of employees on a slight increase (5.88% employees) between the reference years 2018 - 2019.

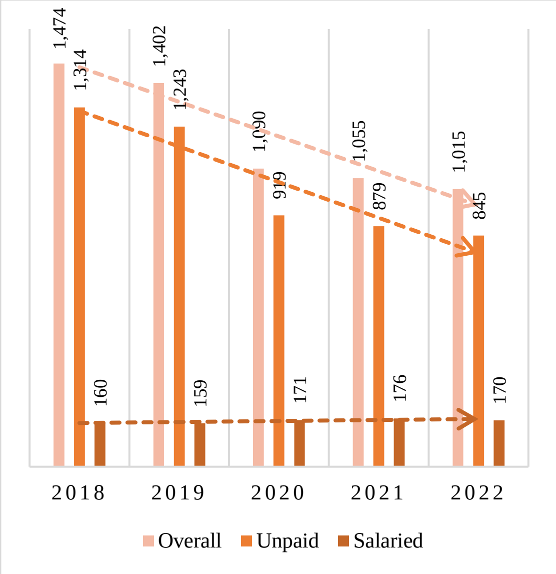

Fig. 6. Labor force dynamics in Romanian agriculture., 2018-2022 (AWU)
Source: Own design based on the data from NIS, http://statistici.insse.ro [12].

This fluctuation occurs for several reasons:
Seasonality - agriculture is often characterized by seasonality, with intensive farming activities at certain times of the year, such as planting and harvesting. Many agricultural workers are employed only during the agricultural season and leave the sector during the rest of the year.
Demographic trends - population migration to cities and other sectors of the economy may reduce the number of people interested in working in agriculture, especially in rural areas.
Crop demand and prices - fluctuations in prices and demand for agricultural crops can influence employment levels. Low prices may lead farmers to reduce labor costs.
Subsidies and government policies - agricultural subsidies and government policies can influence the number of people employed in agriculture.
Education and skills of the workforce - the availability of skilled agricultural workers may vary depending on their level of education and training. If there is a limited supply of skilled labor, this may affect the number of employees.
Unforeseen events - unforeseen situations such as pandemics or conflicts can have a significant impact on employment in agriculture [19].
Fluctuations may vary from one region to another and may be influenced by multiple pedoclimatic, economic, social, technological, geopolitical, etc, factors.
Among other factors, work force is an important capital of which depends the performance in agriculture and agribusiness [9].
The areas under vines in Romania by form of ownership between 2018-2022 are shown in Table 4.

Table 4. The areas under vines in Romania (ha)

Unit of measurement: Hectare						
Categories of vineyards	**Forms of ownership**	**2018**	**2019**	**2020**	**2021**	**2022**
Total - live on fruit	Overall	177,497	178,230	167,346	165,553	161,045
	Private sector	175,662	177,023	165,489	163,914	159,872
	Individual farms	149,025	153,656	141,919	138,782	136,491
Grafted vines on fruit	Overall	92,160	91,799	90,420	88,725	87,056
	Private sector	90,650	90,595	89,244	87,087	85,959
	Individual farms	65,259	69,765	67,467	64,552	64,247
Hybrid vines in fruit	Overall	85,336	86,431	76,926	76,827	73,990
	Private sector	85,011	86,428	76,245	76,827	73,913
	Individual farms	83,766	83,891	74,452	74,230	72,244
Table grapes	Overall	6,335	6,284	6,165	6,270	6,203
	Private sector	6,296	6,244	6,134	6,228	6,147
	Individual farms	5,515	5,520	5,521	5,433	5,434
Wine grapes	Overall	171,162	171,947	161,181	159,283	154,842
	Private sector	169,366	170,778	159,355	157,685	153,725
	Individual farms	143,510	148,136	136,398	133,349	131,057

Source: NIS, http://statistici.insse.ro [12].

The area planted with vines, under vines is the area planted with grafted and hybrid vines, under vines [13].
Vines in bearing - vine plantations that come into bearing after 3 years from planting; these include grafted (noble) vines with wine grape varieties and table grape varieties and vine

plantations with direct producer hybrids (domestic or imported varieties grown on own roots), including those from family gardens. The number of hectares between the reference years 2018 - 2022, expressed in percentages, are the following:
Total - live in fruit = overall -9.27%, private -8.99%, individual -8.41%.
Grafted vines in bearing = overall -5.54 %, private -5.17 %, -1.55 % individual.
Hybrid grafted vines = overall -13.3 %, private -13.05 %, -13.75 % individual.
Table grapes = overall -2.08 %, private -2.37 %, individual -1.47 %.
Wine grapes = overall -9.53 %, private -9.24 %, individual -8.68 %.
The number of fruit trees by form of ownership between 2018-2022 are shown in Table 5.

Table 5. The number of fruit trees in Romania (count)

Unit of measure: Count						
Fruit tree categories	**Forms of ownership**	**2018**	**2019**	**2020**	**2021**	**2022**
Entire	Overall	78,929,084	73,866,869	73,586,476	74,914,434	76,278,474
	Private sector	78,408,286	73,340,212	73,115,452	74,237,894	75,524,215
	Individual farms	67,394,992	67,366,224	67,430,798	66,872,533	68,022,003
Plums trees	Overall	34,534,473	34,459,654	34,214,693	34,195,891	34,210,196
	Private sector	34,487,609	34,374,102	34,144,962	34,101,969	34,157,188
	Individual farms	33,379,279	33,349,797	33,129,307	32,940,859	33,218,798
Apple trees	Overall	28,689,430	23,655,918	24,014,734	24,950,006	24,931,036
	Private sector	28,370,412	23,369,784	23,712,983	24,609,762	24,484,981
	Individual farms	20,714,257	20,690,368	20,949,972	20,832,169	21,515,429
Pear trees	Overall	3,192,913	3,147,062	3,313,645	3,331,620	3,247,171
	Private sector	3,187,765	3,143,750	3,309,028	3,323,803	3,238,024
	Individual farms	3,022,360	3,013,041	3,001,308	2,993,501	2,982,987
Peach trees	Overall	1,135,512	1,184,277	1,095,561	1,142,911	1,094,746
	Private sector	1,046,788	1,093,852	1,042,530	1,045,315	995,919
	Individual farms	782,107	783,072	783,070	773,730	772,757
Nectarine trees	Overall	28,797	39,944	52,855	55,586	31,797
	Private sector	28,757	37,817	52,406	52,812	31,723
	Individual farms	24,721	24,551	24,347	20,213	21,506
Cheery tree and Sour cheery tree	Overall	5,323,535	5,333,720	5,404,675	5,354,406	5,500,738
	Private sector	5,288,979	5,300,079	5,388,690	5,300,582	5,465,439
	Individual farms	4,735,419	4,742,193	4,821,091	4,631,025	4,697,349
Apricot tree and Wild apricot tree	Overall	2,076,955	2,098,513	2,080,913	2,094,294	2,177,181
	Private sector	2,060,142	2,083,409	2,067,445	2,067,411	2,149,413
	Individual farms	1,702,641	1,706,332	1,704,191	1,677,205	1,675,462
Walnuts trees	Overall	1,918,156	1,936,247	2,006,104	2,088,057	2,351,612
	Private sector	1,913,967	1,932,968	2,000,718	2,067,217	2,342,651
	Individual farms	1,767,097	1,844,230	1,784,246	1,777,583	1,879,724

Source: NIS, http://statistici.insse.ro [12].

Orchards have an important role in Romania's horticulture and food safety providing fruit for the population, and processing industry, nectar for bee families which help the pollination and income for tree growers [2].
The number of fruit trees is the total number of fruit trees in orchards and orchard trees in the cultivated area including home gardens, expressed in number of trees.
Analyzing the number of fruit trees by category, between the reference years 2018 – 2022, we observe the following:
Entire = overall -3.36 %, private -3.68 %, individual 0.92 %.
Plums trees = overall -0.94 %, private -0.96 %, individual -0.48 %.
Apples = overall -13.1 %, private -13.7 %, individual 3.72 %.
Pear trees = overall 1.67 %, private 1.55 %, individual -1.3 %.
Peaches trees = overall -3.59 %, private -4.86 %, individual -1.2 %.
Nectarine trees = overall 9.43 %, private 9.35 %, -13.01 % individual -13.01 %.
Cheery tree and Sour cheery tree = overall 3.22 %, private 3.23 %, individual -0.8 %.
Apricot tree and wild apricot tree = overall 4.6%, private 4.15%, individual -1.6%.
Walnuts trees = overall 18.43 %, private 18.3 %, individual 5.99 %.

Solutions to these risks and challenges

Farmers have to decide on what surfaces these crops could be cultivated and what new technologies could be implemented and estimate yields and production costs [17]. Biodiversity should be extended and improved to help the farmers to increase efficiency in cereals production [11,15].

To address the risks and challenges of crop management in Romania, farmers and policy makers can implement a number of solutions and strategies. Here are some of these solutions:

-*Precision farming* - the use of precision farming technologies such as GPS systems, drones and sensors can help farmers monitor and manage crops more efficiently, reducing inefficient use of resources such as water and fertilizers [5].

Conservative agriculture could be an option for crop farming assuring increased yields, with low costs, labor savings, carbon sequestration, healthier soils, improved biodiversity, sustainability [14, 18, 8].

-*Efficient irrigation* - modern irrigation systems can help manage water resources efficiently, ensuring that each crop receives the right amount of water for its needs.

-*Hybrids and varieties resistant to extreme weather conditions* - choosing hybrids and varieties resistant to drought, extreme temperatures and disease can help minimize losses in adverse climatic conditions.

How are natural ecosystems supplied with nitrogen when they sometimes function în extremely difficult soil conditions.

Nitrogen is the basic element of life construction, and it is found in amino acids, peptides, proteins, including nucleic acids, that make life and its reproduction available [1].

-*Pest and disease monitoring and management* - implementing a pest and disease monitoring program and using biological control methods can reduce the negative impact of these threats.

-*Use fertilizers and pesticides responsibly* - farmers can follow fertilizer and pesticide application recommendations and follow integrated pest management practices to reduce negative environmental impacts.

-*Sustainable farming practices* - adopting sustainable farming practices such as conservation tillage, crop rotation and mulching can help maintain soil fertility and conserve natural resources.

-*Crop diversification* - growing more than one type of crop on a farm can reduce the risk associated with price and demand fluctuations for a single crop.

-*Strategic water resource planning* - developing strategies for efficient water storage and use can help manage droughts and water scarcity.

-*Investment in agricultural education and training* - to effectively manage new technologies and farming practices, farmers can benefit from agricultural training and continuing education.

-*Access to agricultural insurance* - agricultural insurance can help farmers cope with losses due to adverse weather or other risks, providing a financial safety net.

-*Agricultural cooperation and partnerships* - farmers can join together and cooperate to benefit from economies of scale, gain access to more efficient technology and resources and strengthen their market position.

-*Upgrading agricultural infrastructure* - upgrading agricultural infrastructure, including irrigation networks, roads and storage, can help improve efficiency and access to markets.

The unitary and/or combined approach of these solutions can help Romanian agriculture to successfully face risks and challenges, ensuring sustainable and efficient agricultural production.

Solutions to attract labor force

Attracting and retaining labor in agriculture in Romania can be challenging due to various factors such as intense physical labor, seasonality and competition with other sectors for skilled workers [10]. However, there are several solutions that can help attract and retain labor in agriculture:

-*Competitive wages and benefits* - offering competitive wages and benefits can attract workers interested in the agricultural sector. Farmers can offer competitive wages, seasonal bonuses and benefits such as health and medical insurance.

-*Training and professional development courses* - providing training and professional development courses can increase the skills of the workforce and make farming more attractive to those who want to learn new skills.

-*Adequate housing and living conditions* - farms can provide adequate housing and living conditions for seasonal workers, which can reduce some of their housing concerns and improve their comfort.

-*Flexible working hours* - offering flexible working hours can be an advantage, especially for workers who want more autonomy in managing their time.

-*Opportunities for advancement* - farmers can offer advancement opportunities for workers eager to develop their careers in agriculture. This may include promotion to supervisory or management positions.

-*Partnerships with educational institutions* - farmers can develop partnerships with schools or agricultural education institutes to attract graduates and offer jobs to young people interested in starting their careers in agriculture.

-*Social networking and online recruitment* - using online recruitment platforms and social media to reach out to potential workers can be effective, particularly in attracting young people and those interested in technology.

-*Promoting working in agriculture as a viable career* - farmers and agricultural organizations can work together to promote agriculture as a viable and rewarding career through awareness campaigns and career guidance events.

-*Working with employment agencies* - farmers can work with employment agencies to identify and recruit suitable candidates for available positions.

-*Positive organizational climate* - creating a positive and supportive work environment where workers feel valued and engaged can contribute to long-term workforce retention.

Attracting and retaining a workforce in agriculture requires a comprehensive approach that addresses competitive wages, living and working conditions, and career development opportunities. Agriculture can offer satisfying and stable jobs for those willing to work in the sector, and so these solutions can help make it more attractive.

Strategies applicable to crops established on large and small areas in Romania

For crops established on large areas, as well as for those established on small areas in Romania, there are strategies that can contribute to agricultural success and maximize yields. Here are some key strategies for both categories of farmers:

For crops established on large areas:

Detailed farm planning - large growers need to develop detailed farm plans that include crop rotation, water management, fertilizer and pesticide use and precision farming technologies.

Investment in technology - the use of state-of-the-art technologies such as modern tractors, GPS systems and farm sensors can increase efficiency and productivity.

Efficient management of water resources - the development of efficient irrigation systems and careful monitoring of water resources can help manage drought and water scarcity.

Sustainability and environmental protection - large farmers should adopt sustainable farming practices and protect the environment through responsible resource management and pollution reduction.

Diversification of farming activities - diversification can include growing more than one crop or even expanding into related sectors such as livestock farming to minimize risks.

Cost saving and financial management - large farmers should implement effective cost saving practices and have good financial management to maximize profitability.

The circular economy is a concept that can no longer be considered a novelty, but which is beginning to gain more and more visibility in the context of the pressure that climate change issues have on the political and economic environment, but also on the planet's inhabitants who are increasingly concerned about the effects that uncontrolled consumption, unsustainable practices and irresponsibility have on the environment [5].

For crops established on small areas*:*

Farm cooperation and partnerships - smallholders can benefit from collaborating and partnering with other farmers to achieve economies of scale and gain access to more efficient resources and technology.

Crop diversification - growing more than one type of crop can reduce the risk of loss in the event of crop failure and ensure a steady stream of income.

Selling direct to consumers - selling direct at fairs, markets or through a delivery system can increase profitability and build loyal relationships with customers.

Organic farming and quality products - small farmers can invest in organic farming and the production of high-quality products, which can bring better prices and attract consumers interested in healthy food.

Education and training - small farmers can benefit from education and training to learn new farming techniques and skills to increase their efficiency.

Access to resources and funding - small farmers can seek funding and resources to grow their business, including government support programs or agricultural grant funding. Regardless of farm size, a sustainable approach, innovation and adaptability to environmental and market changes are key to success in farming in Romania.

S.W.O.T. Analysis

The S.W.O.T. analysis of risks and challenges in crop management in Romania can provide a clearer picture of the situation and how policy makers can address these issues. In Table 6 is presented a S.W.O.T. analysis of the risks and challenges in Romanian agriculture.

Table 6. SWOT Analysis of the risks and challenges in Romanian agriculture

Strengths	**Weaknesses**
Rich natural resources - Romania has fertile land and water resources, which offer potential for rich agricultural production. *Traditional farming experience* - Romanian farmers have a rich farming tradition and knowledge passed down from generation to generation. *Predominance of commercial societies* in working the land- On about 54% of the arable land there are applied modern technologies. *High potential production* - Romania among the top EU producers of wheat, maize and sunflower seeds.	*Un corresponding farm structure*- average farm size 4.4 ha and economic size Euro 4,029/farm standard output, the smallest in the EU. 94% farms have below 5 ha. *The dominance of family subsistence and semi-subsistence farms* lacked of capital. *Aging of the agriculturists* and young work force migration to cities or abroad *Low training level of the agriculturists* *Lack of infrastructure in terms of irrigation systems* *Vulnerability to climate change* - Romanian agriculture is vulnerable to climate change, such as droughts, floods and extreme temperatures. *Water resource management* - water resource management in agriculture is sometimes inefficient, with risks related to drought and depletion of water resources. *Excessive use of pesticides and fertilizers* - uncontrolled use of pesticides and chemical fertilizers can have a negative impact on the environment.
Opportunities	**Threats**
Modernization opportunities - there are significant opportunities for upgrading agricultural infrastructure such as irrigation systems and storage. *Precision farming and innovative technologies* - Implementing precision farming technologies such as IoT sensors and monitoring systems can increase efficiency and productivity. *EU common market and other beneficiaries on the international market* - exporting Romanian agricultural products to the EU countries and other beneficiaries all over the world is an opportunity to increase revenue. *Sustainability and organic farming* - pursuing a sustainable approach to agriculture can bring long-term benefits, such as increased demand for organic products.	*Climate change* - climate change may worsen the risks of drought, floods and extreme temperatures, putting additional pressure on agriculture. *Price and demand fluctuations* - Fluctuating crop prices and volatile demand can affect farmers' incomes. *Agricultural regulations and policies* - Changes in agricultural policies and environmental regulations can have a significant impact on Romanian agriculture. *Lack of skilled labor* - lack of skilled labor can affect productivity and production costs. *Globalization and competition* - Romanian agriculture faces global competition, which can affect prices and access to markets.

Source: Own conception.

S.W.O.T. analysis can help farmers and policy makers in Romanian agriculture to develop effective strategies to exploit potential opportunities, minimize weaknesses and cope with external threats.

CONCLUSIONS

In conclusion, crop management in Romania faces multiple risks and challenges that can affect agricultural production and the sustainability of the sector.

Climate change, drought, pests and diseases, inefficient use of fertilizers and pesticides, and fluctuations in prices and demand are just some of the threats facing farmers.

To address these challenges and manage the risks, the following recommendations are needed:

Precision farming and technology - farmers should invest in precision farming technologies, such as sensors and monitoring systems, to manage resources more efficiently and monitor crop health.

Water resource management - developing efficient irrigation systems and managing water resources properly can reduce the risk of drought and help maintain production.

Promoting sustainability - farmers should adopt sustainable farming practices, such as conservation agriculture and crop rotation, to protect the environment and maintain soil fertility.

Crop diversification - growing more than one type of crop can reduce the risk associated with price and demand fluctuations.

Education and training - investing in agricultural education and continuous training can help farmers manage technological change and adopt best practices.

Agricultural insurance - agricultural insurance can provide a financial safety net in case of losses due to risk factors.

Promoting agriculture as an attractive career - It is important to promote agriculture as a viable and rewarding career to attract new talent to the sector.

Collaboration and innovation - farmers should collaborate with each other and with research institutions to develop and implement innovative risk management solutions.

By adopting these recommendations and proactively addressing risks and challenges, agriculture in Romania can become more resilient and sustainable, further ensuring the supply of high-quality food and contributing to the country's economic development.

REFERENCES

[1]Berca, M., Robescu,V.O., Buzatu, C.S., 2009, Biological model of associative fixation of atmospheric nitrogen in cereal crops and reduction of industrial fixed nitrogen, Annals Food science and Technology, Vol. 10(1), www.afst.valahia.ro, pp. 97-101.

[2]Coadă, C.S., Procop, C.M., Tudor, V.C., 2021, Research on the evolution of fruit farms in Romania, in the period 2005-2016, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 21(2), 177-182.

[3]Coadă, C.S., Tudor, V.C., 2021, Research on the association of fruit growers in Romania, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 21(2), 183-190.

[4]Domșa, D., 22.12.2021, Lifestyle interventions based on risk phenotype improve diabetes prevention, https://www.romedic.ro/interventiile-in-stilul-de-viata-ce-se-bazeaza-pe-fenotipul-de-risc-imbunatatesc-prevenirea-diabetului-0P40709, Accessed on 16.09.2023.

[5]Folnović, T., Digital Blog, Digitising farms for successful EU-funded projects, Agriculturehttps://www.agrivi.com/ro/blog/digitalizare a-fermelor-pentru-proiecte-de-succes-cu-fonduri-ue/, Accessed on 17.09.2023.

[6]Gimbășanu (Dumitru), G.F., Rebega, D.E., Tudor, V.C., 2021, Comparative analysis of the main technical indicators for sunflower crop in Romania, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 21(2), 267-274.

[7]Gimbășanu,G.F., Tudor, V.C., 2019, The evolution of average prices for agricultural products in Romania during 2007-2017, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 19(2), 161-166.

[8]Grigoras, M.A., Popescu, A., Pamfil, D., Has, I., Gidea, M., 2012, Conservation Agriculture versus Conventional Agriculture. The influence of Agriculture System, Fertilization and Plant Protection on Wheat Yield-A Study Case in the Transilvania Area, Romania, Notulae Botanicae Horti Agrobotanici, Cluj-Napoca, Romania, Vol.40(1):188-194.

[9]International Work, 11 July 2022, Agricultural workforce: an important issue for the success of your business, https://work-finder.eu/forta-de-munca-in-

agricultura-un-aspect-important-pentru-succesul-afacerii-tale/, Accessed on 13.09.2023.

[10]Marcuță, A., Tindeche, C., Tudor, V.C., Carbarău (Smedescu), C., Smedescu, D., Marcuță, L., 2021, Application of the principles of the circular economy in conventional agriculture. Case study - pesticide waste recycling, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 21(2), 375-382.

[11]Marcuta, L., Popescu, A., Tindeche, C., Fintineru, A., Smedescu, D., Marcuta, A., 2023, Study on the evolution of fair trade and its role in sustainable development, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 23(2), 427-436.

[12]NIS, Tempo online, Statistical data, http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table, Accessed on 12.09.2023.

[13]NIS, Mureș county, 2018, Area under vines, by forms of ownership, Statistical data, https://mures.insse.ro/wp-content/uploads/2020/01/AGR111A_2018.pdf, Accessed on 12.09.2023

[14]Popescu, A., Dinu, T.A., Stoian, E., Şerban, V., 2023, Climate change and its impact on wheat, maize and sunflower yield in Romania in the period 2017-2021, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 23(1), 587-602.

[15]Popescu, A., Stanciu, M., Şerban, V., Ciocan, H.N., 2022, Cereals production and price in the European Union, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22(4), 565-578.

[16]Popescu, A., Tindeche, C., Marcuta, A., Marcuta, A., Hontus, A., 2023, Concentration of standard output and number of farms in the European Union based on the economic dimension, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 23(1), 619-626.

[17]Popescu, A., Tindeche, C., Marcuta, A., Marcuta, L., Hontus, A., 2022, Cereals production between climate change and price boom in Romania, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22(4), 579-594.

[18]Popescu, A., Tindeche, C., Mărcuță, A., Mărcuță, L., Honțuș, A., 2021, Pesticides - a problem in Romania's agriculture? Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 21(4), 477-486.

[19]Todea, V., 21 April 2023, What are the best ways to motivate employees?, https://truehr.ro/metode-de-motivare-a-angajatilor/, Accessed on 05.09.2023.

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ASSESSMENT OF THE EFFICIENCY OF THE APPLICATION OF FUNGICIDES AND MICROFERTILIZERS IN SUGAR BEET GROWING IN THE FOREST STEPPE OF UKRAINE

Mykola GRABOVSKYI[1], Tetiana MARCHENKO[2], Taras PANCHENKO[1], Yriy FEDORUK[1], Tetiana Grabovska[1], Mykola LOZINSKYI[1], Leonid KOZAK[1], Lesya KACHAN[1], Oleksandr GORODETSKYI[1], Olena MOSTIPAN[1]

[1]Bila Tserkva National Agrarian University, Sobornaya pl. 8/1, Bila Tserkva, Kyiv Region, Ukraine, 09117, Phone/Fax:021/3182411, E-mail: nikgr1977@gmail.com, panchenko.taras@gmail.com, fedoruky_4@ukr.net, grabovskatatiana@gmail.com, lozinskk@ukr.net, kla59@ukr.net, viddilaspirantura@ukr.net, o.gor@ukr.net, mostipan1996@gmail.com

[2]Institute of climate smart agriculture of the national academy of agrarian sciences of Ukraine, St. Mayatska doroga, 24, village Khlybodarske, Bilyaevsky district, Odesa region, Ukraine, 67667, E-mail: icsanaas@ukr.net, tmarchenko74@ukr.net

Corresponding author: nikgr1977@gmail.com

Abstract

The results of research on determining the effectiveness of using microfertilizers and fungicides on hybrid sugar beet crops are given. Research was conducted in 2021-2022 at the experimental field of Bila Tserkva National Agrarian University. In the experiment, sugar beet hybrids were studied: Libero and Margarita KWS; Microfertilizers: control without their use, Florenta beet (1.5 l/ha), Intermag beet (2 l/ha); Fungicides: control (without their application), Alto super 330 EC (0.5 l/ha), Amistar Extra 280 SC (0.6 l/ha), Styer 500 (0.5 l/ha). It was established that the highest yield of root crops and the coefficient of energy efficiency (Cee) in the sugar beet hybrids Libero and Margarita KWS was obtained on the variant with the use of the microfertilizer Intermag beet (2 l/ha) and the fungicide Amistar Extra (0.6 l/ha) – 52.1 і 58.3 т/га та 3.2 і 3.6, respectively. The use of fungicides allows you to increase the sugar content by an average of 0.8–1.2%, microfertilizer Florenta beet (1.5 l/ha) by 0.6%, and microfertilizer Intermag beet (2 l/ha) by 0.8%, compared with control variants. The best indicators of the technological qualities of sugar beet root crops were on the variants of combined application of microfertilizers and fungicides, while the conductometric ash content was the lowest, and calculated sugar content and dry matter content were the highest.

Key words: *sugar beet, microfertilizers, fungicides, yield of root crops, sugar content in root crop*

INTRODUCTION

About 30% of the world's sugar production comes from sugar beet *(Beta vulgaris)*, most of which is produced in industrialized countries. The remaining 70% obtained from sugar cane, which is mainly grown in developing countries with tropical climates [3, 10].

The European Union (EU) is a large producer of beet sugar, producing about 50% of the total amount worldwide [34]. From another point of view, sugar beet is also used for ethanol fuel and biogas production [2, 23, 28].

In Ukraine, sugar production is an export-oriented industry [7]. So, during the period 2000–2021, the area planted under sugar beets decreased by 4.02 times from 855.6 thousand hectares in 2000 to 212.6 thousand hectares in 2021.

It should be noted that the gross harvest of root crops decreased by only 1.34 times from 13198.8 thousand tons in 2000 to 9834.6 thousand tons in 2021 [18]. Due to the increase in the yield of sugar beets in recent years, the decrease in the gross harvest of this crop is less noticeable. This became possible due to the improvement of cultivation technology, the selection of higher quality and productive hybrids, adapted to cultivation in conditions of insufficient moisture and resistant to diseases [38].

The efficiency of sugar production largely depends on the integration processes taking place in this field. Due to the compactness of the raw material zones near the sugar mills, a positive effect on the efficiency of sugar production is noted, because the transport costs for the delivery of raw materials are reduced, as well as the loss of root crops and their sugar content. [17].

The advantages of sugar beets are a lower cycle of crop production, higher yield, high tolerance of a wide range of climatic variations, and low water and fertilizer requirements. Compared to sugar cane, sugar beets require 35-40% less water and fertilizer [6]. Since the investments in the sugar industry are long-term and financially demanding, there is a clear need for the use of modern decision support tools and models in order to ensure good decision support before the investment is made [32].

Climate change affects crop production, in particular the cultivation of sugar beets, especially in the southern and eastern parts of Europe. Plant growth, development, and yield are the result of genetic characteristics of hybrids, environmental influences, and the interaction of these factors. The interaction of the genotype with the environment leads to the fact that sugar beet hybrids have different ranks in different environmental conditions [13].

Modern and energy–intensive technologies are being applied in order to increase the yield [24] leading to the 300-400% increase in the energy demand [39]. Therefore, the relationship between energy and agriculture becomes even more important [9].

Effective energy use is one of the requirements for sustainable agricultural production, because it saves money, conserves fossil fuel, and reduces air pollution [15, 25]. Energy consumption in agriculture is increasing as a response to the increasing population, limited supply of arable land and a need for the higher living standards [29].

Agriculture and energy are fundamental components of the economic development of mankind because they support economic activity and improve the quality of life of people [3]. In modern agricultural production, there are still not enough measures to optimize energy consumption, which leads to high energy consumption [1]. One of the ways to optimize energy consumption is to determine the effectiveness of the technologies used to grow certain crops [31] .

It is important to increase the productivity of sugar beets to reduce the impact of harmful organisms, which affects the reduction of product losses. Therefore, the control of diseases of the leaf apparatus of sugar beets is an important aspect in the technology of growing and increasing the yield potential of this crop [19].

According to S. Kostyuchko [22] the highest yield of sugar beets was obtained with the application of fungicides Falcon (0.8 l/ha) + Abacus (1.5 l/ha) + Rex Duo (0.6 l/ha) – 72.1 t/ha. The yield increase from the application of Falcon fungicide (0.8 l/ha) – 6.4 t/ha, Falcon fungicides (0.8 l/ha) + Abacus (1.5 l/ha) – 14.1 t/ha and from fungicides Falcon (0.8 l/ha) + Abacus (1.5 l/ha) + Rex Duo (0.6 l/ha) – 23.4 t/ha, compared to control. With the use of fungicides, an increase in the sugar content of sugar beet roots by 1.7–2.1% was noted.

But according to the results obtained in Denmark, no significant effect of the use of fungicides before the appearance of visible disease symptoms on sugar collection was noted. The increase in the yield of root crops was significant only in one of 16 cases of fungicide application [16].

An effective method of applying microfertilizers to agricultural crops was to apply them in foliar feeding on vegetative plants. During foliar fertilization, nutrients are delivered directly to the leaf blade, which increases the intensity of the photosynthesis process, activates the action of enzymes, enhances the synthesis of sucrose, and promotes the outflow of mono- and disaccharides to the root crop. Activation of biochemical and physiological processes in plants promotes more intensive use of nutrients from the soil and ensures the achievement of maximum plant productivity. This allows you to reduce the doses of fertilizers without reducing the productivity of the crop [20]. Foliar nutrition with chelated compounds of microelements enhances metabolism, respiration, absorptive and excretory functions of the root system [40].

The use of microfertilizer "Reacom-r-beet" prolonged the life cycle of sugar beet leaves, increased the content of dry matter in leaves and root crops, increased the accumulation of sugars, increased yield and improved the technological quality of root crops [41].

According to M. Kharchenko [21] the use of Combibor microfertilizer in the phase of 6-8 true leaves of sugar beets contributed to an increase in the yield of root crops by 5.4 t/ha, sugar content by 0.7%, which made it possible to obtain an additional 1.1 t/ha of sugar, compared to the control.

Using a mixture of microfertilizers Ca+micro + Boron+Molybdenum + Micro Beetroot and the fungicide Falcon yielded 66.7 t/ha of root crops. A similar scheme of microfertilizers with the use of Alto super fungicide provided a yield of 68.0 t/ha. The use of Alto super fungicide contributed to an increase in sugar yield by 12.1-14.8 t/ha [4].

According to the data received by O. P. Strilec' [35] the use of microfertilizers and fungicides in one technological operation in foliar fertilization increased the yield of root crops by 2.6–3.9 t/ha, their sugar content by 0.5–0.7%, and sugar collection by 0.7–1.0 t/ha ha, compared to the control. The combination of microfertilizer "Reacom-r-beet" in a dose of 5 l/ha and fungicide Impact 0.25 l/ha was determined to be the most effective - the yield of root crops was 47.5 t/ha. At the same time, the content of "harmful" nitrogen in root crops decreased, compared to the control without fungicides, by 0.70–0.85 mg-eq./100 g of raw mass, and the quality of normally purified juice increased by 0.2–1.0% , sugar losses in molasses decreased by 0.26–0.35%, and sugar output at the plant increased by 0.76–1.05%.

One of the possibilities of increasing the economic and energy efficiency of sugar beet production is the use of effective measures in the cultivation technology. One of these measures is the application of fungicides and macro- and microelements in the necessary periods of growth and development of sugar beet plants [5].

The purpose of the research was to determine the effectiveness of using microfertilizers and fungicides on hybrid sugar beet.

MATERIALS AND METHODS

Research was conducted in 2021-2022 at the experimental field of Bila Tserkva National Agrarian University. The experiment was conducted according to the following scheme: Factor A. Sugar beet hybrids. 1. Libero; 2. Margarita KWS. Factor B. Microfertilizers. 1. Control without microfertilizers; 2. Florenta beet (1.5 l/ha); 3. Intermag beet (2 l/ha). Factor C. Fungicides. 1. Control (without the use of fungicides); 2. Alto super 330 EC, concentrate emulsion (0.5 l/ha); 3. Amistar Extra 280 SC, concentrate suspension (0.6 l/ha); 4. Styer 500, concentrate emulsion (0.5 l/ha).

The area of sown plots was 156 m^2, accounting area – 124 m^2. Repetition – three times, placement of repetitions and plots was consistent, systematic. The technology of growing sugar beets is generally accepted for the forest-steppe of Ukraine, except for the techniques that were studied. Fungicides were applied at the beginning of the appearance of diseases on plants in the phase of 3-4 pairs of leaves in sugar beets, subsequent treatments were carried out after 14-16 days. Spraying with microfertilizers was carried out before closing the leaves of sugar beets in the interrows together with the last fungicide application. Consumption of the working solution during the application of fungicides and microfertilizers was 230 l/ha.

Mineral fertilizers $N_{90}P_{90}K_{90}$ (nitroamofoska) were applied during the main tillage (autumn), and nitrogen fertilizers N_{30} (ammonium nitrate) were applied before sowing sugar beet. Harvesting of sugar beets was carried out with a combine harvester from the entire area of the accounting plot with subsequent calculation per 1 ha. Mathematical processing of the received research results using the dispersion method using Statistica 12.

Technological indicators of the quality of sugar beet root crops (dry matter, conductometric ash) and sugar content were

carried out in the laboratory of the Salivonkiv Sugar Factory of the Kyiv Region (Ukraine).
Determination of the energy efficiency of sugar beet cultivation was carried out according to Yu. Tarariko et al. [36]. We took into account the energy value of sugar beet root crops, energy consumption for their cultivation. Coefficient energy efficiency (Cee) is calculated as the ratio of the energy content in the obtained yield of sugar beets to the energy expenditure for its production.

RESULTS AND DISCUSSIONS

On average, over two years, the hybrid Margarita KWS had a 6.0 t/ha higher yield root crop compared to the hybrid Libero (Table 1).

The use of fungicides significantly affected the yield of root crops of sugar beet hybrids. On average, in two years, the hybrids Libero and Margarita KWS, when using Alto super 330 EC increased the yield of root crops by 5.8–6.9 and 6.6–7.5 t/ha, compared to the control. When using the fungicide Amistar Extra this increased in the range of 7.2-8.3 and 7.7-9.1 t/ha and the fungicide Styer – 6.7-7.9 and 7.2-8.4 t /ha.
The increase in the yield of root crops with the use of microfertilizers was less than with the options with the use of fungicides. Thus, the used of microfertilizers Florenta beet and Intermag beet provided an increase in yield by 2.1 and 4.3 t/ha and 3.4 and 5.5 t/ha, respectively, in the hybrids Libero and Margarita KWS.

Table 1. Yield of root crops of hybrids sugar beet, t/ha

Hybrid (A)	Microfertilizers(B)	Fungicides (C)	2021	2022	Average
Libero	Control (without microfertilizer)	Control	43.3	36.6	40.0
		Alto super	50.5	43.1	46.8
		Amistar Extra	51.5	43.7	47.6
		Styer	51.1	43.1	47.1
	Florenta beet	Control	46.7	38.1	42.4
		Alto super	53.8	42.8	48.3
		Amistar Extra	55.1	44.3	49.7
		Styer	54.7	43.8	49.3
	Intermag beet	Control	48.5	39.4	44.0
		Alto super	56.4	45.0	50.7
		Amistar Extra	57.7	46.5	52.1
		Styer	57.5	46.0	51.8
Margarita KWS	Control (without microfertilizer)	Control	47.8	41.5	44.7
		Alto super	55.8	46.9	51.4
		Amistar Extra	57.2	47.8	52.5
		Styer	56.4	47.2	51.8
	Florenta beet	Control	51.4	43.9	47.7
		Alto super	60.3	49.2	54.8
		Amistar Extra	61.4	50.5	56.0
		Styer	60.7	50.3	55.5
	Intermag beet	Control	53.6	45.1	49.4
		Alto super	62.3	51.1	56.7
		Amistar Extra	63.9	52.7	58.3
		Styer	63.4	52.1	57.8
SD_{05}, t/ha		A	3,5	3.0	
		B	1.4	1.1	
		C	0.6	0.8	
		ABC	5.1	4.7	

Source: Authors own results.

The highest productivity of sugar beets was obtained with the combined combination of the fungicide Amistar Extra 280 SC and microfertilizer Intermag beet – 52.1 and 58.3 t/ha, respectively in hybrids Libero and Margarita KWS.
It should be noted the unreliable difference between the third and fourth options for the

use of fungicides, which in the years of research was in the range of 0.2–0.5 t/ha (SD_{05} = 0.6 in 2021, SD_{05} = 0.8 in 2022).

On average, during the years of research, the sugar content of the roots of the sugar beet hybrids Libero and Margarita KWS was 17.4 and 17.6 % (Fig. 1). That is, there was no significant difference between the hybrids. The minimum values of this indicator were obtained on the control variants without the use of fungicides and microfertilizers of 16.2 and 16.3 %, respectively, in the hybrids Libero and Margarita KWS.

The use of the fungicide Alto super 330 ES increased the sugar content of root crops by 0.8–1.0%, Amistar Extra 280 SC by 1.0–1.2 %, and Styer 500 by 0.9–1.1%, compared to the control.

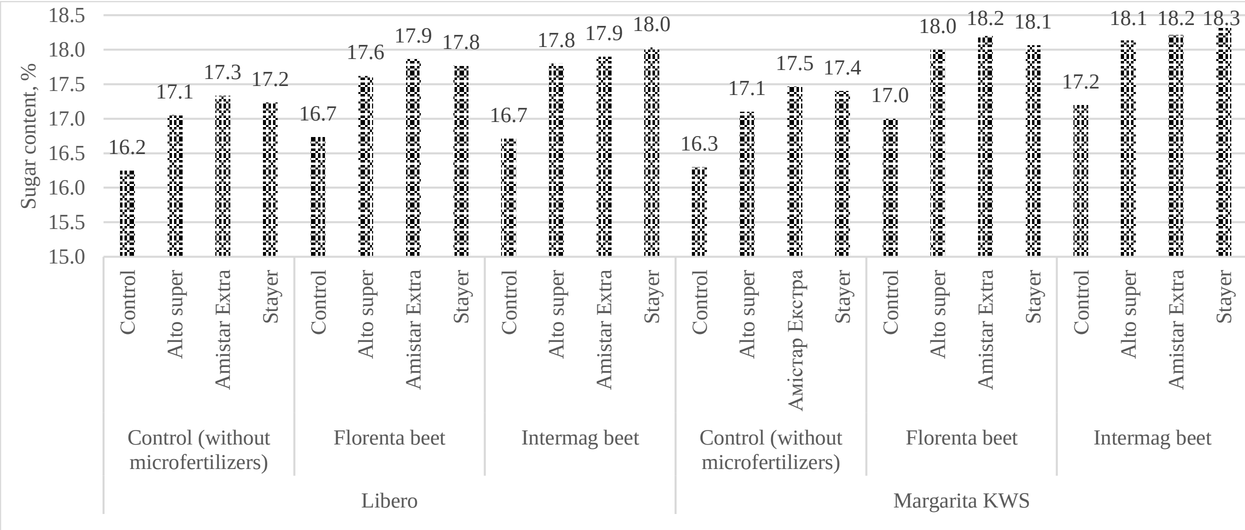

Fig. 1. Sugar content in sugar beet roots (average for 2021–2022), %
Source: Authors own results.

An important factor affecting the technological processes of sugar production is the technological quality of sugar beet roots. Technological indicators include chemical, biological and physical indicators of root crops after storage and in fresh form, they determine the level of losses and the amount of output of crystalline white sugar at the sugar factory [27].

The sugar beet root consists of 75% water and about 25% dry matter, which includes approximately 17.5% sugar and 7.5% non-sugars. Non-sugars are divided into those not soluble in water (5%), which are called pulp, and soluble non-sugars (2.5%). The pulp consists of cell wall components and a small amount of other substances that are not soluble in water. The composition of the pulp includes the following components: pectin substances – 2.4 %, hemicellulose – 1.1 %, fiber – 1.2 %, proteins 0.11 %, saponins – 0.1 %, ash – 0.1 % [40].

The use of high doses of mineral fertilizers reduces the sugar content of root crops, sharply increases the content of conductometric ash in them. This causes an increase in sugar losses in molasses, an increase in the MB factor, a decrease in the quality of normally purified juice and the yield of crystallized sugar at the sugar factory [26]. Increased doses of nitrogen fertilizers significantly increase the content of non-protein nitrogen in root crops [11]. The use of organic fertilizers helps to increase the yield of sugar at the sugar factory, improves the technological qualities of root crops and reduces the content of non-protein nitrogenous substances [14].

The use of microfertilizers and fungicides affected the technological qualities of sugar beet root crops (Table 2). Application of microfertilizers Florenta beet and Intermag beet to foliar fertilization increased the dry matter content in root crops by 0.4-1.0%, the estimated sugar yield by 0.7-1.2%, and also contributed to the reduction of conductometric ash by 0.07-0.09% and molasses by 0.4-0.6%, compared to the control.

An increase in the sugar content of root crops by 0.9-1.3%, the content of dry matter by 0.2-0.7%, as well as a decrease in the content of conductometric ash by 0.01-0.02% and molasses by 0.1-0, 2% when using fungicides on sugar beet crops. This is also confirmed by the data obtained by A. Shamsutdinova [33] which notes that the application of microfertilizers reduced the content of non-protein nitrogen, phosphorus and potassium in the roots of sugar beets and allowed to obtain a factory output of sugar – 12.8 t/ha.

The hybrid Margarita KWS had a higher content of dry matter and at the same time lower indicators of the estimated sugar content, compared to the hybrid Libero. It was established that the best indicators of the technological qualities of sugar beet roots were obtained with the simultaneous application of fungicides and microfertilizers, while the calculated sugar content and dry matter content were the highest and the conductometric ash was the lowest.

Table 2. Technological indicators of the quality of root crops of hybrids sugar beet (average for 2021–2022)

Hybrid	Microfertilizers	Fungicides	Dry matter content, %	Conductometric ash, %	Output of molasses, %	Estimated sugar content, %
Libero	Control (without microfertilizer)	Control	20.7	0.604	4.4	13.0
		Alto super	21.1	0.587	4.3	13.9
		Amistar Extra	21.0	0.574	4.2	14.2
		Styer	21.2	0.576	4.2	14.1
	Florenta beet	Control	21.2	0.534	3.9	13.7
		Alto super	21.6	0.521	3.8	14.7
		Amistar Extra	21.6	0.516	3.8	14.9
		Styer	21.7	0.526	3.8	14.8
	Intermag beet	Control	21.3	0.519	3.8	13.8
		Alto super	21.8	0.511	3.7	14.9
		Amistar Extra	22.0	0.508	3.7	15.0
		Styer	21.9	0.506	3.7	15.1
Margarita KWS	Control (without microfertilizer)	Control	21.0	0.588	4.3	13.1
		Alto super	21.5	0.577	4.2	13.9
		Amistar Extra	21.5	0.568	4.2	14.3
		Styer	21.7	0.575	4.2	14.2
	Florenta beet	Control	21.6	0.52	3.8	14.1
		Alto super	22.0	0.508	3.7	15.1
		Amistar Extra	22.0	0.506	3.7	15.3
		Styer	22.2	0.516	3.8	15.1
	Intermag beet	Control	21.7	0.507	3.7	14.3
		Alto super	21.9	0.496	3.6	15.3
		Amistar Extra	22.1	0.502	3.7	15.3
		Styer	22.1	0.493	3.6	15.5

Source: Authors own results.

Another factor addressed to evaluate the efficiency of sugar beet production is the energy consumption. Data collected from 146 sugar beet farms in Tokat (Turkey) revealed that the profit–cost ratio of farms was 1.17. The highest energy cost items were labor, land renting, depreciation and fertilizers [8]. Analyses of input and output energies in the production of agricultural products are usually based on the determination of energy consumption and environmental impacts of production systems. This data is used to compare different cropping systems and to determine how best to use energy [30].

According to the results of research conducted in Iran, it was found that the total energy costs for growing sugar beets were about 58487.80 MJ ha−1. Among these energy costs, the largest share falls on mineral fertilizers (24.5%), electricity (23.62%) and water (22.45%). Of the total energy consumption, 77.39% were non-renewable Benefit-to-cost ratio was calculated in sugar beet 1.05 fields and production productivity was calculated 9.15 kg $^{−1}$ [12]. Based on data touching 1400 farms of Slovakia, sugar beet helps those farms to increase their productivity rates and to scale up the wages [37].

In our researches, was noted an increase in energy expenditure by 1.6-3.0 GJ ha^{-1} and by 3.1-3.3 GJ ha^{-1} in the options with the use of fungicides and microfertilizers, compared to the control options (Table 3). Due to fungicides, an increase in the energy intensity of the sugar beet crop was noted by 37.1-54.8% and due to microfertilizers by 13.8-33.0%, compared to the control options.

There was no significant difference in energy efficiency between the fungicidal protection options. Thus, when using Alto super 330 EC, the energy intensity of the crop and the coefficient of energy efficiency (Cee) were in the range of 226.1-298.3 GJ ha^{-1} and 2.9-3.4, Amistar Extra 280 SC – 231.2-312, 0 GJ ha^{-1} and 3.0-3.6, Styer 500 – 226.4-307.0 GJ ha^{-1} and 2.9-3.5.

Table 3. Energy efficiency of using microfertilizers and fungicides in sugar beet (average for 2021–2022)

Hybrid	Microfertilizers	Fungicides	The energy intensity of the crop, GJ ha^{-1}	Energy expenditure, GJ ha^{-1}	Coefficient of energy efficiency (Cee)
Libero	Control (without microfertilizer)	Control	189.0	76.1	2.5
		Alto super	226.1	77.9	2.9
		Amistar Extra	231.2	78.3	3.0
		Styer	226.4	77.7	2.9
	Florenta beet	Control	202.5	78.7	2.6
		Alto super	236.7	81.1	2.9
		Amistar Extra	244.5	81.5	3.0
		Styer	244.0	81.2	3.0
	Intermag beet	Control	214.4	79.0	2.7
		Alto super	250.1	81.3	3.1
		Amistar Extra	258.6	81.5	3.2
		Styer	254.2	81.5	3.1
Margarita KWS	Control (without microfertilizer)	Control	225.3	81.7	2.8
		Alto super	266.5	84.4	3.2
		Amistar Extra	275.8	84.9	3.2
		Styer	270.1	84.7	3.2
	Florenta beet	Control	242.7	85.0	2.9
		Alto super	288.9	87.1	3.3
		Amistar Extra	297.2	87.7	3.4
		Styer	294.4	87.5	3.4
	Intermag beet	Control	252.2	85.3	3.0
		Alto super	298.3	87.6	3.4
		Amistar Extra	312.0	87.8	3.6
		Styer	307.0	87.5	3.5

Source: Authors own results.

The use of microfertilizer Florenta beet provides an increase in the coefficient energy efficiency by 0.2 and 0.3%, and Intermag beet by 6.1 and 7.5%, respectively in hybrids Libero and Margarita KWS.

The hybrid Margarita KWS has a energy intensity of the crop (277.5 GJ ha^{-1}) and Cee (3.2) compared to the hybrid Libero (231.5 GJ ha^{-1} and 2.9).

CONCLUSIONS

The maximum yield of root crops in the hybrids sugar beet Libero and Margarita KWS was 52.1 and 58.3 t/ha in the variant with the used of the fungicide Amistar Extra (0.6 l/ha) and microfertilizer Intermag beet (2 l/ha). At the same time, the difference between the options used the fungicides Amistar Extra (0.6

l/ha) and Styer (0.5 l/ha) was unreliable in the years of research. The hybrid Margarita KWS exceeded the hybrid Libero by 5.5 t/ha in root crop yield.

The sugar content in the root crop of hybrids Libero and Margarita KWS was 17.4 and 17.6%. The use of fungicides increases the sugar content by an average of 0.8-1.2%, microfertilizers Florenta beet (1.5 l/ha) and Intermag beet (2 l/ha) by 0.6 and 0.8%, compared to the control options

The indicators of the technological qualities of the root crops of sugar beet hybrids were the best with the simultaneous application of fungicides and microfertilizers while the sugar content and dry matter content were the highest and the conductometric ash was the lowest. From the energy vision, the best option was the combined application of the microfertilizer Intermag beet (2 l/ha) and the fungicide Amistar Extra 280 SC (0.6 l/ha). The coefficient of energy efficiency (Cee) was 3.2 and 3.6, respectively in hybrids Libero and Margarita KWS.

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REFERENCES

[1]Abrishambaf, O., Faria, P., Vale, Z., Corchado, J.M., 2019, Energy Scheduling Using Decision Trees and Emulation: Agriculture Irrigation with Run-of-the-River Hydroelectricity and a PV Case Study. Energies, 12, 3987. https://doi.org/10.3390/en12203987

[2]Arshad, M. Hussain, T., Iqbal, M., Abbas, M., 2017, Enhanced ethanol production at commercial scale from molasses using high gravity technology by mutant S. Cerevisiae. Braz. J. Microbiol., 48, 403-409 https://doi.org/10.1016/j.bjm.2017.02.003

[3]Asgharipour, M. R., Mondani, F., Riahinia, S., 2012, Energy use efficiency and economic analysis of sugar beet production system in Iran: A case study in Khorasan Razavi province. Energy, Vol. 44, Is. 1, 1078-1084. https://doi.org/10.1016/j.energy.2012.04.023

[4]Askarov, V. R., 2016, The effect of microfertilizers and fungicides on the yield and quality of sugar beets. Collection of scientific works of the NSC "Institute of Agriculture of the National Academy of Sciences", 2, 89-95. [in Ukrainian]

[5]Askarov, V. R., 2016, The effect of microfertilizers and fungicides on yield, quality and efficiency of sugar beet cultivation. Scientific reports of NUBiP of Ukraine, 5. http://journals.nubip.edu.ua/index.php/Dopovidi/article/view/7241 [in Ukrainian] Accessed on 19.04.2023.

[6]Balat, M., Balat, H., 2009, Recent trends in global production and utilization of bio-ethanol fuel. Applied energy, 86(11), 2273-2282, http://dx.doi.org/10.1016/j.apenergy.2009.03.015

[7]Dashko, I. M., 2018, Production efficiency of sugar processing enterprises in Ukraine. Efficient economy, №4.http://www.economy.nayka.com.ua/?op=1&z=7679 [in Ukrainian] Accessed on 25.04.2023.

[8]Erdal, G., Esengün, K., Erdal, H., Gündüz, O., 2007, Energy use and economic analysis of sugar beet production in Tokat province of Turkey. Energy, 32(1), 35-41.

[9]Falcone, G., Stillitano, T., De Luca, A.I., Di Vita, G., Iofrida, N., Strano, A., Gulisano, G., Pecorino, B., D'Amico, M., 2020, Energetic and Economic Analyses for Agricultural Management Models: The Calabria PGI Clementine Case Study. Energies, 13, 1289. https://doi.org/10.3390/en13051289

[10]FAO Statistics. http://www.fao.org/faostat/en/#data, Accessed on 25.04.2023.

[11]Filonenko, S. V., 2013, Productivity and technological qualities of sugar beet root crops depending on foliar application of growth regulator "Mars-1". Bulletin of the Poltava State Agrarian Academy, 4, 14-18. [in Ukrainian]

[12]Firouzi, S., Gholami Parashkoohi, M., Zamani, D. M., Ranjber, I., 2022, An Investigation of the Environmental Impacts and Energy-Economic Analysis for Sugar Beet and Sugarcane Production Systems. Sugar Tech., 24, 1851–1866. https://doi.org/10.1007/s12355-022-01135-1

[13]Glevaskyi, I. V., Kravchenko, A. A., 1991, Basics of beet growing. Kyiv, 216 p. [in Ukrainian]

[14]Gorodetskyi, O. S., Grabovskyi, M. B., 2018, Technological qualities of root crops and economic efficiency of growing sugar beet hybrids of the KWS company in the conditions of FG "Rasavske" of Kagarlytsky district, Kyiv region. Agrobiology, 2, 34-40. [in Ukrainian]

[15]Grabovskyi, M., Lozinskyi, M., Grabovska, T. Roubík H., 2023, Green mass to biogas in Ukraine – bioenergy potential of corn and sweet sorghum. Biomass Conversion and Biorefinery, 13, 3309-3317. https://doi.org/10.1007/s13399-021-01316-0

[16]Heick, T. M., Hansen, A. L., Munk, L., Labouriau, R., Wu, K., Jørgensen, L. N., 2020, The effect of fungicide sprays on powdery mildew and rust and yield

of sugar beet in Denmark. Crop Protection, 135, 105199. https://doi.org/10.1016/j.cropro.2020.105199.
[17]Ilkiv, L., 2018, Current status and efficiency of sugar beet production. A young scientist, 11 (63), 1124-1127. [in Ukrainian]
[18]International Association of Official Statistics (IAOS). https://www.iaos-isi.org/Accessed on 05.04.2023.
[19]Jammer, A., Albacete, A., Schulz, B., Koch, W., Weltmeier, F., Pfeifhofer, H. W., Roitsch, T.G., 2020, Early-stage sugar beet taproot development is characterized by three distinct physiological phases. Plant Direct., 1;4(7):e00221. doi: 10.1002/pld3.221
[20]Karpuk, L. M., Krykunova, O. V., Vakhniy, S. P., 2015, Peculiarities of foliar feeding of sugar beets with microfertilizers. A collection of scientific works of the "Institute of Agriculture of the National Academy of Sciences", 3, 38-45. [in Ukrainian]
[21]Kharchenko, M., 2004, Combibor microfertilizer on sugar beets. Sugar beets,1, 14-15. [in Ukrainian]
[22]Kostyuchko, S. S., 2016, Optimizing the elements of sugar beet cultivation technology in the conditions of the Western Forest Steppe: abstract of the dissertation of the candidate of agricultural sciences. Podillia Institute of Fodder and Agriculture, Vinnitsa, 24 p. [in Ukrainian]
[23]Kucheruk, P. P., Matveev, Yu. B., Khodakivska, T. V., Grabovskyi, M. B., 2013, Prospects of biogas production from mixtures of livestock manure waste and vegetable raw materials in Ukraine. Industrial heat engineering, 35(1), 107-113. [in Ukrainian]
[24]Lal, B., Rajput, D.S., Tamhankar, M.B., Agarwal, I., Sharma, M.S., 2003, Energy use and output assessment of food-forage production systems. J. Agron. Crop Sci., 189, 57-62. https://doi.org/10.1046/j.1439-037X.2003.00004.x
[25]Lyas, H. M. A., Safa, M., Bailey, A., Rauf, S.,Khan, A., 2020, Energy Efficiency Outlook of New Zealand Dairy Farming Systems: An Application of Data Envelopment Analysis (DEA) Approach. Energies, 13, 251. https://doi.org/10.3390/en13010251
[26]Lyuta, Yu., Kosenko, N., Stepanov, Yu., 2013, Influence of mineral fertilizers on the dynamics of quality indicators of table beet under drip irrigation. Scientific bulletin of NUBiP of Ukraine. Series: Agronomy, 183, 134-142. [in Ukrainian]
[27]Mazur, G., 2007, The influence of fertilization systems on the technological quality of sugar beet root crops. Sugar beets, 5, 9-11. [in Ukrainian]
[28]Nicodème, T., Berchem, T., Jacquet, N., Richel, A., 2018, Thermochemical conversion of sugar industry by-products to biofuels. Renew. Sustain. Energy Rev., 88, 151-159, 10.1016/j.rser.2018.02.037
[29]Ortiz-Cañavate, J., Hernanz, J. L., 1999, Energy analysis. In CIGR Handbook of Agricultural Engineering; Kitani, O. American Society of Agricultural Engineers: Michigan, MI, USA,. Vol. 3. 13-42.
[30]Ozkan, B., A. Kurklu, Akcaoz H., 2004, An input-output energy analysis in greenhouse vegetable production: A case study for Antalya region of Turkey. Biomass and Bioenergy, 26, 89-95.
[31]Rozman, Č., Kljajić, M., Pažek, K., 2015, Sugar Beet Production: A System Dynamics Model and Economic Analysis. Organizacija, 48(3), 145-154. https://doi.org/10.1515/orga-2015-0017
[32]Rozman, Č., Pažek, K., Kljajić, M., Bavec, M., Turk, J., Bavec, F., Škraba, A., 2013, The dynamic simulation of organic farming development scenarios– A case study in Slovenia. Computers and Electronics in Agriculture, 96, 163-172, http://dx.doi.org/10.1016/j.compag.2013.05.005
[33]Shamsutdinova, A. V., 2016, Productivity and economic efficiency of sugar beet cultivation depending on foliar fertilizing with microfertilizers. Scientific reports of NUBiP of Ukraine, 5, 17-17. [in Ukrainian]
[34]Soare, E., Dobre, I., David, L., 2021, Research on sugar beet production and trade -worldwide overview. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", 21(4): 533-539.
[35]Strilec', O. P., 2014, Productivity of sugar beets depending on the complex application of microfertilizers and fungicides in the conditions of the Right Bank part of the Forest Steppe of Ukraine : abstract of the dissertation of the candidate of agricultural sciences. Institute of Bioenergy Crops and Sugar Beet, Kyiv, 20 p. [in Ukrainian]
[36]Tarariko, Yu., Nesmashna, O., Glushchenko, L., 2001, Energy assessment of farming systems and technologies for growing agricultural crops: methodical recommendations. Kyiv, 60 p. [in Ukrainian]
[37]Tóth, M., Holúbek, I. Boháčiková, A., 2017, Impact of Sugar Beet Production on the Economic Performance of Farms in Slovakia. Listy Cukrovarnické a Reparské, 133(11), 344-350.
[38]Vasylkovska, K. V., Andrienko, O. O., Malakhovska, V. O., 2022, Dynamics of sugar beet production in Ukraine and analysis of sugar export. Collection of scientific works of the Uman National University of Horticulture, 100(2), 74-84. DOI: 10.31395/2415-8240-2022-100-2-74-84 [in Ukrainian]
[39]Wang, Y.W., 2009, Sustainable agricultural practices: Energy inputs and outputs, pesticide, fertilizer and greenhouse gas management. Asia Pac. J. Clin. Nutr., 18, 498–500.
[40]Zaryshnyak, A. S., 2006, Foliar application of fertilizers during the cultivation of sugar beets. Sugar beets, 4, 17-19. [in Ukrainian]
[41]Zherdetskyi, I.M., 2008, Foliar application of microfertilizers as a way to increase the productivity of sugar beets. Sugar beets, 3-4, 35-37. [in Ukrainian]

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ECONOMIC AND ENERGY EFFICIENCY OF THE USE OF BIOLOGIZED AGROTECHNOLOGIES FOR CORN CULTIVATION

Yaroslav HADZALO[1], Yaroslav LIKAR[2], Raisa VOZHEHOVA[3], Tetiana MARCHENKO[3]

[1]National Academy of Agrarian Sciences of Ukraine, 9, Mikhail Omelyanovich-Pavlenko Str., Kyiv, 01010, Ukraine, Phone/Fax: +38 0445219277; E-mail: prezid@naas.gov.ua
[2]National University of Life and Environmental Sciences of Ukraine, 15, Heroyiv Oborony Str., Kyiv, 01041, Ukraine, Phone/Fax: +38 0679943312; E-mail: rectorat@nubip.edu.ua
[3]Institute of Climate Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, 24, Mayatska doroga Str., Khlybodarske, Bilyaivsky district, Odesa region, 67667, Ukraine, Phone/Fax: +38 0509791239, +38 0954429212; E-mail: izz.biblio@ukr.net, tmarchenko74@ukr.net

Corresponding author: tmarchenko74@ukr.net

Abstract

The study was conducted in 2017–2019 at the experimental field of the Institute of Irrigated Agriculture of NAAS (now the Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine). Factor A studied different maturity groups of corn hybrids selected by the Institute of Irrigated Agriculture of the NAAS:Stepovyi, Skadovs`kyi, Inhul`s`kyi, Chonhar, Arabat. Factor B – protection system: control, water treatment; biological; chemical; integrated. The highest conditionally net profit and profitability of hybrids of all FAO groups was observed under the integrated method of plant protection. The maximum value of conditional net profit is 2.26 and 3.26 thousand euro ha^{-1} was observed in mid-late hybrids Chonhar (FAO 420) and Arabat (FAO 430) under integrated plant protection systems. The mid-late Arabat hybrid (FAO 430) showed the maximum level of profitability of 117–141%. It is most economically profitable to grow mid-late hybrids Chonhar (FAO 420) and Arabat (FAO 430) under systems of integrated plant protection.

Key words: *corn hybrids, economic efficiency, energy efficiency, elements of technology*

INTRODUCTION

Crop cultivation is of special importance for covering the demand for consumption and animal feed and, to a growing extent, also for energy [5]. The socioeconomic progress, scientific and technical advancements, and hence the economic development result in an ongoing increase in electricity and transport fuel consumption globally, which triggers an increase in the concentration of pollution and environmental degradation (water, soil, air) [22, 2, 7]. The danger that is associated with this matter is the continued increase of unemployment and famine factors, unless intensive and preventive tasks are introduced, especially in saving agro-systems transformation. At the same time, the rapid changes in the conditions of the agro-systems environment and the growing demand for new, more effective technologies require the simultaneous contribution of knowledge not only in the field of food production, but also in the field of the quality of newly created products, their marketing and maintaining the ethical principles of their acquisition, processing and distribution.

Analyzing the technology of growing corn hybrids on the irrigated lands of the South of Ukraine, we can conclude that it requires substantial expenditure of material resources, which are compensated by profit and profitability based on the results of the sale of finished products (grain). At the initial stage, it is necessary to plan the costs of resources with the help of technological maps, which should predict the costs of applying irrigation, applying mineral fertilizers, pesticides, biological preparations, soil treatments, harvesting, etc. [20].

In the conditions of climate change and the use of intensive technologies of agricultural production, disruption of crop rotations and unbalanced application of mineral fertilizers, the pressure of pests and diseases on agrocenoses has increased, as well as the level of potential clogging of the arable layer of the soil with weeds [4]. According to FAO, annual crop losses from insects, weeds and diseases are estimated at 20-40% similar to those 50 years ago [3].

Climate changes make certain corrections in the direction of deterioration of the phytosanitary condition of corn crops. Namely, weather conditions lead to an increase in the number of pathogens and pests, a shortening of their development interval and an increase in the number of generations.

In intensive agriculture with the progressive development of the agrochemical industry, the chemical method of protecting agricultural crops with the use of pesticides has dominated for a long time [8].

The list of drugs recommended for use contains a significant number of items and is constantly updated. Manufacturers offer a variety of drugs - according to active substances, terms of application, norms of use, etc. Timely application of pre-emergence (soil) and post-emergence (insurance) herbicides, as well as in combination with other elements of plant protection, can provide a significant increase in corn grain production.

A highly effective measure of protection against pathogenic microflora is the treatment of corn seeds with fungicides. In terms of efficiency, the chemical measure outperforms all others and requires consideration of phytosanitary status and environmental safety [23].

Agricultural producers, in today's conditions, to fight against plant pests and diseases of fungal and bacterial origin, are offered a significant range of chemical seed poisons, which are included in the list of permitted agrochemicals and pesticides in Ukraine. The vast majority of modern chemical poisons eliminate the problem of the spread of diseases and pests, but lead to the deterioration of the ecological condition of agrocenoses. Therefore, the biological method of protection, which is based on the use of living microorganisms and products of their metabolism, is becoming more and more widespread in agricultural technologies during the cultivation of grain crops [21, 9].

Protection of plants from diseases caused by various pathogenic microorganisms is an economically and socially important problem; losses in crop production reach 20% of the harvest in different parts of the world. The use of chemical pesticides is the main method of plant protection. However, chemical preparations have a number of serious disadvantages. Biological preparations for plant protection are now beginning to be used more intensively. The world's largest chemical companies BASF, Bayer and Syngenta show great interest in the market of biological control drugs. According to expert data, the market value of biological drugs will exceed $1 billion USD by 2025. Pesticides based on microorganisms and their products have proven their high efficiency, species specificity and environmental friendliness, which led to their introduction into pest control strategies around the world. The market of microbial biopreparations accounts for about 90% of the total volume of biopesticides, and has many opportunities for further development in agriculture [1, 10, 12, 13, 16].

Practical industrial production and use of biological preparations have been studied by numerous foreign and Ukrainian scientists [11, 12, 19, 24].

Due to the significant deterioration in recent years of the phytosanitary state of agrocenoses, primarily caused by harmful beetles such as wireworms and false wireworms, the damage caused by these pests has increased, necessitating enhanced protection measures for corn seedlings and the comprehensive control of both soil and surface pests. Withdrawal and introduction of hybrids resistant crops, particularly corn, is one of the most environmentally friendly measures in protecting plants from diseases and pests. An important issue is the evaluation assortment of modern maize hybrids for resistance against specialized pests. The most effective method of protection against corn pests is an integrated system (resistant varieties, agronomic and biological methods, chemical events) which allows incur the lowest costs until they complete avoidance when growing crops.

MATERIALS AND METHODS

The study was conducted in 2017–2019 at the experimental field of the Institute of Irrigated Agriculture of NAAS (now the Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine). Factor A studied different maturity groups of corn hybrids selected by the Institute of Irrigated Agriculture ofthe NAAS: Stepovyi, Skadovs`kyi, Inhul`s`kyi, Chonhar, Arabat. Factor B – protection system: control, water treatment; biological; chemical; integrated.

The cultivation technology of corn was generally accepted for irrigated conditions and met the requirements of corn production technologies for agroecological conditions of the Steppe zone of Ukraine [18].

During the growing season, phenological observations and biometric records were performed according to appropriate methods. After harvesting a structural analysis of the cobs was performed in the laboratory of the Institute. The experiments were performed under irrigation. The main criterion for planning the irrigation regime was the level of preirrigation soil moisture (LPSM). The biologically optimal regime of corn irrigation is the regime in which at all the stages of the plant organogenesis LPSM is maintained at the level of 80% FC. The methodology of the study is generally accepted for field experiments in the conditions of irrigation and plant breeding studies with corn plant [17].

Insure®Perform – the first two-component broad-spectrum cereal seed fungicide containing strobilurin with effective disease control and a pronounced physiological effect AgCelence®. Group of Plant Protection Means (PPM) – Poisoners. Manufacturer BASF. Active substance: Pyraclostrobin, 40 g/l, Triticonazole, 80 g/l. Preparative form – liquid concentrate for seed treatment (so-called). Chemical group: strobilurins, triazoles. Toxicity class (WHO Classification) – III.

Insecticide Kanonir Duo is a contact systemic drug that protects cultivated plants from many types of insect pests. Group of PPM – insecticide. Active substance: Imidacloprid, 300 g/l, Lambda-cyhalothrin, 100 g/l. Preparative form is a concentrated suspension. Chemical group: neonicotinoids and pyrethroids. Toxicity class (WHO classification) – II.

Harness Herbicide (acetochlor, 2.0 l/ha) – selective pre-emergence soil herbicide for use on corn crops, a means of combating annual cereal weeds. Group of PPM – herbicide. Active substance: acetochlor 900 g/l. Chemical group: chloroacetanilides. The preparation form is a concentrated emulsion. Toxicity class (WHO Classification) – III.

Milagro (nicosulfuron, 1.0 l/ha) is the most dangerous graminicide for corn.Group of PPM – herbicide. Active substance content: 40 g/l Nicosulfuron. Chemical group: Sulfonylureas. Preparative form: Suspension concentrate. Toxicity class (WHO Classification) – III.

Biological insecticide-fungicide Guapsin, 150 ml (Haupsin) – a biological insecticidal and fungicidal preparation for the protection of plants from fungal diseases and pests. Composition: aqueous suspension of strains of the bacteria *Pseudomonas aureofaciens* B-111 (IBM B-7096) and *Pseudomonas aureofaciens* B-306 (IBM B-7097), products of their metabolism, starting doses of macronutrients (N, P, K). Protects plants as a fungicide against root and leaf diseases, and as an insecticide against insect pests; stimulates the growth of the root system and improves plant nutrition; increases the resistance of crops to frost and drought; does not cause resistance of pathogens; increases yield. Processing times: I phase – seed processing, II phase – tillering, III phase – flag leaf stage.

RESULTS AND DISCUSSIONS

During the studied years, an assessment of economic indicators was carried out in order to assess the economic efficiency of the studied elements of technology as widely and accurately as possible. The cost of gross production and other economic indicators of the cultivation of corn hybrids are taken at the prices that have actually developed in Ukraine (https://ukrse.com.ua/).

In order to establish the economic efficiency of the use of different FAO groups of corn hybrids, an analysis of the economic efficiency of corn grain cultivation was carried out depending on the influence of the studied factors. At the same time, generally accepted standards of production, current prices for various types of work, etc. were chosen. They were accepted according to established norms, regulations, and standards recommended for grain production in Ukraine.

To calculate the cost of gross production from 1 ha of corn sown area, the main type of production was taken as corn grain. The economic evaluation of the results of our research shows that the fluctuation of the indicators of the cost of gross production during the cultivation of corn fluctuates in directions related to the yield of the crop (Table 1).

Table 1. Indicators of the economic efficiency of growing corn hybrids depending on plant protection systems, (average for 2017–2019)

Hybrids (factor A)	Plant protection (factor B)	Economic indicators				
		Gross output value, thous. euro ha^{-1}	Spending on basic products, thous. euro ha^{-1}	Cost, thous. euro t^{-1}	Net operating profit, thous. euro ha^{-1}	The level of profitability, %
Stepovyi (FAO 180)	Control, water treatment	2.49	1.90	0.33	0.59	31
	Biological	2.86	2.01	0.30	0.85	42
	Chemical	2.80	2.05	0.32	0.75	36
	Integrated	3.06	2.10	0.29	0.97	46
Skadovs`kyi (FAO 290)	Control, water treatment	2.82	1.93	0.29	0.90	46
	Biological	3.07	2.02	0.28	1.04	51
	Chemical	3.24	2.08	0.27	1.16	55
	Integrated	3.45	2.13	0.26	1.32	62
Inhul`s`kyi (FAO 350)	Control, water treatment	3.72	2.00	0.23	1.72	85
	Biological	3.84	2.09	0.24	1.75	83
	Chemical	4.15	2.16	0.22	1.99	92
	Integrated	4.21	2.19	0.24	2.02	92
Chonhar (FAO 420)	Control, water treatment	4.00	2.02	0.22	1.98	97
	Biological	4.15	2.11	0.23	2.04	96
	Chemical	4.20	2.16	0.22	2.04	94
	Integrated	4.46	2.21	0.21	2.25	101
Arabat (FAO 430)	Control, water treatment	4.16	2.04	0.21	2.12	104
	Biological	4.70	2.16	0.19	2.54	117
	Chemical	5.11	2.24	0.18	2.87	128
	Integrated	5.56	2.30	0.17	3.26	141

Source: Own study. The gross value of the product was calculated using the prices on FOB Ukraine dated for July, 02, 2020.

The cost of gross production was the lowest, at the level of 2.49 thous. euro ha^{-1} for cultivation of Stepovyi hybrid (FAO 180). In addition, the maximum (5.56 thous. euro ha^{-1}) of this indicator was formed in the variant with Arabat hybrid (FAO 430), which is 2.3 times more than the above-mentioned variant. In Chonhar hybrid (FAO 420), the cost of gross production exceeded 4.0 thous. euro ha^{-1} for compliance with chemical and integrated plant protection.

The production costs spending on basic products for growing corn grain changed to a lesser extent in different variants of hybrid composition and plant protection and increased in the direction from early-ripening hybrids to late-ripening ones, as well as from the control variant to biological, chemical and integrated, which can be explained by the increase in the costs of harvesting an additional crop, and also for the purchase and application of plant protection products. The minimum is 1.90 thousand. euro ha^{-1} this indicator was under control in the variant with the Stepovyi hybrid (FAO 180), and the maximum (2.30 thous. euro ha^{-1}) under integrated protection when growing the Arabat hybrid (FAO 430), exceeding the worst result by 21.4%.

A noticeable decrease in the cost of 1 ton of corn grain to 0.17–0.19 thous. euro was noted in variants with plant protection in the hybrid Arabat (FAO 430). The highest value of this indicator is up to 0.30–0.32 thousand. euro t^{-1} appeared in the variant with the Stepovyi hybrid (FAO 180) in experimental plots without plant protection, as well as with biological and chemical plant protection. In other studied hybrids Skadovs`kyi (FAO 290), Inhul`s`kyi (FAO 350), Chonhar (FAO 420), this indicator occupied an intermediate value and ranged from 2.11 to 2.94 thous. euro t^{-1}.

In terms of conditional net profit, the advantage of growing Arabat hybrid (FAO 430) was shown. At the same time, the growth of this indicator to 2.54 was recorded; 2.87; 3.26 thousand. euro ha^{-1}. Therefore, there was a decrease in net income compared to the worst result in the field experiment (the control variant in the hybrid Stepovyi (FAO 180) – 0.59 thous. euro ha^{-1} by 4.3, 4.9, 5.5 times, respectively.

The level of profitability exceeded 100% for the cultivation of the hybrid Chonhar (FAO 420) in areas with integrated plant protection, as well as in all variants of factor B in the hybrid Arabat (FAO 430). Its minimum level in the range of 31.1 - 36.7% appeared in the Stepovyi hybrid (FAO 180) in the control variant, as well as under chemical plant protection.

The purpose of energy analysis in agricultural production is to optimize energy costs based on the study of energy flows at the "input" and "output" of the crop cultivation system. The total energy spent on the creation of plant products should not exceed the energy of the obtained crop accumulated in the process of photosynthesis [6]. Bioenergy assessment is particularly dependent on the intensification of agricultural production, as this is followed by an increase in the energy intensity of crop cultivation, which requires detailed calculations of the energy consumption of all technological operations. This method makes it possible to most accurately study and unambiguously express both the direct energy costs for technological processes and operations, as well as the energy invested in the means of production, as well as the obtained products through energy equivalence. This, in turn, will make it possible to identify and implement energy-saving technologies and increase the energy efficiency of crop cultivation [14].

It is customary to estimate the energy input by the size of the biological harvest formed by the culture, which includes not only the amount of the main product, but also stem, leaf and root mass, which is very difficult to estimate energetically. Therefore, scientists believe that this problem should be divided into two parts - the evaluation of the efficiency of production and the efficiency of the functioning of the agroecosystem [15]. The amount of energy input and expenditure significantly depended on the amount of crop grain yield and the technological methods of growing, which were put to study. Depending on one or another combination of experimental options, the increase in energy varied.

As a result of the dry conditions of 2019, in the field with corn hybrids, there was a slight decrease in energy input with the harvest. There was an increasing trend of this indicator in the direction from early-ripening to late-ripening hybrids, as well as from control to options with chemical and integrated plant protection. More than 80 GJ ha^{-1} of energy input occurred in the variant with a late-ripening hybrid and the use of chemical and integrated plant protection. Its decrease by more than 2 times occurred in the control variant of factor B in the plots of Stepovyi (FAO 180).

Energy consumption was minimal (31.5 GJ ha^{-1}) also obtained in the above-mentioned variant. Its growth by 20.3% (up to 37.9 GJ ha^{-1}) occurred in the variant with the Arabat hybrid using integrated plant protection. This can be explained by the increase in energy costs for harvesting an additional crop, as well as additional costs for plant protection, especially for integrated protection (Table 2).

Table 2. Energy efficiency of growing corn hybrids depending on different plant protection systems (average for 2017–2019)

Hybrids (factor A)	Plant protection (factor B)	Energy indicators				
		energy input, GJ ha^{-1}	energy consumption, GJ ha^{-1}	energy gain, GJ ha^{-1}	coefficient of energy efficiency	energy intensity, GJ t^{-1}
Stepovyi (FAO 180)	Control, water treatment	42.5	31.5	11.0	1.35	5.79
	Biological	50.0	33.0	17.0	1.51	5.17
	Chemical	48.9	33.1	15.8	1.48	5.30
	Integrated	53.8	34.4	19.4	1.56	5.01
Skadovs`kyi (FAO 290)	Control, water treatment	49.3	32.2	17.1	1.53	5.11
	Biological	53.8	33.4	20.4	1.61	4.86
	Chemical	57.0	34.0	23.0	1.68	4.67
	Integrated	60.8	35.2	25.7	1.73	4.52
Inhul`s`kyi (FAO 350)	Control, water treatment	65.6	33.9	31.7	1.93	4.05
	Biological	67.9	34.9	32.9	1.94	4.03
	Chemical	73.5	35.7	37.8	2.06	3.81
	Integrated	74.6	36.6	38.0	2.04	3.84
Chonhar (FAO 420)	Control, water treatment	70.8	34.5	36.4	2.05	3.81
	Biological	73.0	35.5	37.5	2.06	3.80
	Chemical	74.4	35.8	38.6	2.08	3.77
	Integrated	79.2	37.1	42.1	2.13	3.67
Arabat (FAO 430)	Control, water treatment	73.6	34.8	38.9	2.12	3.70
	Biological	79.4	36.2	43.3	2.20	3.56
	Chemical	82.5	36.7	45.8	2.25	3.48
	Integrated	87.0	37.9	49.1	2.29	3.41

Source: Own study.

The indicator of total energy growth showed high differences. Thus, in the variant with chemical and integrated protection for the cultivation of Arabat hybrid (FAO 430), it reached 45.8 – 49.1 GJ ha^{-1}. The energy gain decreased by 4.3–4.5 times in the variant (to 11.0 GJ ha^{-1}) in the control variant of the Stepovyi hybrid (FAO 180).

The coefficient of energy efficiency showed a clear trend of growth above 2.0 starting from the variant with the hybrid Inhul`s`kyi (FAO 350) under chemical plant protection. Moreover, the highest value of this energy indicator – 2.29, was for growing the late-ripening hybrid Arabat (FAO 430) with integrated plant protection. The lowest coefficient of energy efficiency (1.35) was obtained in the first position of the field experiment – hybrid Stepovyi (FAO 180) on the control variant (treatment with clean water). The difference between the maximum and minimum values of this indicator was 69.6%.

The energy content of the grown corn grain also fluctuated according to the dependencies shown by the other indicators discussed above. Its decrease to 3.41–3.48 GJ t^{-1} was manifested in variants with integrated and chemical protection on the hybrid of the late ripening Arabat group (FAO 430). This indicator significantly increased by 67.3 – 69.8% in the variant where the Stepovyi hybrid (FAO 180) was grown without the use of biological or chemical means of plant protection.

CONCLUSIONS

The highest conditionally net profit and profitability of hybrids of all FAO groups was observed under the integrated method of plant protection.

The lowest cost of production was observed in the hybrid Arabat (FAO 430) – 0.17–0.19 thous. euro t^{-1}.

The maximum value of conditional net profit is 2.26 and 3.26 thousand. euro ha^{-1} was observed in mid-late hybrids Chonhar (FAO 420) and Arabat (FAO 430) under integrated plant protection systems.

The mid-late Arabat hybrid (FAO 430) showed the maximum level of profitability of 117–141%.

It is most economically profitable to grow mid-late hybrids Chonhar (FAO 420) and Arabat (FAO 430) under systems of integrated plant protection.

Calculations of energy efficiency showed that with the introduction of such elements as the use of different methods of plant protection into the technology of corn cultivation, the increase in energy increased significantly from 11.0 in the Stepovyi hybrid (FAO 180 on the control variant to 49.1 in the Arabat hybrid (FAO 430) under the integrated method of protection.

REFERENCES

[1]Azizbekyan, R., 2019, Biological preparations for the protection of agricultural plants (Review), Applied Biochemistry and Microbiology, 55:816–823.

[2]Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., Farhani, S., 2018, How economic growth, renewable electricity and natural resources contribute to CO_2 emissions?, Energy Policy, 113:356–367.

[3]Food and Agriculture Organization of the United Naations, 2021, Climate change fans spread of pests and threatens plants and crops, new FAO study, https://www.fao.org/news/story/en/item/1402920/icode/,Accessed on January 20, 2023.

[4]Ivashchenko, O.O., Remenyuk S.O., 2018, Problems of potential soil contamination in Ukraine, Herald of Agrarian Science, 8:58–69.

[5]Jeziorska-Thöle, A., Rudnicki, R., Kluba, M., 2016, Development of energy crops cultivation for biomass production in Poland, Renew. Sustain. Energy Rev, 62:534–545.

[6]Kalinichenko, O.V., 2018, The theoretical essence of the categories "energy efficiency" and "energy efficiency in crop production", Economy of Agro-Industrial Complex, 10:86–95.

[7]Katircioglu, S.T., 2014, International tourism, energy consumption, and environmental pollution: The case of Turkey, Renew. Sustain. Energy Rev, 36:180–187.

[8]Kierzek, R., Paradowski, A., Kaczmarek, S., 2012, Chemical methods of weed control in maize (*Zea mays* L.) in variable weather conditions, Agricultura, 11(4):35–52.

[9]Kobiljonovna, Y.S., Zaylobidinovna, S.R., 2022, The importance of biological protection in cooperated fight against plant pests, European Journal of Agricultural and Rural Education (EJARE), 3(5):44–47.

[10]Koul, O., 2011, Microbial biopesticides: Opportunities and challenges, CAB Reviews Perspectives in Agriculture Veterinary Science Nutrition and Natural Resources, 6, 056.

[11]Krutyakova, V., 2017, Effective technological equipment for mass production of entomophagous insects and mites used for biological control, Journal of Agricultural Science and Technology, 7:179–186.

[12]Marchenko, T.Yu., 2019, Innovative elements of cultivation technology of corn hybrids of different FAO groups in the conditions of irrigation, in: Natural sciences and modern technological solutions: knowledge integration in the XXI century, Lviv-Torun, Liha-Pres, pp. 137–153.

[13]Parnell, J.J., Berka, R., Young, H.A., Sturino, J.M., Kang, Y., Barnhart, D.M., DiLeo, M.V., 2016, From the lab to the farm: an industrial perspective of plant beneficial microorganisms, Frontiers in Plant Science, 7, 1110.

[14]Repilevskyi, D.E., Ivaniv, M.O., 2021, Economic and energy assessment of growing hybrids of corn of different FAO groups depending on irrigation methods in the conditions of the southern steppe of Ukraine, Taurian Scientific Bulletin, 120:131–140.

[15]Revtyo, O.Ya., 2013, Energy efficiency of growing corn for grain under irrigation, Scientific Works of the Institute of Bioenergy Crops and Sugar Beet, 17(1):279–283.

[16]Thomas, B., Murphy, D.J., Murray, B.G., 2016-2017, Encyclopedia of Applied Plant Sciences.2nd.ed.
Plant breeding. Botany. Seed Treatments. Oxford Academic Press, 1719 p.

[17]Ushkarenko, V.O., Nikishenko, V.L., Holoborodko, S.P., Kokovikhin, S.V., 2008, Analysis

of variance and correlation analysis in agriculture and crop science, Kherson, Ailant, 272 p.
[18]Ushkarenko, V.O., Vozhehova, R.A., Holoborodko, S.P., Kokovikhin, S.V., 2014, Methodology of field experiment (Irrigated agriculture). Kherson, Hrin D.S., 448 p.
[19]Van Lenteren, J.C., Bolckmans, K., Köhl, J., Ravensberg, W.J., Urbaneja, A., 2018, Biological control using invertebrates and microorganisms: plenty of new, BioControl, 63:39–59.
[20]Vozhehova, R., Marchenko, T., Lavrynenko, Y., Piliarska, O., Zabara, P., Zaiets, S., Tyshchenko, A., Mishchenko, S., Kormosh, S., 2022, Productivity of lines – parental components of maize hybrids depending on plant density and application of biopreparations under drip irrigation, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(1):695–704.
[21]Vozhehova, R., Marchenko, T., Piliarska, O., Lavrynenko, Y., Halchenko, N., Lykhovyd, P., 2021, Grain corn product yield and gross value depending on the hybrids and application of biopreparations in the irrigated conditions. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 21(4):611–619.
[22]Wang, T., Lin, B., 2019, Fuel consumption in road transport: A comparative study of China and OECD countries, J. Clean. Prod, 206:156–170.
[23]Wise, K., Mueller, D., 2011, Are fungicides no longer just for fungi? An analysis of foliar fungicide use in corn, APSnet Features Articles, doi: 10.1094/APSnetFeature-2011-0531.
[24]Zhang, J., Huang, Y., Pu, R., Gonzalez-Moren, P., Yuan, L., Wu, K., Huang, W., 2019, Monitoring plant diseases and pests through remote sensing technology: A review, Computers and Electronics in Agriculture, 165, 104943.

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AGROPHYSICAL PROPERTIES OF SOIL IN THE IRRIGATED CROPS OF WINTER BARLEY UNDER THE INFLUENCE OF BASIC TILLAGE AND ORGANIC-MINERAL FERTILIZATION IN THE SOUTHERN STEPPE OF UKRAINE

Liudmyla HRANOVSKA, Nadiia REZNICHENKO, Pavlo LYKHOVYD, Serhii ROI

Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, Mayatska doroha 24, vil. Khlibodarske, Odesa region, Ukraine, Phone: 380992451868; E-mails: G_Ludmila15@ukr.net, nadezhda.reznichenko@ukr.net, pavel.likhovid@gmail.com, roysergey11@gmail.com.

Corresponding author: pavel.likhovid@gmail.com

Abstract

The study was performed in Askanian State Agricultural Research Station of the Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, located in the Southern Steppe zone of the country. The experiments were carried out in a stationary field in the period 2015-2020 within a four-field crop rotation (winter barley with post-harvest sowing of green manure crop-soybean- winter wheat with post-harvest sowing of green manure crop-grain maize) and resulted in scientific substantiation of the influence of different systems of basic tillage and organic-mineral fertilization systems on the agrophysical parameters of dark-chestnut soil and formation of winter barley yields. It was determined that the no-till variations, which outperformed the bulk density in the control (under the conduct of mechanical tillage) by 4.0%, are responsible for the soil's maximum bulk density (1.30 g/cm^3). The bulk density of the dark-chestnut soil was decreased by 1.6% when post-harvest green manure was used, and by 2.3% when continuous no-till farming was used. The bulk density of the arable layer of dark-chestnut soil in the range of 1.22-1.26 g/cm^3 produces the maximum productivity of winter barley. Crop yields are impacted by a reduction in bulk density brought on by excessive soil loosening as well as soil compaction.

Key words: *water permeability, soil porosity, soil tillage systems, green manure crop, bulk density of the soil, winter barley*

INTRODUCTION

Processes of soil degradation are observed in many countries of the world, including Ukraine. Among the factors affecting the intensity of soil degradation processes are their natural salinity and sodification, the natural aridity of the land, which is accompanied by insufficient rainfall, a negative water balance, and the related conditions of soil formation. For example, the erosion area of the Ukrainian lands currently reaches approximately 17.0 million hectares, with a share of 41% to the total agricultural land area and is annually increased by 80,000 hectares [1]. This is especially relevant to the most fertile and over-ploughed black-earth soils, which occupy 60% of the arable land in Ukraine.

The harmful impacts of natural and anthropogenic factors on soil resources cause, first, deterioration of soil structure, mechanical destruction and compaction of soil, permanent depletion of humus and nutrients, water and wind erosion, soil contamination with mineral fertilisers and chemicals. Agrophysical degradation associated with soil compaction, is a wide-scale problem. Bulk density is an important component of soil fertility, the main indicator of its physical conditions, on which the water, air, and thermal regimes of the soil depend. Therefore, the main reasons for the decrease in fertility in over-compacted soils are insufficient or poor water permeability and deterioration of the water regime in general, and on too loose soils – a low concentration of moisture and nutrients in the upper layer and unproductive water uptake for evaporation.

In the soil-ecological zone of the Southern steppe of Ukraine, Southern chernozems, dark chestnut and chestnut soils, which were formed under a significant natural moisture deficit, are common. A feature of these soils is a compact transition horizon and low water permeability. The upper layers of the soil have physical characteristics favourable for the development of plants, in contrast to the deeper layers of the subsoil horizon. Therefore, the question of ensuring optimal bulk density of the soil during the growing season, which will contribute to the most efficient water use, better development of the root system and vegetative mass, and as a result – an increase in productivity, is relevant.

Among numerous agricultural measures that affect soil agrophysical parameters, tillage is of greatest importance, because in the vast majority cases the bulk density and structure of the soil are regulated by the way and depth of tillage.

Mechanical tillage, together with crop rotation and fertilisers, is an important link in the systems of intensive farming. Under the influence of rational soil tillage, its agronomic properties change, favourable parameters of the structure and density of the arable layer are created, the water-air, heat and nutrient regime improves, which in its turn leads to an increase in the yield of cultivated crops [7].

Tillage systems, which are currently used in Ukraine, are one of the most actively discussed questions of modern agriculture and have always received special attention of the scientists. The development of tillage systems is closely related to the general organisational and economic changes in the agricultural sector, the nature of land resource use, the structure of cultivated areas, crop rotations, social and demographic processes, trends in climate change, and reclamation measures. To study the influence of different tillage systems, ways, and depth of loosening on the processes of soil formation and crop yields in different soil and climatic zones of Ukraine, stationary experiments were carried out. A significant contribution to the study of the mentioned problems was made by domestic scientists V. F. Saiko, A. M. Malienko, V. M. Polovyi, M. P. Maliarchuk, etc., who proved that soil tillage systems should rationally combine multi-depth ploughing with the operations conducted using sub-surface tiller [12, 19, 20, 28].

Thus, according to the results of the long-term study by I. D. Primak and O. B. Panchenko, conducted on black-earth soils, which are typical for the Central Forest-Steppe of Ukraine, it was established that under sub-surface, differentiated, and continuous shallow tillage, the bulk density of the arable layer of the soil, compared to ploughing, is greater by 0.10, 0.06 and 0.04 g/cm^3, respectively. A significant increase in the volume of non-capillary pores is observed only under continuous shallow tillage with the application of 12 tons of manure + $N_{83}P_{116}$ [18].

On the dark grey podzol slightly-loamy soils of the Western Forest Steppe, the application of different methods of basic tillage for winter wheat (namely, ploughing at 20–22 cm, harrowing at 10–12 cm and 6–8 cm) ensured a favourable bulk density of the soil for the crop in the layers 0–10 and 10–20 cm, respectively, 1.14–1.27 and 1.24–1.36 g/cm^3. However, in the layer 20–30 cm, a sub-plough compaction occurred in all the variants, especially where shallow tillage was applied. The use of by-products for fertilisation contributed to a certain decrease in soil compaction, but led to an increase in weediness, which increased with a decrease in the depth of tillage [17].

In the Precarpathia sod-podzolic surface gley soils, ploughing at 20–22 cm with loosening of the subsoil layer at 12–14 cm ensures a decrease in the bulk density of the soil of 0.01–0.04 g/cm^3, which has a positive effect on the growth and development of winter rye [2].

On the irrigated lands of the Southern Steppe of Ukraine, more favourable agrophysical properties of the soil are created when the mouldboard tillage at the depth of 25–27 is interchanged with tillage at 14–16 cm in the systems of multi-depth and differentiated tillage in crop rotation, which ensures the formation of higher productivity of spring rapeseed with the lowest production cost of seeds and the best profitability [3]. Against the background of shallow mulching tillage, as a result of reducing the loosening depth to

12–14 and 14–16 cm, there is some compaction of the 0–30 cm soil layer, but the optimal density parameters are not exceeded [22].

In modern agriculture, the specialisation of farms, crop rotations, and the amount of minimal tillage (shallow, surface) is increasing.

The no-till system, which is considered by scientists and agricultural producers the main factor in preserving soil fertility, increases soil resistance to wind and water erosion, and is increasingly widespread [10, 14, 15]. There is a recent study, which proves high economic efficiency and technological rationality of no-till implementation in the cultivation of grain corn in the South of Ukraine [5]. At the same time, scientists have proven several drawbacks of this technology, among which the bulk density of soils under crops is greater than under conventional tillage systems. Therefore, continuous investigation of tillage in crop rotations, conducted in the Southern Steppe zone of Ukraine, showed that the highest benefits both for the cultivated crops and soil conditions are recorded under the systems of differentiated tillage, which foresees changing of shallow plough less tillage and deep chisel loosening of the soil [13].

A significant contribution to the development of the theoretical foundations of minimal tillage was made by US scientists, who in the middle of the twentieth century started the world's first research project on conservation (zero) tillage and are developing it as a main strategy of modern agriculture. Furthermore, the central component of the concept when applying zero-tillage technology are cover crops, which can be used both in single species crops and in the form of crop mixtures. The results of US scientists testified that soil compaction in no-till systems was significantly reduced by cover crop mixtures, and the use of radish oilseeds in crop mixtures provides an average improvement effect of approximately 40% [8, 16, 21].

Therefore, the diversity of views on this problem led to a more detailed and in-depth study of the influence of various tillage technologies in combination with the use of cover crops (namely, post-harvest green manure crops) in the fertilisation system on the agrophysical parameters of the soil and the formation of the crop yield under irrigated conditions of the Southern Steppe of Ukraine.

MATERIALS AND METHODS

The study was carried out on the irrigated lands of the Askanian State Agricultural Research Station of the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine. The stationary field experiment has been performing since 2007. Experiments are carried out in a four-field crop rotation, namely: winter barley with post-harvest sowing of green manure crop - soybean - winter wheat with post-harvest sowing of green manure crop - grain maize. The study assessed the influence of different systems of basic tillage and organic-mineral fertilization systems on agrophysical properties of the dark-chestnut soil and yields of winter barley.

The soil of the experimental field is represented by dark-chestnut middle-loamy residually slightly saline soil. Soil-forming rock is represented by loess enriched with lime and gypsum, which is at a depth of approximately 2 metres from the surface. High yields of crops can be obtained on dark-chestnut soils in the years with enough precipitation or under irrigation [4].

The arable soil layer is 0–22 cm deep, and contains 2.3% of humus, 0.18%, 0.16, and 2.7% of the gross forms of nitrogen, phosphorus, and potassium, respectively. The pH of the aqueous soil extract is 7.0–7.2 points. The field water-holding capacity of the soil layer 0–100 cm is 21.3%, wilting point is 9.5%, the content of water-resistant aggregates is 34.1%, the equilibrium bulk density is 1.29 g/cm^3, the porosity is 49.2%, water permeability – 1.25 mm/min. The groundwater is located deeper than 10 m.

Because, due to its biological features, winter barley has the shortest vegetation period among cereal crops, it vacates the field earlier and acts as a good fore crop for the use of post-harvest green manure crops in the structure of the sown areas of irrigated crop rotations.

The study on the optimal agrotechnological complex for the cultivation of winter barley in a stationary field experiment, conducted in the period 2016–2020, included the following factors and options.

Factor A – four systems of basic soil tillage used for winter barley applying different methods and depths: disk tillage to the depth of 12–14 cm within a differentiated system of tillage in the crop rotation (control 1); disk tillage to the depth of 12–14 cm within the system of shallow tillage (no plough used) in the crop rotation; chisel tillage to the depth of 23–25 cm within the system of multi-depth tillage with no plough in the crop rotation; continuous (exceeding 10 years period) no tillage in the crop rotation.

Factor B – four systems of fertilisation: application of mineral fertilisers $N_{120}P_{40}$ for winter barley in all experimental variants on the background of the after-action of different fertilisers, applied in the field of a fore crop (grain maize): 1 – green manure + $N_{120}P_{40}$; 2 – green manure + $N_{150}P_{40}$; 3 – green manure + $N_{180}P_{40}$; 4 – $N_{180}P_{40}$ (control 2) and by-products, used as fertiliser.

Disk tillage was performed using a heavy disk harrow BDVP-4.2; chisel loosening was performed using a CASE-7300 ripper. In the no-till variant, the leaves and stems of the fore crop were shredded using the Schulte machine.

Winter barley was seeded in the first ten-day period of October using a Great Plains drill, which is used to sow in uncultivated soil. The sowing rate was 4.5 million of seeds per hectare.

The field experiments were conducted in four replications. The plots were systematically located by the tillage options with further division by the fertilisation rates. The total area of the experiment was 3.0 ha. The plot area – 450 m^2, the accounted area – 50 m^2.

The crop was cultivated with accordance to common cultivation technology for the South of Ukraine, in exception of the studied factors. Irrigation was performed by the machine «Zimmatik».

Spring mustard *var. Mriya* (included in the State Register of Plant Varieties Suitable for Dissemination in Ukraine since 2000) was sown as a green manure crop after the harvest of winter cereals. The crop has a short growing season; therefore, it could be used in intermediate crops in the grain-row crop rotation. The green manure crop was mown in the flowering stage - the first ten-day period of September. In the non-till variants, the green mass of the crop was left on the field surface as mulch, and in the variants with conventional tillage it was wrapped in the soil. The green mass of mustard at the time of mowing reached 9.4–10.7 t/ha.

The study was carried out using field, weighing, calculation, comparison, mathematical, and statistical methods, which were carried out according to the corresponding methodologies. Statistical data processing was performed to evaluate the significance of the differences between the experimental variants using the two-way ANOVA algorithm with the calculation of Fisher's least significant difference at $p<0.05$ (LSD_{05}) [11, 23, 24, 26, 27].

RESULTS AND DISCUSSIONS

The study's findings showed that the bulk density of the soil in the 0-40 cm layer in the control (with a differentiated system of basic tillage) and the variants without the use of post-harvest green manure was, on average, 1.25 g/cm^3 at the start of the winter barley growing season. The bulk density was 2.4% lower under the plough-less multi-depth system with chisel tillage than it was under the control, whereas it was 0.8% higher under the shallow ploughing method. The no-till choices had the highest bulk density of the soil (1.30 g/cm^3), which was 4.0% higher than the bulk density of the control (Fig. 1). These results are supported by the work of other scientific groups tested the effects of no-till options on the soil compaction [6].

The bulk density in the 0–40 cm soil layer was somewhat lower in the experimental versions where the effectiveness of green manure was investigated. When the green mass of the crop was wrapped to a depth of 28–30 cm, and the soil bulk density was reduced by 1.6%, the green manure crop had the largest impact on the multi-depth plough-less system.

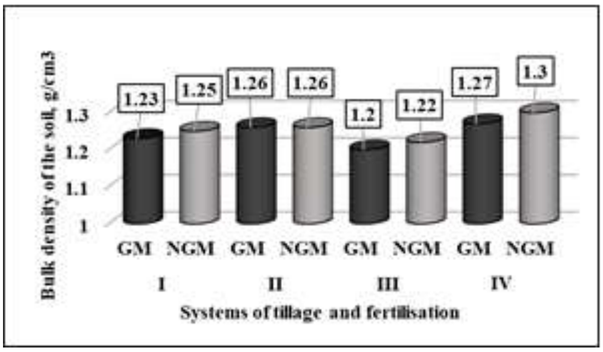

Fig.1. Bulk density of the soil in 0–40 cm layer at the beginning of winter barley growing season under different basic tillage and fertilisation systems, g/cm^3 (averaged for 2016–2020)

Notes. I – differentiated multi-depth system of soil tillage in the crop rotation; II – system of shallow plough-less tillage; III– system of differentiated plough-less tillage; IV – no-till; GM – green manure crop sown as the intermediate crop; NGM – no green manure crop sown.

Source: Own calculation and graphical work based on data from the conducted research

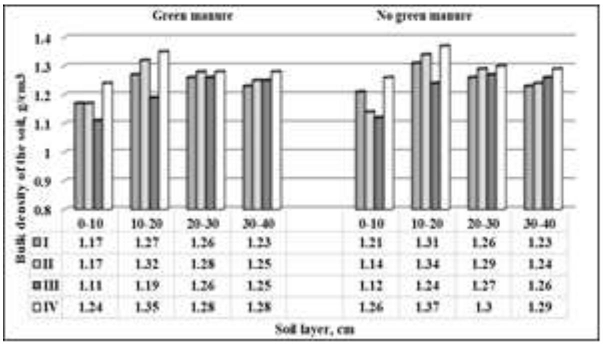

Fig. 2. Bulk density of the soil in the layers 0–10 cm, 10–20 cm, 20–30 cm and 30–40 cm at the beginning of winter barley's growing season under the different systems of basic tillage and fertilisation, g/cm^3 (averaged for 2016-2020)

Notes. I – differentiated multi-depth system of soil tillage in the crop rotation; II – system of shallow plough-less tillage; III– system of differentiated plough-less tillage; IV – no-till; GM – green manure crop sown as the intermediate crop; NGM – no green manure crop sown.

Source: Own calculation and graphical work based on data from the conducted research.

The slightest effect of green manure was on the variant with continuous shallow plough-less tillage. No-till, on average, resulted in a decrease in the bulk density of the soil by 2.3% (it was 1.27 g/cm^3).

The highest (0–10 cm) layer of the soil was the least compacted for all basic tillage and no-till systems; the examined parameter's value was 1.11–1.24 g/cm^3 for variants with green manure crop seeded and 1.12-1.26 g/cm^3 for variations without. (Fig. 2). The established fact is in agreement with other studies on this subject [6].

Soil compaction was seen beginning at a depth of 10 cm in the disk tillage and no-till variations at a depth of 12–14 cm. The soil layer 10–20 cm on these variants had the maximum bulk density, ranging between 1.31 and 1.37 g/cm^3 for the variants without a green manure crop and 1.27 to 1.35 g/cm^3 for the variants with a green manure crop seeded.

Soil compaction under the plough-less tillage approach with chisel loosening was measured up to 1.26 and 1.27 g/cm^3 in the layer 20–30 cm.

The bulk density of the soil was found to be lower in all the basic tillage variants investigated, ranging from 1.23-1.29 g/cm^3 in the versions without the green manure crop to 1.23-1.28 g/cm^3 in the variants when the green manure crop was seeded.

The study's findings also demonstrate that, when grown on dark-chestnut soil, winter barley yields are highest when the bulk density of the soil's arable layer is between 1.20 and 1.26 g/cm^3. Crop production is decreased by both an increase in the indicator under study and a drop in bulk density brought on by excessive soil loosening.

Among the physical properties of the soil, which are important to characterise its structure and mechanical composition, is total porosity. Soil porosity is influenced by the nature of the soil-forming process and tillage. Bulk density and soil porosity are inter-related values: the lower the soil density is, the greater its porosity is.

According to the study's findings, at the start of the winter barley growing season, the total porosity of the soil layer 0-40 cm in the versions without green manure use was at a level of 50.2-53.2%.

The highest soil porosity in the 0–40 cm layer was observed for the systems of multi-depth plough-less tillage with chisel loosening, where it was 53.2%. It was somewhat lower for the differentiated and shallow single-depth tillage systems with disk loosening – 52.0 and 51.9%, respectively. The no-till variants provided the lowest porosity of the soil – 50.2% (Fig. 3).

The variants with green manure crop had higher porosity was all the tillage systems, and it reached 51.5% for no-till, and up to 53.9% for deep chisel tillage. A slight increase in the total porosity of the soil layer 0–40 cm was recorded in the variants with the green manure crop: for the differentiated system with disk tillage and deep chisel tillage without ploughing – by 0.7%, for no-till – by 1.3 %.

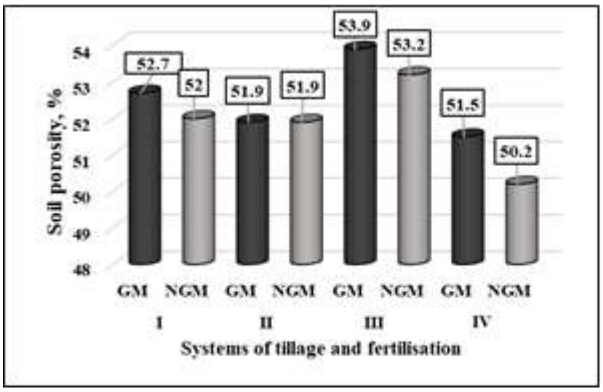

Fig. 3. Soil porosity in the 0–40 cm at the beginning of winter barley's growing season under the different systems of basic tillage and fertilisation, % (averaged for 2016-2020)

Notes. I – differentiated multi-depth system of soil tillage in the crop rotation; II – system of shallow plough-less tillage; III– system of differentiated plough-less tillage; IV – no-till; GM – green manure crop sown as the intermediate crop; NGM – no green manure crop sown.

Source: Own calculation and graphical work based on data from the conducted research.

During the growing season, crop rotation under the influence of weather conditions, irrigation, and agrotechnical measures increased the bulk density of the soil, leading to a slight decrease in its porosity by an average of 1.0–1.4%.

The value of soil water permeability depends not only on the type of soil and its moisture storage, but also on tillage.

As evidenced by the results of the current study, the methods of tillage that provide a lower bulk density of the soil and its greater porosity contribute to better absorption of water into the soil.

Depending on the basic tillage systems in crop rotation, the water permeability of the soil at the beginning of the winter barley growing season in the control (variants without a green manure crop) was 2.33–4.08 mm/min.

On average, during the study years, the best soil water permeability (4.08 mm/min) was provided by plough-less tillage to a depth of 23–25 cm using chisel tools.

The lowest rate of water absorption was recorded in the no-till variants (2.33 mm/min) (Fig. 4).

Among the reasons are higher bulk density, lower total porosity and the ability of untreated soil to retain moisture for a longer period.

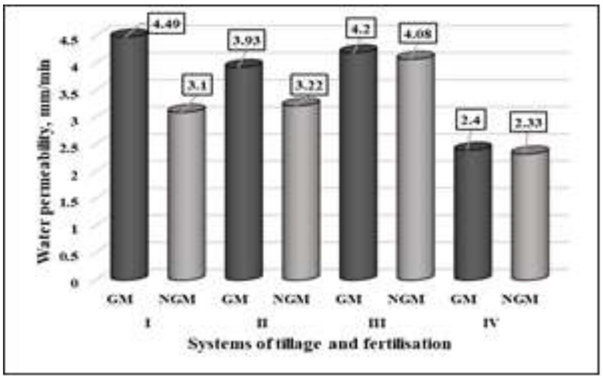

Fig. 4. Soil water permeability in the period of spring growth renovation of winter barley under the different systems of basic tillage and fertilisation, mm/min (averaged for 2016–2020)

Notes. I – differentiated multi-depth system of soil tillage in the crop rotation; II – system of shallow plough-less tillage; III– system of differentiated plough-less tillage; IV – no-till; GM – green manure crop sown as the intermediate crop; NGM – no green manure crop sown.

Source: Own calculation and graphical work based on data from the conducted research.

An increase in the water permeability of the soil was recorded in the variants with green manure crop.

With the differentiated tillage system, the rate of water permeability was higher by 1.39 mm/min, with a shallow plough-less system – by 0.71 mm/min, with a multi-depth plough-less system – by 0.12 mm/min, with no-till – by 0.07 mm/min, respectively.

The study's findings show that winter barley is a good fore crop for post-harvest green manure crops and efficiently exploits the yield-forming effects of green manure application.

It was found that in the differentiated basic tillage system (control 1), the winter barley yield was on average 5.93 t/ha, and increased from 5.46 to 6.50 t/ha with an increase in the dose of mineral fertilisers applied under the fore crop (Table 1).

Under the shallow single-depth and multi-depth plough-less basic tillage systems, barley formed a slightly higher average yield - 0.15 and 0.19 t/ha, respectively.

Table 1. Yields of winter barley grain depending on under the different systems of basic tillage and fertilization, t/ha (averaged for 2016-2020)

Soil tillage system (Factor A)	$N_{120}P_{40}$ +green manure	$N_{150}P_{40}$ +green manure	$N_{180}P_{40}$ +green manure	$N_{180}P_{40}$	**Average by the Factor A**
Differentiated, using disk at 12-14 cm	5.46	5.88	6.5	5.88	5.93
Shallow plough-less, using disk at 12-14 cm	5.63	5.9	6.62	6.16	6.08
Multi-depth plough-less, using chisel at 23-25 cm	5.84	6.07	6.68	5.88	6.12
No-till	4.82	5.22	5.69	5.29	5.26
Average by the Factor B	5.44	5.77	6.37	5.80	
LSD_{05}, t/ha: A=0.26; B=0.19.					

Source: Own calculation based on data from the conducted research.

The lowest yield was formed by winter barley without till - 5.26 t/ha, which was less than the control variant by 0.67 t/ha at LSD_{05} 0.26 t/ha. This result is supported by another long-term study, where the best yields of the crop were obtained under conventional deep plough tillage rather than shallow tillage without ploughing [9].

The yield of winter barley was more influenced by fertilisation methods. Winter barley yield increased in all basic tillage systems with an increase in nitrogen fertiliser application from 120 to 180 kg/ha per year, when combined with the use of post-harvest sowing of spring mustard. This increase was 1.04 t/ha for a differentiated system with disk tillage done to a depth of 12–14 cm, 0.99 t/ha for a shallow single-depth system, and 1.04 t/ha for a multi-depth system with chisel loose Green manure fertilisers also had a favourable impact on the development of the yield of the crop. In the green manure variants, an increase in winter barley yield was up to 0.62 t/ha in the differentiated system, 0.46 t/ha in the shallow tillage system, 0.80 t/ha in the multi-depth system of tillage without ploughing, and 0.40 t/ha for no-till at the LSD_{05} value of 0.19 t/ha. The fact that fertilisers had a decisive effect on the crop productivity is not surprising, as it is well-established fact that most crops provide better feedback for nutrition rather than tillage options [25].

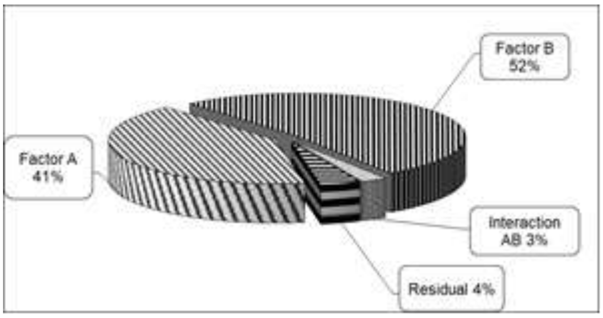

Fig. 5. Share of each of the studied factors and their interaction in determination of winter barley productivity

Source: Own calculation and graphical work based on data from the conducted research.

The statistical analysis of the study results proved that the variability of the effective signs of winter barley crop formation in the crop rotation under irrigation was 41% dependent on the choice of basic tillage system and 52% on the fertilisation system (Fig. 5).

The use of green manure crop in the short crop rotation allows to reduce the amount of mineral fertilizers applied for other cultivated crops. According to the results of the current study, the saving of mineral fertilisers in maize cultivation (as a fore crop for winter barley) is within 17% for differentiated, shallow single-depth and no-till systems, and about 37% for the multi-depth plough-less system.

CONCLUSIONS

The results of the study confirmed that:

– the highest bulk density of the soil (1.30 g/cm^3) was recorded for the no-till options, exceeding the control by 4.0%;

– the use of post-harvest green manure crop allows to reduce the bulk density of the dark-chestnut soil by 1.6% under disk and chisel tillage, and by 2.3% if continuous no-till is applied;

- the highest winter barley yields are obtained when the bulk density of the upper soil layer does not surpass 1.22–1.26 g/cm^3. Both increase and decrease in the indicator leads to a drop in the crop yield;

– the maximum water absorption was under chisel tillage, while the worst soil water permeability was fixed in the no-till variants;

- the use of shallow disk tillage (12–14 cm) or chisel tillage (23–25 cm) together with a fertilisation system using spring mustard as a green manure crop with further the application of mineral fertilisers $N_{180}P_{40}$ ensures the formation of the highest winter barley productivity of 6.08–6.12 t/ha on the irrigated dark-chestnut soils of the southern steppe zone of Ukraine.

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REFERENCES

[1]Averchenko, V.I., Samoilenko, N.M., 2018, Soil Science, Kharkiv, Machulin, pp. 101.

[2]Begei, S.S., Karasevych, N.V., 2021, Influecne of basic soil tillage on its bulk density and moisture content in winter rye crops on the mountainside lands of Precarpathia. Pre-mountain and Mountain Agriculture and Animal Husbandry, 70(1): 34–48.

[3]Bulba, I.O., 2014, Influence of basic tillage on agrophysical soil properties and spring rapeseed productivity under irrigation in the South of Ukraine. Irrigated Agriculture, 61: 101–104.

[4]Demiokhin, A.V., 2007, Soils of Kherson region, their productivity and rational use, Kyiv, Koloobih, pp. 132.

[5]Didenko, N., Lavrenko, S., Lavrenko, N., Sardak, A., Didenko, S., Mrynskii, I., 2022, Economic efficiency of corn grain cultivation with the new technologies of tillage and irrigation, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.22(3), 187-194.
https://managementjournal.usamv.ro/pdf/vol.22_3/Art19.pdf, Accessed on July 1st, 2023.

[6]Gál, A., Vyn, T. J., Michéli, E., Kladivko, E. J., McFee, W. W., 2007, Soil carbon and nitrogen accumulation with long-term no-till versus moldboard plowing overestimated with tilled-zone sampling depths. Soil and Tillage Research, 96(1-2): 42–51.

[7]Gamayunova, V.V., Philipjev, I.D., Sydiakina, O.V., 2005, Current state and problems of soil fertility in the Southern region of Ukraine. Tavrian Scientific Herald, 40: 130–135.

[8]Islam, R., Reeder, R., 2014, No-till and conservation agriculture in the United States: An example from the David Brandt farm, Carroll, Ohio. International Soil and Water Conservation Research, 2(1): 97–107.

[9]Kyrylyuk, V., Tymoshchuk, T., Kotelnytska, G., 2018, Yield and quality of barley grain according to the systems of basic tillage and fertilization. Scientific Horizons, 9(82): 36–44.

[10]Kosolap, M.P., Krotinov, O.P., 2011, System of No-Till Agriculture, Kyiv, NULES, pp. 110-122.

[11]Krotinov, O.P., Maksymchuk, I.P., Manko, Yu.P., Rudenko, I.S., 1993, Laboratory guidelines. Lessons on agriculture: a textbook. Kyiv, USGA Publishing House, pp. 280.

[12]Maliarchuk, M.P., 2014, Historical road for the formation of tillage systems in the crop rotations on the reclaimed lands. Irrigated Agriculture, 62: 19–22.

[13]Maliarchuk, M., Maliarchuk, A., Tomnytskyi, A., Maliarchuk, V., Lykhovid, P., 2021, Influence of basic systems and fertilization on productivity and economic efficiency of irrigated crop rotation, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.21(4), 345-

353, https://managementjournal.usamv.ro/pdf/vol.21_4/Art39.pdf, Accessed on July 1st, 2023

[14]Malienko, A.M., 2009, No-till: for and against. Proposal, 5: 26–27.

[15]Manushkina, T., Drobitko, A., Kachanova, T., Heraschenko, O., 2020, Ecological features of No-till technology in the conditions of the Southern Steppe of Ukraine. Ukrainian Black Sea Region Agrarian Science, 4: 47–53.

[16]Plumer, B., 2013, No-till farming is on the rise. That's actually a big deal. Washington Post, 9: 23-26.

[17]Poliovyi, V., Furmanets, M., Snizhok, O., 2023, The influence of tillage and by-products on the yield of winter wheat in the conditions of the Western Forest Steppe. Herald of Agrarian Science, 3: 28–34.

[18]Prymak, I.D., Panchenko, O.B., 2015, Productivity change of typical black soils method of cultivation and fertilizing in the Central Forest-Steppe of Ukraine. Scientific Reports of NULES of Ukraine, 6: 1–14.

[19]Saiko, V.F., 2008, Agriculture in the context of climate change. Scientific collection of the National scientific center «Institute of Agriculture of UAAS», Special Issue: 3–14.

[20]Saiko, V.F., Malienko, A.M., 2007, Systems of soil tillage in Ukraine, Kyiv, Publishing House «EKMO», pp. 44.

[21]Silici, L., 2014, Spreading the word about the no-till agricultural revolution, International Institute for Environment and Development, https://www.iied.org/spreading-word-about-no-till-agricultural-revolution, Accessed on July 2nd, 2023.

[22]Tsyliuryk. O., Chorna. V., Gavryushenko. O., Desiatnyk. L., 2021, Change of agrophysical properties of ordinary chernozem under the tillage in crop rotation and on recultivated land in the steppe zone of Ukraine. Grain Crops, 5(1): 115–124.

[23]Ushkarenko, V.O., Vozhehova, R.A., Holoborodko, S.P., Kokovikhin, S.V., 2013, Statistical analysis of field trials in agronomy, Kherson, Ailant, pp. 404.

[24]Vozhehova, R.A., Lavrynenko, Yu.O., Maliarchuk, M.P., 2014, Methods of field and laboratory studies on the irrigated lands, Kherson, Hrin D.S., pp. 286.

[25]Vozhehova, R. A., Maliarchuk, M. P., Biliaieva, I. M., Maliarchuk, A. S., Tomnytskyi, A. V., Lykhovyd, P. V., Kozyrev, V. V., Markovska, O. Y., 2019, The effect of tillage system and fertilization on corn yield and water use efficiency in irrigated conditions of the South of Ukraine. Biosystems Diversity, 27(2): 125–130.

[26]Williams, L.J., Abdi, H., 2010, Fisher's least significant difference (LSD) test. Encyclopedia of Research Design, 218(4): 840–853.

[27]Yeshchenko, V.O.., Kopytko, P.H., Opryshko, V.P., Kostohryz, P.V., 2005, Bases of scientific research in agronomy, Kyiv, Diya. pp. 288.

[28]Zubets, M.V., 2010, Scientific bases of agro-industrial production in the Steppe zone of Ukraine, Kyiv, Agrarna nauka, pp. 986.

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THE EVOLUTION AND IMPACT OF BIOGAS RESEARCH IN MITIGATING CLIMATE CHANGE: A BIBLIOMETRIC APPROACH

Diana Maria ILIE[1], Eduard Alexandru DUMITRU[1], Rozi BEREVOIANU[1], Raluca Alexandra RĂDOI[2], Mirela STOIAN[3]

[1]Research Institute for the Economy of Agriculture and Rural Development, 61 Mărăști Boulevard, District 1, 011464, Bucharest, Romania, Phone: +4021.313.60.87, Fax: + 021.313.60.96, E-mails: necula.diana@iceadr.ro, dumitru.eduard@iceadr.ro, berevoianu.rozi@iceadr.ro
[2]University of Agricultural Sciences and Veterinary Medicine Bucharest, 59 Mărăști Boulevard, District 1, 011464, Bucharest Romania, Phone: +40213182564, Fax: +40213182888, E-mail: raluca_nec@yahoo.com
[3]The Bucharest University of Economic Studies, 6 Piața Romană, Bucharest, Romania, Phone: 004 0723013238, E-mail: mirela.stoian@eam.ase.ro

Corresponding author: raluca_nec@yahoo.com

Abstract

As a solution to mitigate the effects of climate change, scientists have been looking for more environmentally friendly energy production alternatives, so, since the 2000s, renewable energy production has increased across Europe. Climate change has a negative impact on our planet, with increased emissions of greenhouse gases contributing to global warming. In this context, biogas has become a promising solution for reducing greenhouse gas emissions and improving environmental quality. The purpose of the study is to review the evolution of research and development in this field, identify trends and gaps in existing knowledge, and assess the impact and significance of published research. In this sense, a bibliometric analysis was carried out, based on the topics "renewable energy" and "biogas", in which VosViewer software was used to create maps. The research results show that existing policies worldwide encourage transfer and synergy between researchers from different countries, achieving important results. Practically, researches and examples of good practise show that biogas can be a viable solution to mitigate the effects of climate change, and in the coming decades, under the conditions of the population growth estimates materialization, we will most likely witness an intensification of agriculture to ensure the population's food needs.

Key words: *renewable energy, biogas, bibliometric analysis, climate change*

INTRODUCTION

Lately, researchers around the world have focused their research on protecting the environment by finding innovative solutions for alternative energy sources. This approach has been determined by significant increases in average temperatures over the past 150 years, driven by rising greenhouse emissions, and it is estimated that by the end of 2100, these temperatures will rise between 1.8^o C and 4^o C [24]. Rising average temperatures have led to the impairment of many natural systems, including glacial lakes or lakes and river temperatures, with the effects of climate change becoming increasingly pronounced over the past 30 years [6]. Practically, climate change is negatively affecting natural systems, human populations, and regions (Figure 1).

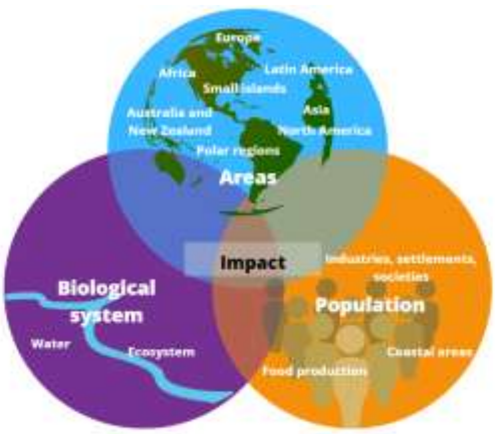


Fig. 1. Perspectives of the global warming impact
Source: [16].

As a solution to mitigate the effects of climate change, scientists and practitioners alike have been looking for more environmentally friendly alternatives, so that, since the 2000s, renewable energy production has increased across Europe [4]. Mutaqin [23] notes that the demand for renewable energy has been on an upward trend so far, which is due to both the decrease in fossil fuel reserves and the public's awareness on the effects of climate change, and thus, the need to use more environmentally friendly energy sources. This process is increasingly present in developing countries (e.g. Indonesia), where this type of energy is having a positive impact on the whole society. Fossil fuels are present in few geographic areas and are limited resources, making countries outside these areas dependent on imports. In order to prevent an energy crisis like that in the 1970s, global efforts have focused on trying to replace fossil fuels with renewable ones, increasing interest in biogas.

Biogas is a good source of renewable energy, offering the possibility of recycling various agricultural residues and secondary agricultural products, industrial and domestic wastewater, sewage sludge, and its production is sustainable and environmentally friendly.

Only 40 million ha of the EU surface could be used for producing biogas and the largest amount of wastes used in biogas production come from the urban areas [11].

Alternative forms of energy largely contribute to sustainable rural and regional development Renewable energy can be seen as a way to improve the economic situation of farms, and in addition can help develop other companies involved in agro-bio-energy plants [25].

Climate change has a negative impact on our planet, with increasing greenhouse gas emissions contributing to global warming [5]. In this context, biogas has become a promising solution for reducing greenhouse gas emissions and improving environmental quality. By converting organic residues into energy, biogas can be used to generate electricity and heat, thus reducing dependence on fossil energy sources [26].

Looking for a healthier food production and to mitigate the impact of climate change, new sustainable energy options have been developed.

Of the total methane gas produced by human activities, 30% is carried out by livestock. Also, the use of chemical fertilizers increases emissions as well as the greenhouses polluting effects.

Biogas is an alternative to reduce the dependence of producers to oil and optimize agricultural production systems, helping the reduction of the environmental impact of human activities [28].

Organic waste is an environmental problem that society is facing more and more [2] and, as a result, sustainable waste management, is a major policy priority for many countries around the world, which can make an important contribution to joint efforts to reduce pollution, GHG and climate change impacts [29].

Although biogas combustion releases carbon dioxide, the difference from fossil fuels is the origin of the carbon in biogas, which has a closed cycle in a very short period of time [15]. Biogas production through anaerobic digestion also contributes to reducing methane and nitrous oxide emissions resulting from the storage and use of manure as fertiliser, with a much higher greenhouse potential compared to carbon dioxide [13].

Biogas production is a sustainable process used to simultaneously generate renewable energy and to treat organic waste. The growing interest in using biogas as a substitute for natural gas or exploiting it for transport fuel has opened new perspectives in the development of biogas upgrading techniques [1].

Biogas production primarily involves a well-established technology for renewable energy generation and also, for the organic residues' valorisation. Biogas and digestate are the final products of a biologically mediated process, so-called anaerobic digestion, in which a multitude of microorganisms follow various metabolic pathways to decompose organic matter. Therefore, biogas being a combustible gas, it can be used for the production of heat and electricity, and the decomposed substrate i.e., digestate, it can utilised in agriculture as fertiliser due to its richness in macronutrients and micronutrients, that are essential for plants growth.

In a circular economy, the biogas production can play an important role in, since a renewable fuel can be produced from organic waste. Therefore, resource-efficient biogas production must consider both biological and energy performance [21, 30].

Biogas, in addition to being able to contribute to improving the country's energy balance, helps to conserve natural resources and to improve environmental conditions. On top of this, it has numerous benefits for the farmers involved in its production.

The aim of the study is to examine the evolution of research and development in this field, identifying trends and gaps in existing knowledge, and to assess the impact and importance of published researches, in the same field. The study also provides a general review of the most important attainments and issues biogas’s use as a source of renewable energy, thus easing the ways to develop the energy production solutions and strategies.

Review of the scientific literature

One of the most important issues that society is facing today is climate change, with negative impacts on people's lives and on the environment. Massive greenhouse gas emissions are the main cause of global warming, and this has led to an urgent need for solutions to reduce their negative impact. Climate change has an important effect on ecosystems and the environment. As shown in the study published by Chen (2017), climate change has a major effect on thermal changes and environmental and soil changes around the world [9, 18].

Biogas can be seen as an important solution in this context as it converts organic waste into energy, reduces greenhouse gas emissions and contributes to the conservation of natural resources. The biogas production process is based on the fermentation of organic materials such as agricultural and household waste, thus producing electricity and heat.

Also, to add at the environmental benefits, biogas is also a resource to elevate the energy efficiency and to decrease reduce the costs for consumers. For example, biogas can be used in thermal power stations or even biogas-powered vehicles, which can reduce dependence on fossil fuels and contribute to sustainable economic development.

Biogas is a cleaner and less polluting option than other fuels, especially compared to fossil fuels. An article published by Mitsui [22] reveals that biogas is a clean fuel and therefore significantly reduces emissions of greenhouse gases and pollutants that affect air quality.

The authors Lanzerstorfer and Jager [19] found, from their analysis, an increase in the number of biogas power stations as well as in their size and also appreciated that the raw material mainly used for biogas production is renewable organic material. In addition, older biogas power station use mainly organic waste, while larger stations built in recent years use organic material. Petersson [27] states that biogas contains not only methane, carbon dioxide, and water, but also other impurities, which can affect equipment for biogas use through corrosion and mechanical wear.

Biogas digestion has experienced a quick development due to its unique characteristics in dealing with energy shortages and environmental pollution, asserts Chen [8] in his paper titled "History of Biogas Production in China". He also said that small farms in China are becoming larger and larger while developing biogas plants.

The standardisation of biogas technology is extremely important to promote the biogas industry worldwide. China has built a comprehensive biogas standard system, which involves common standards, household biogas, biogas digester for household wastewater treatment, production utilization and service system standards. The potential problems and barriers to biogas standardisation in China are analysed and reduced to slow standards, overlapping standards, government-dominated standards and lagging international standards; therefore, all potential biogas standards should be evaluated and placed under the same department in the company [20].

Benato [3] states that Italy occupies an important position in the ranking of biogas producing countries. Agricultural, storage, sewage and manure substrates through anaerobic digestion, are transformed into biogas and after into heat and electricity through internal combustion engines that are properly adapted. Thus, in the study cited above [3, 17], after overviewing the European context, the authors present the stage of the Italian biogas sector, in regard to the trends and factors development that favour/block the expansion of biogas production and use. Even if biogas is a renewable gas and involves a consolidated technology usage, it is necessary to examine the real costs, the composition of biogas and the combustion products of engines. Analysis of biogas production shows an increasing growth rate until the end of 2012, due to generous government subsidies, while, after the reduction of support, a continuous reduction of biogas installations was observed. Actual on-site measurements have demonstrated the variable composition of biogas, while engine emissions remain comparable to natural gas.

Biogas has many different ways that can be used: direct combustion with only heat production, combined heat and power (CHP) generation, or it can be transformed into biomethane and subsequently used for vehicles as a fuel or injected into the natural gas grid. The question arises: what is the most feasible way to use biogas? Assessing the feasibility and performance of a single modality cannot be based solely on economic criteria, such as costs and related economic benefits [12].

The purpose of the study is to review the evolution of research and development in this field, identify trends and gaps in existing knowledge, and assess the impact and significance of published research. In this sense, a bibliometric analysis was carried out, based on the topics "renewable energy" and "biogas", in which VosViewer software was used to create maps.

MATERIALS AND METHODS

In order to identify the direction of the biogas production segment in recent years, data were collected from the Eurostat platform, starting with year 2014, which was the beginning of a new programming period focused even more on climate change mitigation [16].

Next, through the Web of Science platform, publications with "renewable energy" and "biogas" as the main topic were collected and then entered into the Vosviewer software in order to generate maps showing the link between the topics.

In this respect, by the end of 2022, 158,577 results had been generated on the topic 'renewable energy', while the topic 'biogas' generated 31,644 results.

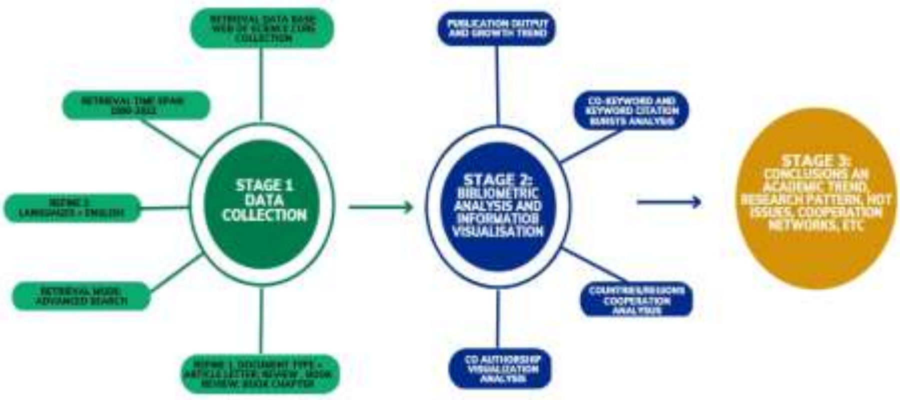


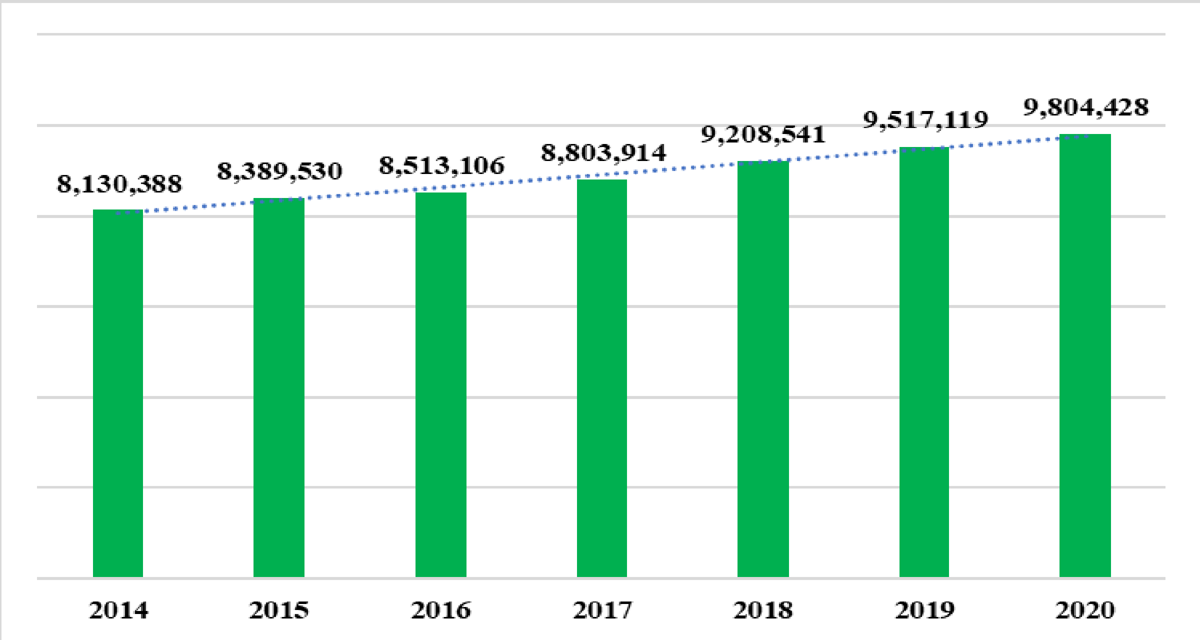
Fig. 2. Steps in data collection and analysis.
Source: processing after [16] using Canva [6].

Scientometrics is seen as a particularly important scientific discipline, representing an informational process that quantitatively analyses a specific scientific field. Thus, the aim of the process is to provide an objective picture through which science develops over a period of time, from the assessment of timeliness, through the generation of the main topics of interest for academic activity, to the optimal organisation of research systems and activities [16].

Alan Pritchaed used the term bibliometrics for the first time, as early as year 1969, as a statistical and mathematical method whose field of applicability are books and publications [16]. Using VOSsviewer software (Centre for Science and Technology Studies, Leiden University, Leiden, The Netherlands), once the data have been entered, keyword-based maps of existing publications in the Web of Science are generated, thus producing unique results. Basically, this type of analysis involves three steps, as shown in Figure 2.

RESULTS AND DISCUSSIONS

The main energy production from renewable sources and biofuels has a continuous increasing trend in the European Union, therefore by comparing the production from year 2020 to one in year 2014, there is an increase of 20.6% (Figure 3).



Fig, 3. Primary energy production from renewable sources and biofuels in the EU-27 (terajoule)
Source: Processing of the Eurostat database, Accessed 20.01.2022 [14].

It is worth noting that Germany, France, and Italy are among the top "green" energy producing countries, each producing more than 1 million terajoules, and are also the largest energy consuming countries. This is driven by the need of these highly industrialised countries to secure their domestic needs and limit their dependence on energy from conventional sources. At the same time, the last year of analysis (2020) shows a decrease in consumption of total energy caused by the temporary closure of industrial centres due to the Covid-19 pandemic (Figure 3).

Regarding the use of energy from gasification installations for biogas, there was a decrease of 8.5% in 2018 compared to the previous year. However, these decreases are driven by high production costs, which result in higher prices compared to other production sources (Figure 4). This segment is fully covered by only three countries: Germany (95% of use), Hungary, and Croatia.

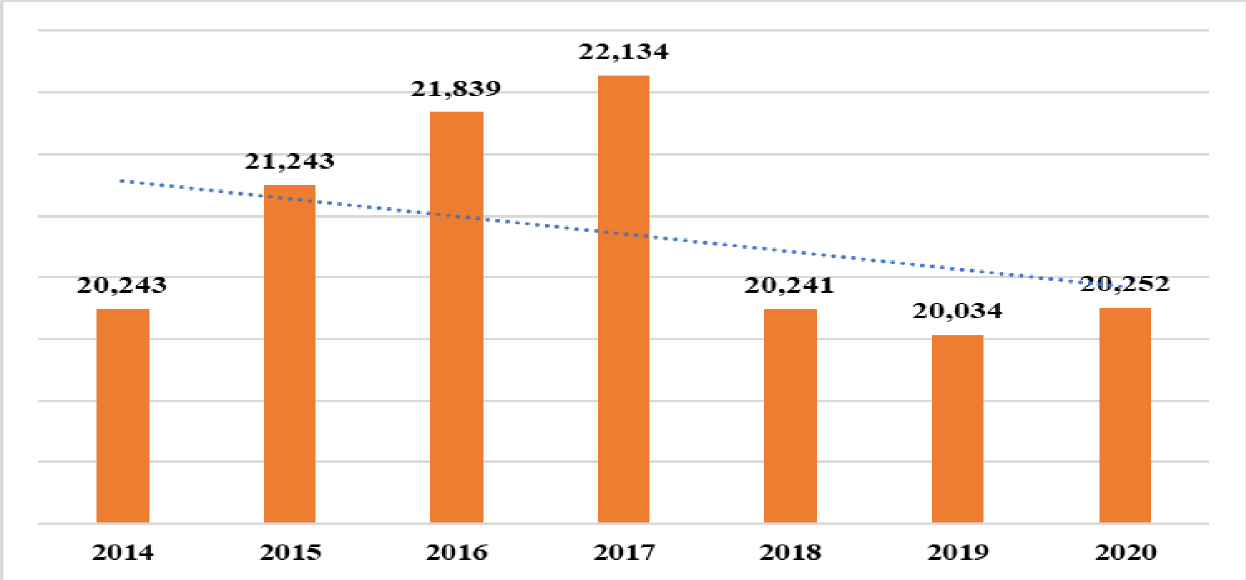


Fig. 4. Energy use from gasification installations for biogas at EU level (terajoules)
Source: Processing of the Eurostat database, accessed 20.01.2022 [14].

The following presents the information obtained from the bibliometric analysis, which is used to measure the impact and quality of research on the topics mentioned, as well as to identify trends, and is of particular importance in terms of resource allocation and identifying opportunities for collaboration.

Thus, by collecting data from the Web of Science database, a total of 158,577 papers on the topic "renewable energy" were identified between 1990 and 2022, while the topic "biogas" recorded a total of 31,644 publications. According to Figure 5, a continuous upward trend in the number of publications in these fields can be observed, except for the year 2022, when a slight decrease was recorded due to the energy instability in the world. This reality has led to a moderation of the measures regarding the implementation and use of renewable sources, through which the European Union can ensure its energy security (Figure 5).

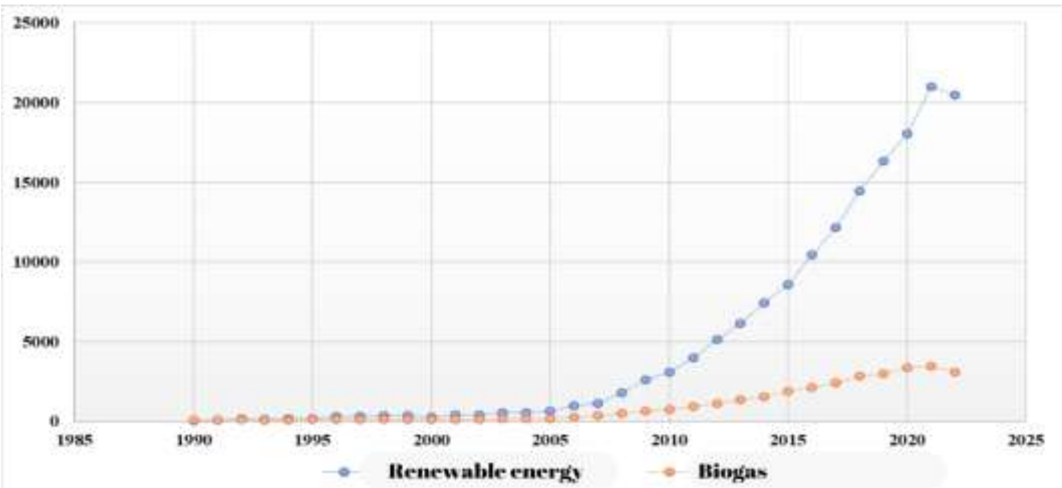


Fig. 5. Evolution of the number of articles published in the Web of Science Core Collection according to the analysed fields
Source: own processing, [10] Accessed 08.01.2023.

The main terms related to the research topic "renewable energy" are: wind energy, solar energy, wave energy, geothermal energy, energy security, energy consumption, energy poverty, environment, economy, energy reuse technologies, feed-in tariff, eco-innovation,

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energy policy, clean energy, grouped in four clusters (Figure 6). Basically, the analysis shows the most widely used renewable energy sources and their implications for the environment and the economy.

The first cluster includes terms such as biomass, biogas, hydrogen, energy mix, energy efficiency, renewables, energy security, energy consumption, energy poverty, environment, economy, integration, penetration, optimisation, power generation, planned energy, photovoltaics, solar, heat (Figure 6). This cluster group studies in less researched than well-known areas such as biomass and biogas with a focus on energy efficiency and process optimisation with the aim of becoming a viable alternative in all respects.

The second cluster refers to capacity, resources, system, investment in the project, innovation, determination, barriers, strategies, development, wind power, energy reuse technologies, feed-in tariff, Eco innovation, energy policy, geothermal energy, promotions, implementation, impact, sustainability, policy (Figure 6.). Like any relatively new or emerging field, it faces certain challenges, so this cluster groups terms related to investment sources and existing policies.

The third cluster interconnects our research topic with energy consumption, carbon emissions, cointegration, impact, consumption, oil price, carbon, cooperation, dynamics, non-renewable energy consumption, evidence of economic growth, non-renewable energy, unit root test, clear energy, new evidence, linkages, panel data analysis (Figure 6). This group can be said to bring together positive evidence on the use of energy from renewable sources compared to the use of energy from conventional sources.

The fourth cluster refers to terms such as wind energy, solar energy, wave energy, geothermal energy, renewable biomass energy, tri-energy, hydropower, sustainable energy, bioenergy, hydropower, future (Figure 6). Finally, the last cluster covers the most widely used sources of green energy, which is considered the future of energy production.

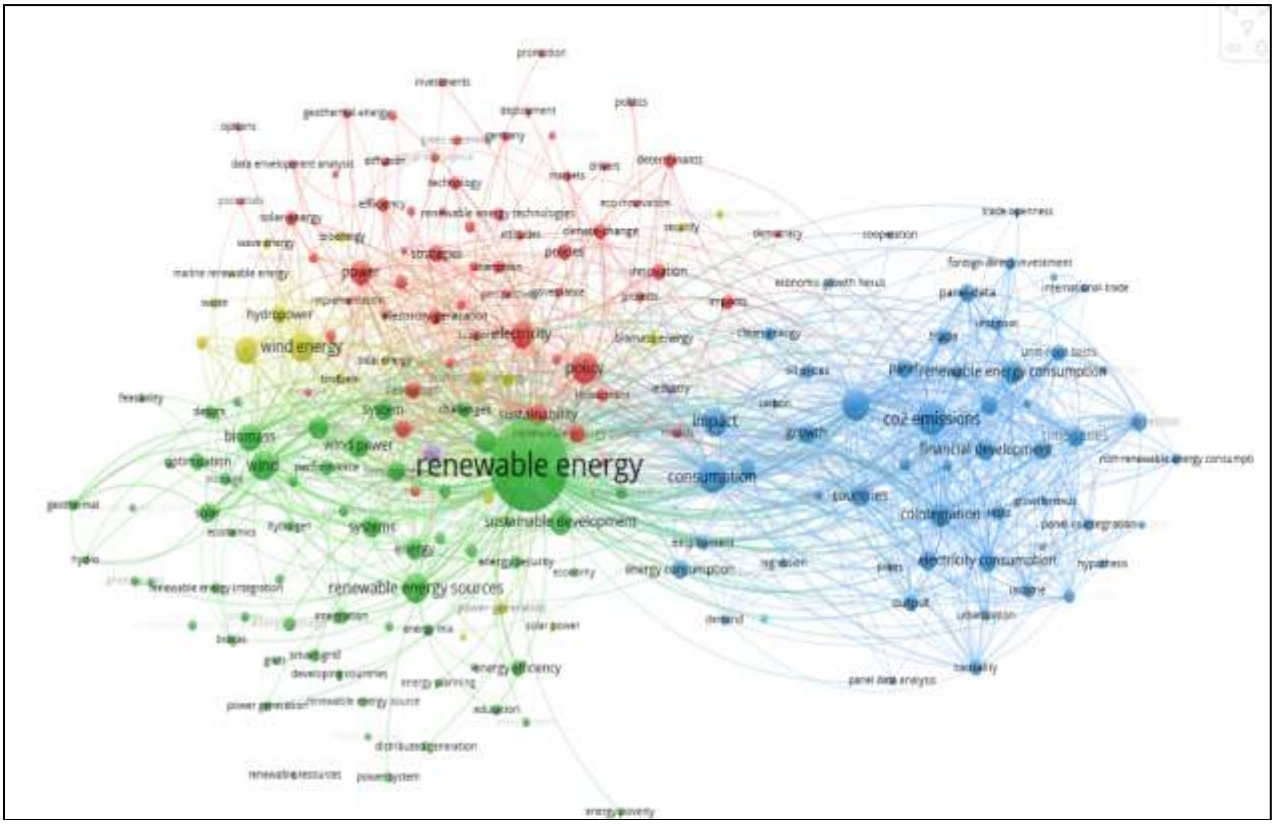

Fig. 6. Link between renewable energy and other related terms
Source: own processing based on WoS[10] results using VOSviewer [31].

Analysing the keywords by year, it can be seen that in 2014, 2015 and 2016 researchers were concerned with: renewable energy sources such as biomass, biogas, hydrogen, energy mix, energy efficiency, renewables, energy security, energy consumption, energy poverty, environment, economics, integration, penetration, optimisation, power generation, planned energy, wind power, energy reuse technologies, feed-in tariff, eco-innovation, energy policy, geothermal energy, promotions, implementation, sustainability, policy, employees. The evolution identified in the graphical representation highlights the steps taken by this topic to identify alternative sources of green energy and quantify the results through the implementation of these sources, as a result of investment measures driven by governments around the world, in the desire to limit the effects of climate change and to try to reduce energy dependence on conventional sources, concentrated in certain countries. In 2017-2018, the focus was on impact, consumption, solar energy, cointegration, foreign direct investment, outputs, panel data, growth, countries, impact, innovation, oil price, industry, models (Figure 7) direction driven by the investment impact assessment made in this sector.

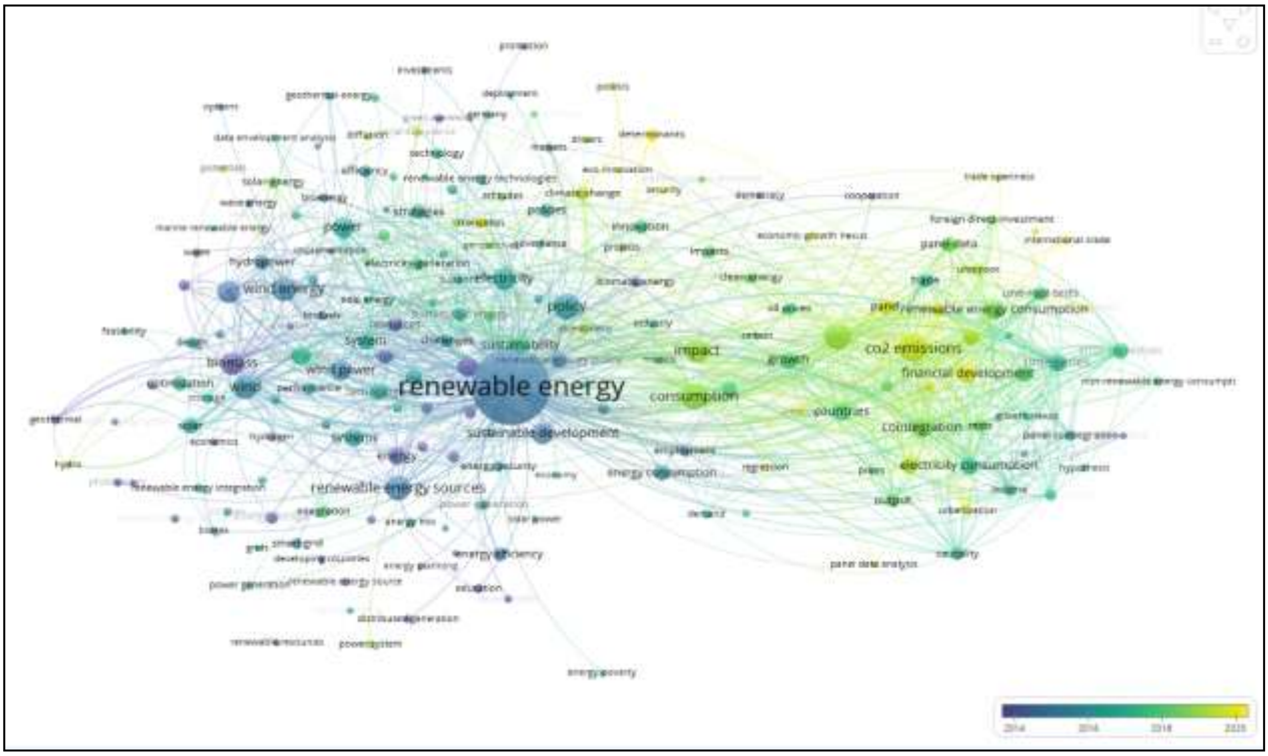

Fig. 7. Relationship between renewable energy and other related terms by year
Source: own processing based on WoS results using VOSviewer [10, 31].

In 2019 and 2020 the main topics were consumption, carbon emissions, renewable energy, economic growth, financial development, determination, security, politics, international trade and urbanisation (Figure 7).

Analysing the link between the co-author countries, it can be seen that countries such as China, Turkey and the United States of America give particular importance to the subject, while China, Denmark, India and the United States of America are in close cooperation. Also, countries in the European Union such as Germany, Belgium, Finland, Italy, and the Netherlands are in close contact and approach research in a different direction compared to the other countries presented above (Figure 8). Basically, the countries that pollute the environment the most, mostly due to their high degree of industrialisation, allocate significant funds to research to identify and optimise green energy sources, also determined by the international agreements they have to take into account. At the same time, the European Union's policy, through the required research programmes, encourages collaboration between member countries on renewable energy sources, perhaps the most important objective set at EU level.

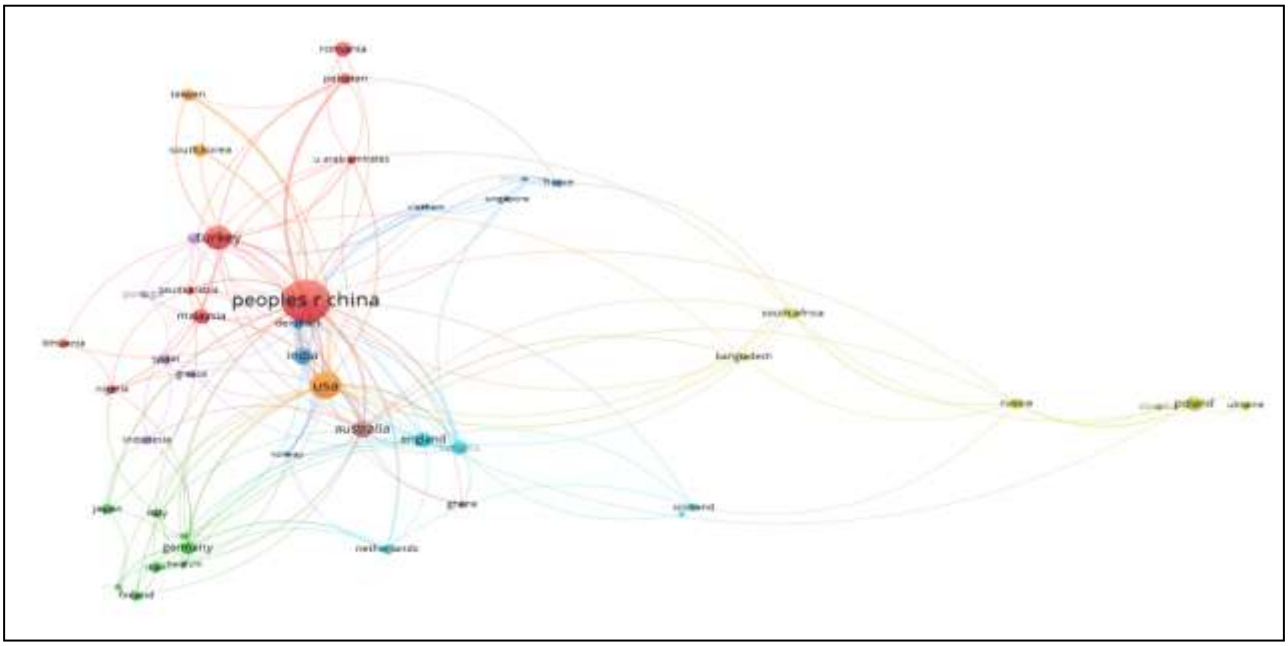

Fig. 8. Link between co-author countries (renewables and other related terms)
Source: own processing based on WoS results using VOSviewer [10, 31].

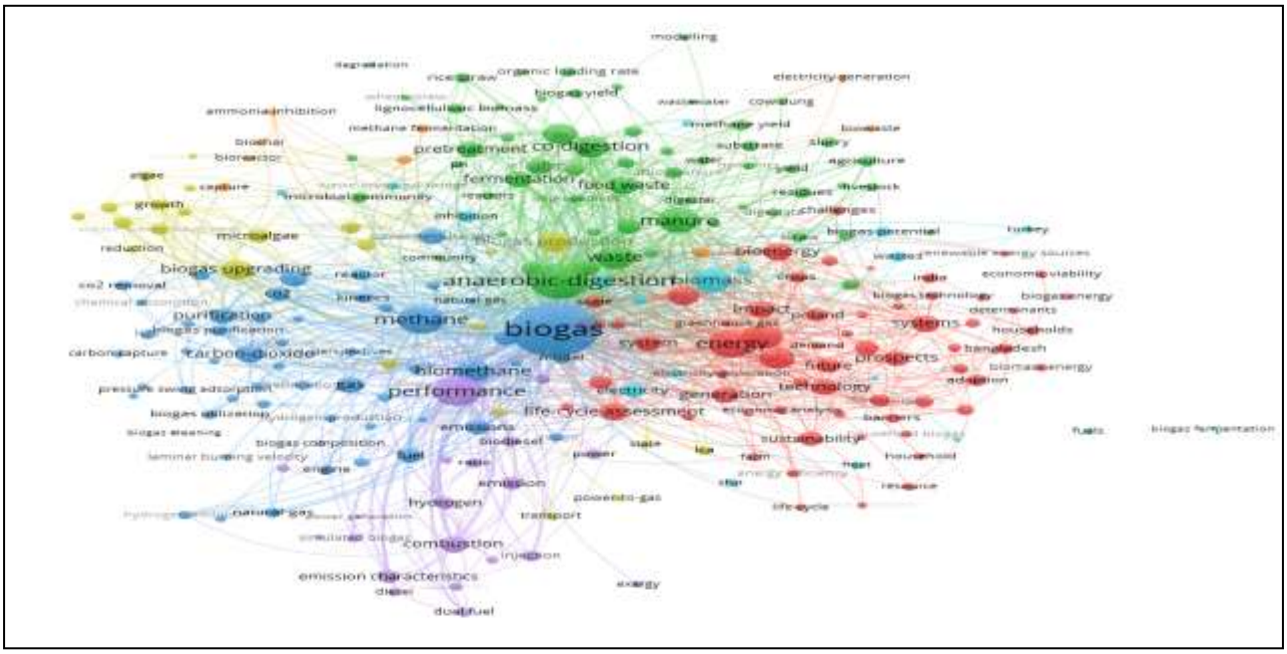

Fig. 9. Link between biogas and related terms
Source: own processing based on WoS results using VOSviewer [10, 31].

The main terms related to biogas are biodiesel, biomass, bioenergy, energy, waste, emissions, biogas use, pre-treatment, anaerobic digestion, fermentation, purification, biogas upgrading, life cycle allocation, technology, electricity, economic analysis, sustainability, etc. (Figure 9). The graphical representation on this more specific biogas segment reflects an in-depth analysis of process optimisation for biogas**.**

Unlike the general topic shown in Figure 6 on renewable energy, this topic and related terms are grouped into five clusters. The first cluster refers to the chemical compounds of biogas, such as carbon dioxide, methane, carbon dioxide removal, carbon capture, natural gas, hydrogen production, but also other terms such as inhibition, kinetics, pressure fluctuation, fuel, biogas cleaning, sludge, spent activated sludge, sewage sludge, reactor, design (Figure 9.).

The second cluster is interlinked with terms such as anaerobic digestion, waste, garbage, food waste, water waste, residues, water, surface, agriculture, livestock, household, biogas yield, sludge, straw, rice straw, fermentation, pre-treatment, organic loading rate, substrate, dynamics, upgrading. Cluster number 3 covers terms such as energy, biogas energy, biogas technology, greenhouse gases, technology, system, generation, adaptation, economic viability, harvests, sustainability, farms, resources, barriers, future, demand, challenges, life cycle allocation, life cycle, prospect. Cluster number four covers performance, biodiesel, hydrogen, emissions, fuels, dual fuels, biogas stimulation, emissions characteristics, power generated. The fifth cluster interconnects biogas with biogas production, biogas upgrading, algae, microalgae, growth, conversion, wastewater treatment, transport, gas power (Figure 9). In contrast to the general term renewable energy, this topic is mainly approached from the perspective of the chemical processes involved in the biogas process, with a lack of links to economic efficiency or special policies to encourage biogas production. Thus, until as much analysis as possible is carried out on the chemical processes, other associations are premature.

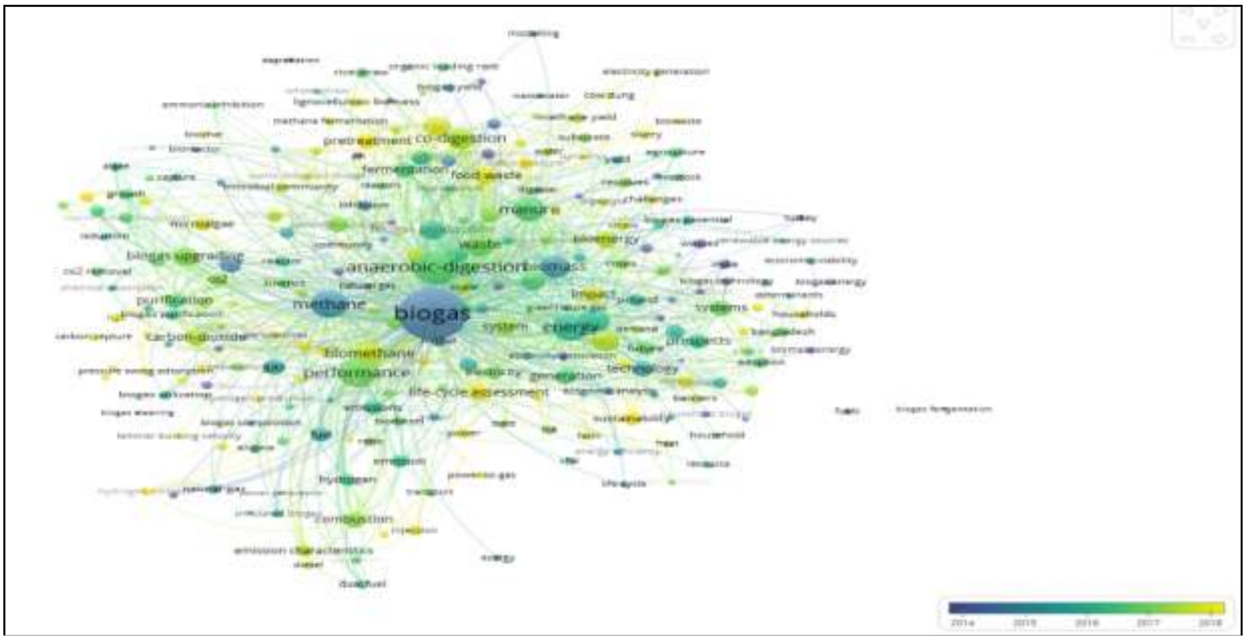

Fig. 10. Relationship of keywords used by year between biogas and related terms
Source: own processing based on WoS results using VOSviewer [10, 31].

Figure 10 shows, by year, the terms related to biogas, also grouped into clusters. Thus in 2014 - 2015, researchers were concerned with biomass, methane, natural gas, economic analysis, biogas technology, waste, biogas yield, degradation, bioreactor, electricity generation, fuel, design. In the next 2 years, 2016 and 2017, the main topics were biomass, energy, adaptation, emissions, fermentation, biogas purification, biogas use, hydrogen, natural gas, algae, anaerobic digestion, waste, purification, biogas upgrading, fuel growth, electricity, systems, agriculture, adaptation, sludge, sewage sludge, fermentation. Later in 2018, researchers paid attention to terms such as life cycle allocation, biomethane, sustainability, farms, carbon capture, pre-treatment, sludge, food waste, biomethane fermentation, straw, challenges, biowaste, households (Figure 10). Overall, research in recent years has focused on the chemical aspects of biogas, driven by the novelty of the field under consideration.

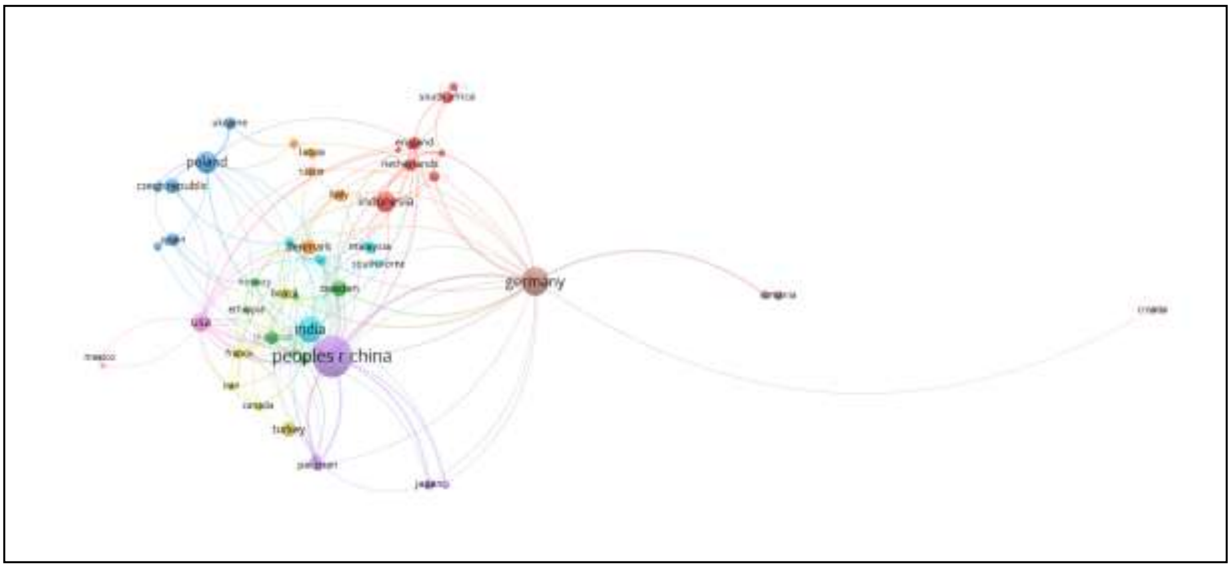

Fig. 11. Link betweenco-authorcountries (biogasandrelatedterms)
Source: ownprocessingbased on WoSresultsusingVOSviewer [10, 31].

Analysing the frequency of co-authors according to country of origin, we can see the degree of relationship between the countries interested in this research. Large nodes represent countries with increased interest in the topic of our study, with connections between nodes representing cooperative relationships between institutions. The distance between nodes and the thickness of connections represent the level of cooperation between countries, and the diversity of colours on the map indicates the diversification of research directions. Thus China, Germany and Indonesia are particularly interested in biogas, with Romania closely linked to Germany (Figure 11). The issues presented in Figure 8 are also reflected in Figure 11, where the countries that have paid particular attention to renewable energy research are basically the highly industrialised and polluting countries of the world, which are constrained in finding innovative solutions.

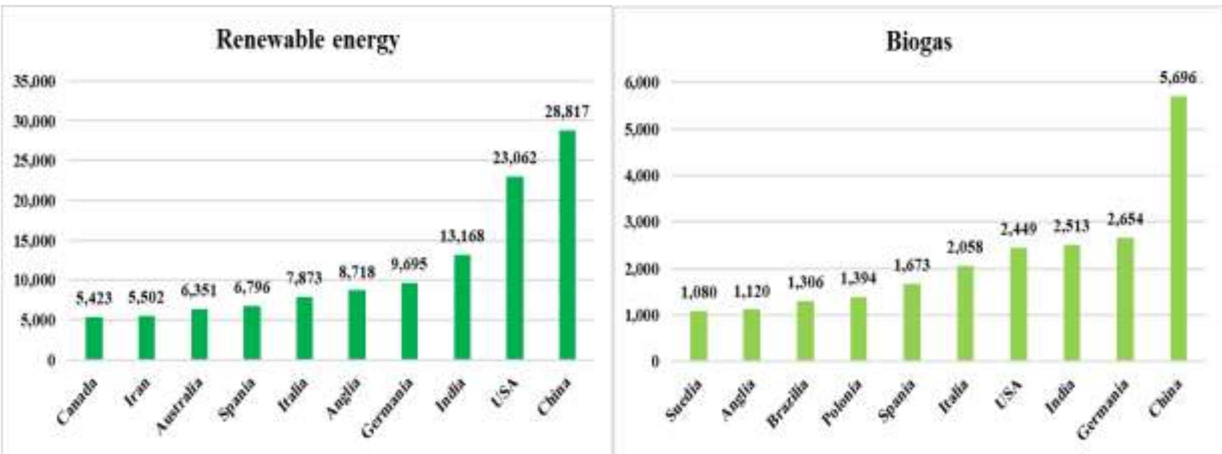

Fig. 12. Top countries ranked by number of publications on "renewableenergy" and "biogas" topics
Source: ownprocessingbased on WoSresultsusingVOSviewer [10, 31].

China has by far the highest number of publications in both the "renewable energy" and "biogas" fields. This is driven by a growing appetite for the field, fuelled by sustained economic growth, innovation and research. It is worth noting that the top countries are mainly countries that are dependent on imported conventional energy (Figure 12).

CONCLUSIONS

The field of renewable energy and biofuels plays an important role in the context of the energy security of the need to improve the European Union, offering the possibility of a variety of original approaches. Based on the huge potential of biogas in the RES sphere, the research undertaken is important in identifying the most feasible combinations or portfolio of biogas options and other related terms.

Addressing the two topics of "renewable energy" and "biogas", even if the former includes the latter term, significant differences in the state of the research process are highlighted. The importance of the first topic is already quite far back in time, and the need to identify 'green' sources has resulted in one of the many options being researched, including biogas.

Clearly, the results of the analysis show that there is a great deal of academic activity on renewable energy, given the large number of publications and the many links between this topic and other related terms. Clearly, existing policies worldwide encourage transfer and synergy between researchers in different countries, thus achieving important results. Awareness of the effects of global warming contributes to important research in the identification and analysis of different sources of green energy. Despite the importance and high potential of this field, the topic of biogas is in an early stage of development and has not been explored by researchers around the world. Most existing researches focus on understanding the chemical mechanisms that take place in the biogas production process. It is likely that as time goes by, this topic will be approached and investigated in a similar way to the generalist topic, "renewable energy".

In practical terms, biogas may be a viable solution to mitigate the effects of climate change, especially since the raw material comes from the agricultural sector, and expectations of population growth will most likely lead to an intensification of agriculture in the desire to provide food for the population, with more by-products expected to be produced suitable for biogas. However, the sector needs continuous funding to develop further and to be economically and energetically competitive with non-renewable energy sources.

REFERENCES

[1]Angelidaki, I., Treu, L., Tsapekos, P., Luo, G., Campanaro, S., Wenzel, H., Kougias, P., 2018, Biogas upgrading and utilization: Current status and perspectives. Biotechnology Advances, 36(2), 452-466. https://doi.org/10.1016/j.biotechadv.2018.01.011

[2]Banzhaf, E., Anderson, S., Grandin, G., Hardiman, R., Jensen, A., Jones, L., Knopp, J., Levin, G., Russel, D., Wu, W., 2022, Urban-Rural Dependencies and Opportunities to Design Nature-Based Solutions for Resilience in Europe and China. Land, 11, 480. https://doi.org/10.3390/land11040480

[3]Benato, A., Macor, A., 2019, Italian Biogas Plants: Trend, Subsidies, Cost, Biogas Composition and Engine Emissions. Energies 2019, 12, 979. https://doi.org/10.3390/en12060979

[4]Biesbroek, G.R., Swart, R.J., Carter, T.R., Cowan, C., Henrichs, T., Mela, H., Morecroft, M.D., Rey, D., 2010, Europe adapts to climate change: Comparing National Adaptation Strategies. Glob. Environ. Change-Hum. Policy Dimens., 20, 440–450. https://doi.org/10.1016/j.gloenvcha.2010.03.005

[5]Campos, I., Vizinho, A., Coelho, C., Alves, F., Truninger, M., Pereira, C., Santos, F., Penha-Lopes, G., 2016, Participation, scenarios and pathways in long-term planning for climate change adaptation. Plan. Theory Pract., 17, 537–556. https://doi.org/10.1080/14649357.2016.1215511

[6]Canva, https://www.canva.com/ro_ro/, Accessed on July 5, 2023

[7]Carrico, A.R., Truelove, H.B., Vandenbergh, M.P., Dana, D., 2015, Does learning about climate change adaptation change support for mitigation? J. Environ. Psychol, 41, 19–29. https://doi.org/10.1016/j.jenvp.2014.10.009

[8]Chen, B., Hayat, T., Alsaedi, A., 2017, History of Biogas Production in China. In: Biogas Systems in China. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-55498-2_1

[9]Chen, W., 2017, Global Climate Change and Its Impacts on Environmental and Soil Pollution. Journal of Cleaner Production, 161, 1160–1167. https://doi.org/10.1016/j.jclepro.2017.06.063

[10]Clarivate, Web of Science Core Collection, https://clarivate.com/products/scientific-and-academic-research/research-discovery-and-workflow-solutions/webofscience-platform/web-of-science-core-collection/, Accessed on July 5, 2023

[11]Dumitru, M., 2015, Development trends in biogas, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.15(1), 165-160.

[12]Dzene, I., Romagnoli, F., Seile, G., Blumberga, D., 2014, Comparison of different biogas use pathways for Latvia: biogas use in CHP vs. biogas upgrading, The 9th International Conference "Environmental Engineering" 22–23 May 2014, Vilnius, Lithuania, http://dx.doi.org/10.3846/enviro.2014.017

[13]Eriksen, S.H., Nightingale, A.J., Eakin, H., 2015, Reframing adaptation: The political nature of climate change adaptation. Glob. Environ. Change, 35, 523–533. https://doi.org/10.1016/j.gloenvcha.2015.09.014

[14]Eurostatdatabase, Renewable energy statistics, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics Accessed on 20.01.2022.

[15]Flach, C., Conti, F., Bayraktar, A., Goldbrunner, M., 2022, Direct Methanation and Storage Concepts for the Flexibilization of Biogas Plants. Chemical Engineering & Technology. https://doi.org/10.1002/ceat.202200239

[16]Iancu, T., Tudor, V.C., Dumitru, E.A., Sterie, C.M., Micu, M.M., Smedescu, D., Marcuta, L., Tonea, E., Stoicea, P., Vintu, C., Jitareanu, A.F., Costuleanu, L.C., 2022, A Scientometric Analysis of Climate Change Adaptation Studies. Sustainability, 14, 12945. https://doi.org/10.3390/su141912945

[17]Iglinski, B., Buczkowski, R., Iglinska, A., 2012, Agricultural biogas plants in Poland: Investment process, economical and environmental aspects, biogas potential, Renewable and Sustainable Energy Reviews Vol. 16(7), 4890-4900, https://doi.org/10.1016/j.rser.2012.04.037

[18]Kougias, P., Angelidaki, I., 2018, Biogas and its opportunities—A review, Front. Environ. Sci. Eng., Vol. 12 (30):14, DOI: 10.1007/s11783-018-1037-8

[19]Lanzerstorfer, C., Jäger, A., 2008, Decentralized integrated biogas and bioethanol production, Zuckerindustrie. Sugar industry 133(133):642-45.

[20]Li, C.J., Liao, Y.C., Wen, X.X., Wang, Y.F., Yang, F., 2017, The development and countermeasures of household biogas in northwest grain for green project areas of China. Renewable & Sustainable Energy Reviews, 44, 835-846. https://doi.org/10.1016/j.rser.2015.01.027

[21]Lindkvist, E., Karlsson, M., 2018, Biogas production plants; existing classifications and proposed categories, Journal of Cleaner Production Vol.174, 10 February 2018, pp.1588-1597, https://doi.org/10.1016/j.jclepro.2017.10.317

[22]Mitsui, M., 2019, The potential of biogas as a renewable and clean fuel. Applied Energy, 242, 1163–1177. https://doi.org/10.1016/j.apenergy.2019.02.092

[23]Mutaqin, M. I., Widyarani, U., Hamidah, S. A., Janetasari, Muchlis, Sintawardarni, N., 2019, Biogas Consumption Pattern in Indonesia: (A Case Study of Sumedang Community Biogas Plant, Indonesia), International Conference on Sustainable Energy Engineering and Application (ICSEEA), 2019, 113-118, doi: 10.1109/ICSEEA47812.2019.8938624.

[24]Neset, T.-S., Opach, T., Lion, P., Lilja, A., Johansson, J., 2016, Map-Based Web Tools Supporting Climate Change Adaptation. Prof. Geogr, 68, 103–114. https://doi.org/10.1080/00330124.2015.1033670

[25]Palkova, S., Palko, M., 2017, Green energies for agriculture; comparation study for Slovakia and the Netherlands, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.17(2), 269-274.

[26]Panda, A., 2018, Transformational adaptation of agricultural systems to climate change. WIREs Clim. Change, 9, e520. https://doi.org/10.1002/wcc.520

[27]Petersson, A., 2013, Biogas cleaning. Biogas Handbook: Science, Production and Applications, 52, 329-341. https://doi.org/10.1533/9780857097415.3.329

[28]Saborio Viquez, C., 2013, Biogas as an alternative energy source to promote indigenous communities development, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.13(1), 345-352

[29]Stadler, F., Houghton, L., 2019, Breathing life into climate change adaptation. J. Ind. Ecol., 24, 400–409. https://doi.org/10.1111/jiec.12922

[30]Sturmer, B., Leiers, D., Anspach, V., Brugging, E., Scharfy, D., Wissel, T.,2021, Agricultural biogas production: A regional comparison of technical parameters, Renewable Energy Vol. 164, Fe. 2021, 171-182. https://doi.org/10.1016/j.renene.2020.09.074

[31]VoSViewer, Visualizing scientific landscapes, https://www.vosviewer.com/, Accessed on July 10, 2023.

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THE ROLE OF AGRICULTURE IN ROMANIA'S ECONOMY IN THE PERIOD 2013-2022

Sorin IONITESCU

Romanian Academy, Institute for World Economy, 13 Calea 13 Septembrie, District 5, 050711, Bucharest, Romania, Phone: +40745139159, E-mail: sorin.ionitescu@gmail.com

Corresponding author: sorin.ionitescu@gmail.com

Abstract

The purpose of the study was to analyze the main indicators carried out in agriculture for assessing the contribution of agriculture to the economic development in Romania in the period 2013-2022 based on the data provided by National Institute of Statistics. The data were processed using fixed and structural indices, regression equations, determination coefficient, graphical illustrations and comparisons. The results highlighted that in the studied period, Romania's Gross Domestic Product (GDP) increased 2.21 times reaching Lei 1,409 Billion in 2022. Agriculture produced Lei 63.04 Billion GDP in 2022, and its contribution to Romania's GDP is 4.5%. Gross Value Added (GVA) increased 2.28 times in the economy accounting for Lei 1,282.3 Billion in 2022. Despite that GVA raised by 118.6% in agriculture, accounting for Lei 58.98 Billion in 2022, agriculture's contribution was only 4.6%. Gross Fixed Capital Formation (GFCF) raised in the economy by +131.55% accounting for Lei 377,2 Billion in 2022, but in agriculture it was very small, only Lei 2.65 Billion. Net Investment Rate (NIR) was 27.4% in 2022, but in agriculture only 4.5%. A decline by 8.7% in the number of employees was noticed in the economy, employment reaching 7,806 thousand persons in 2022, but in agriculture the reduction was 65.7% remaining only 878 thousand employees. Despite that both export and import value increased, the trade balance was a negative one, the deficit at the end of 2022 being EUR -34,101 Million. The agro-food export value raised by +126.32% and reached EUR 11,960 Million in 2022, which means that agriculture contributes by about 13% to Romania's exports, while the contribution to imports raised by +167.54%, accounting for EUR 13,248.6 Million. The deficit in the agro-food trade balance accounted for EUR -1,288.6 Million, Romania being a net importing country. Despite of its increased contribution to GDP and GVA, agriculture is facing a gap versus industry and services in GFCF and NIR. Without a better technical endowment and higher investment, agriculture cannot apply modern technologies to increase production and sustain internal market and export and to diminish imports.

Key words: *agriculture, importance in economy, GDP, GVA, GFCF, NIR, agro-food trade, Romania*

INTRODUCTION

Agriculture represents the basic economic branch in the economy and has a complex and multiple role to sustain the economic development of a country.

In the case of Romania, an important series of transformations, reforms and strategies were applied after Romania's entry in the EU, aiming to align its policy concerning the agriculture development according to CAP.

Agriculture and food industry play the key role in supplying raw products and food of high quality to ensure food security and safety [7].

Also, agriculture, being the main activity in the rural areas, must be much more involved is sustaining the rural development, contributing to poverty reduction, food security, nutrition, biodiversity, and environmental sustainability [2].

Bioeconomy and circular economy must strengthen agriculture and sustain it to contribute to the reduction of pollution, the maintaining of a health environment, biodiversity preservation and reduction of food waste.

Organic agriculture, new production technologies adapted to climate changes, reduction of fertilizers and chemical substances used in plant protection, new soil tillage methods aiming to preserve humus content into the soil, to incorporate carbon by means of crop cultures and capture the Nitrogen from the atmosphere will enable agriculture to sustain Green Economy and provide high quality and healthy food to the population as specified in the EU Green Deal for the 2040-2050 horizon when Europe has to be a continent with zero Carbon [4, 8, 9].

Moreover, production technologies should be optimised and digitalisation should be used to sustain modelling and finding the best solutions for increasing production, reducing costs, improving crops and animal structures, increasing farmers' income and profitability of their businesses [12, 13, 14].

Better technologies will enhance agricultural production and agriculture's contribution to GDP [15].

The period of the pandemic Covid-19 has reduced the expenditures of the households "for food away from home" [3], which led to the increased e-commerce for food supply and stimulating the short food chains [5, 38].

GDP, as the key macroeconomic indicator, reflects much better the increase of the market value of all the commodities achieved by all the economic branches of a country in a year.

Agriculture's contribution to GDP growth must be intensified as volume, as at present in Romania, it is still smaller compared to industry and services. In this respect, not to forget, that GDP value is conditioned by its factors of influence: consumption (C), investment (In), exports (E) and imports (I), according to the formula: GDP = C + In + E - I. As this formula shows, consumption, investment and export have a positive impact, while import diminishes GDP value [19].

GDP value differs from a country to another depending on the level of its determinant factors. In 2022, the EU carried out Euro 15.9 Trillion GDP, compared to Euro 11.5 Trillion in 2013, meaning by 38.26% higher. Agriculture 's contribution to the EU GDP was 1.4% in 2022 [16].

Some studies analyzed the dynamics of GDP created in Romania and its relationship with employment and unemployment [20], also the regional convergence based on GDP [21], the influence of final consumption on GDP [24], the contribution of agriculture to Romania's GDP [25], the relationship between GDP, fixed assets and employment [27], the relationship between GDP and its resources [29], the concentration of GDP in Romania [30], also the correlation existing between economic growth and unemployment and employment [28].

In Latin America and Caribbean, De Sormeaux (2011) studied the factors which influence contribution of agriculture to GDP [6].

Paz et al (2009) measured the performance of GDP achieved in agriculture [18].

However, it is recognized that that agriculture has the lowest contribution to GDP compared to other economic branches [35].

But, van Arendonk (2015) analyzed how to grow the share of agriculture in GDP and employment [41].

Gross Value Added (GVA) is another important macroeconomic indicator which reflects the differences between GDP plus Subsidies on products minus Taxes on products. Therefore, after deducting the intermediate consumption value from the produced output we could calculate GVA.

The EU has a well-developed agriculture, as proved by high GVA in its agricultural industry which in 2022 accounted for Euro 220.7 billion [10].

Agriculture has a major importance in the rural areas, where it is the main job for the local population, to whom it assures income and the living standard.

Agriculture valorises natural, material and human resources existing in the rural areas, sustaining the families and communities to develop agri-business and small industry and services like agro-tourism, ecotourism and rural tourism [36, 37, 39, 40].

Agriculture is a job beneficial for the local population, even though employment is expected to be reduced when the modern technologies assisted by IT and AI tools will be extended.

Age structure of the population and youth's migration to the cities looking for better paid jobs are present features in the EU rural areas and that its why special funding Programmes are implemented for enhancing young farmers and encourage the development of the rural areas [31, 32, 33].

The diversification of the activities in the rural space could bring additional incomes besides the ones from agriculture. It creates the

premises for developing investment in new modern farms, for improving training level of the rural population and farmers and diminishing poverty [11].
In the EU, Romania and Bulgaria have the highest poverty level, accounting for 55% and, respectively, 51.4% in the weak populated areas, 31% and 41.5% in the semi-urban areas and 27.9% and 30 % in the areas with a high density of the population [1].
From an economic point of view, besides the other economic branches, agriculture contributes to the development of the country's trade on the international markets, by its two components: export and import, whose dynamics as volume and value could lead to a positive or negative trade balance.
Romania has a high deficit in its trade balance, not only for all the commercialized goods, but also for agro-food products. The import rate exceeds the export rate, which makes the internal market to be dominated by imported products, situation which affects the local producers. But imports are justified for ensuring the population's requirements.
The main trade partner for Romania is the EU, which has a share of about 80% in imports and about 70% in exports [22, 23, 26, 34].
In this context, the goal of this study to analyze the dynamics of GDP and of some other factors of influence in Romania in order to identify the main trends in the last decade, 2013-2022. The examined indicators are: Gross Domestic Product (GDP), Gross Value Added (GVA), Gross Fixed Capital Formation (GFCF), Net Investment rate (NIR), Employment (Em), Romania's external trade (T) and its external agri-food trade (AFT), involving: Export (E), Import (I) and trade balance (TB).

MATERIALS AND METHODS

For this research, the data from the National Institute of Statistics and Eurostat were used for the following selected macroeconomic indicators from national economic accounts reflecting the role of agriculture in Romania's economy: GDP, GVA, GFCF, NIR, Em, T, AFT, E, I, TB.
The period of references was the last decade 2013-2022.
The methodology used involved: Fixed basis index, Structural index, Average growth rate, regression linear and polynomial equations, coefficient of determination, comparisons, graphical illustrations and the connected comments of the obtained results.

RESULTS AND DISCUSSIONS

Gross Domestic Product (GDP)

In the period 2013-2022, Romania's GDP increased 2.21 times from Lei 637.5 Billion in 2013 to Lei 1,409 Billion in 2022 (Fig. 1).

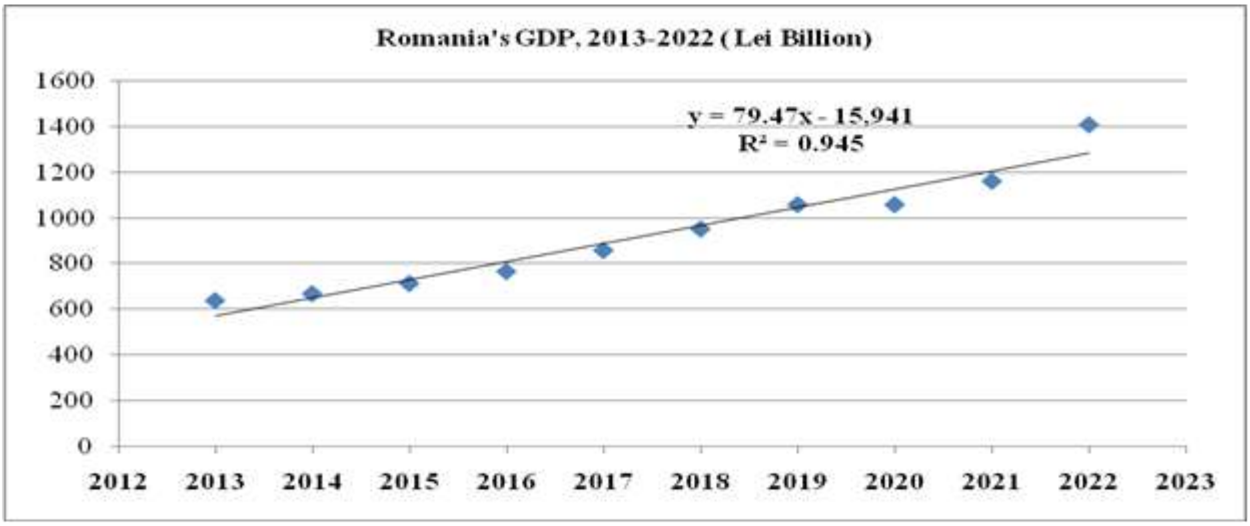

Fig. 1. Evolution of Romania's GDP, 2013-2022 (Lei Billion)
Source: Own design based on the data from NIS, 2023 [17].

GDP created in agriculture has also increased, but only by +83.14%, from Lei 34.42 Billion in 2013 to Lei 63.04 Billion in 2022 (Fig. 2).

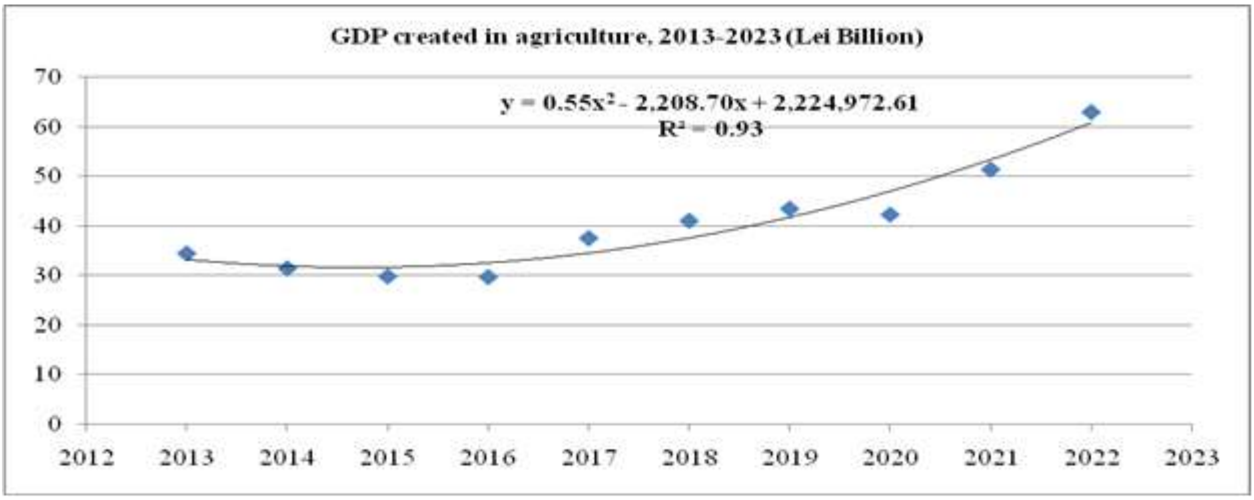

Fig. 2. Evolution of GDP created in Romania's agriculture, 2013-2022 (Lei Billion)
Source: Own design based on the data from NIS, 2023 [17].

As the growth rate of GDP created in agriculture was lower compared to Romania's GDP growth rate, the percentage contribution of agriculture to Romania's GDP recorded a decreasing trend from 5.4% in 2013 to 4.5% in 2022, meaning -0.9 pp.

Compared to other economic sectors like industry, services and constructions, in agriculture it is the smallest GDP. On the top position is the sector of services, followed by industry, constructions and agriculture which comes on the 4th position, both in the year 2013 and in 2022 (Fig. 3 and Fig. 4).

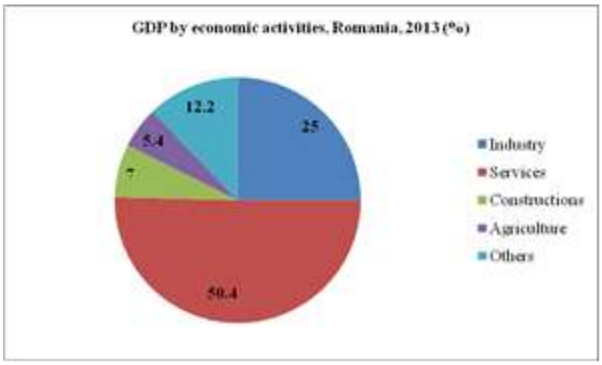

Fig. 3. Romania's GDP by activity, 2013 (%)
Source: Own calculation based on NIS data, 2023 [17].

GDP of Romania is not as large in other EU countries and to make a comparison, usually it is considered GDP/inhabitant in PPS (purchasing power standard).

In the EU-27, the average GDP accounted for Euro 35,200 in the year 2022. Compared to This means that Romania's GDP/capita represents only 77.27%, and compared to the other EU member states, Romania is ranked 22nd, like Portugal.

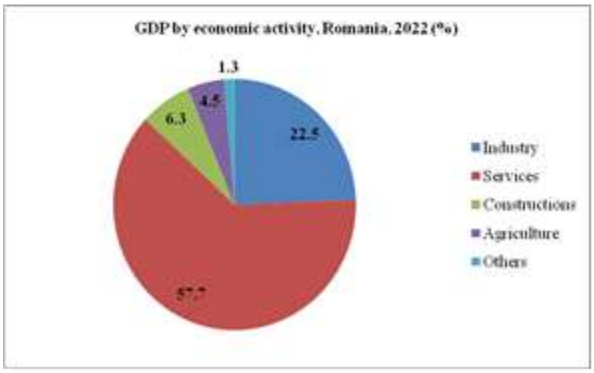

Fig. 4. Romania's GDP by activity, 2022 (%)
Source: Own calculation based on NIS data, 2023 [17].

A number of 11 countries have a higher GDP/capita than the EU mean: Luxembourg, Ireland, Denmark, Netherlands, Austria, Belgium, Sweden, Germany, Finland, Malta and France (Fig.5).

Gross Value Added (GVA)

GVA is another important macro economic indicator, which showed an ascending trend from Lei 561.5 Billion in 2013 to Lei 1,282.3 Billion in 2022, when it was 2.28 higher than in the 1st year of analysis (Fig. 6).

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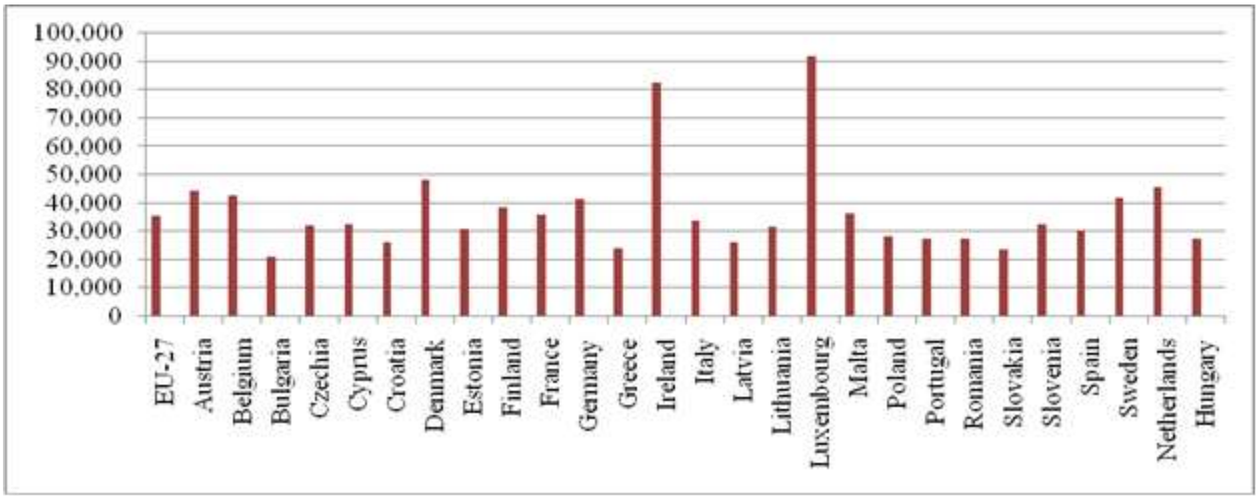

Fig. 5. GDP/capita in the EU-27 (Euro)
Source: Eurostat, 2023 [10].

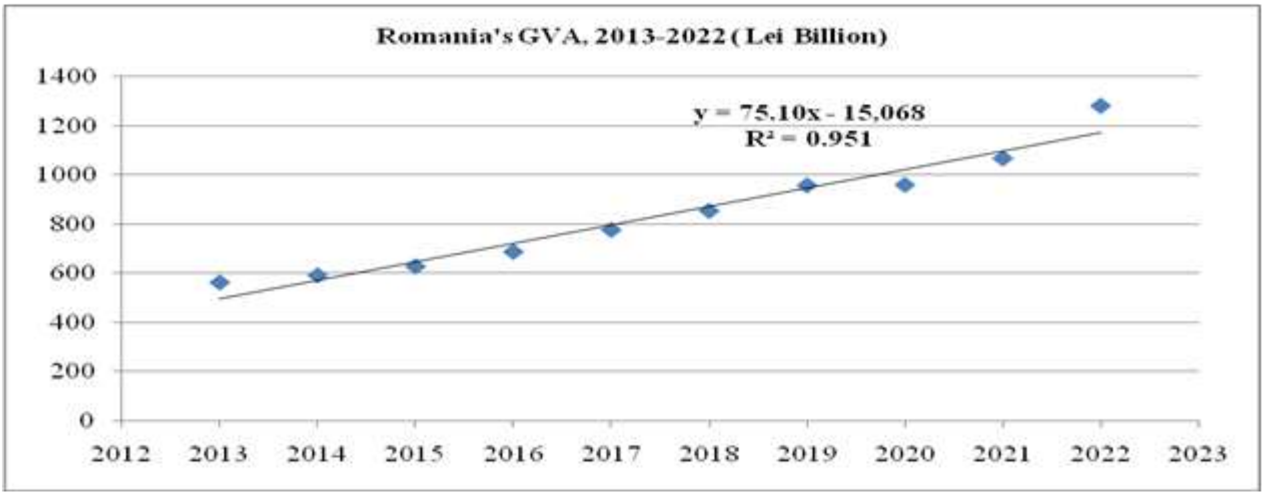

Fig. 6. Evolution of GVA in Romania's economy, 2013-2022 (Lei Billion)
Source: Own design based on the data from NIS, 2023 [17].

GVA produced in agriculture is much smaller, but it also carried out an increasing trend from Lei 26.98 Billion in 2013 to Lei 58.98 Billion in 2022, when it was by 118.6% higher than in the 1st year of the study (Fig, 7).

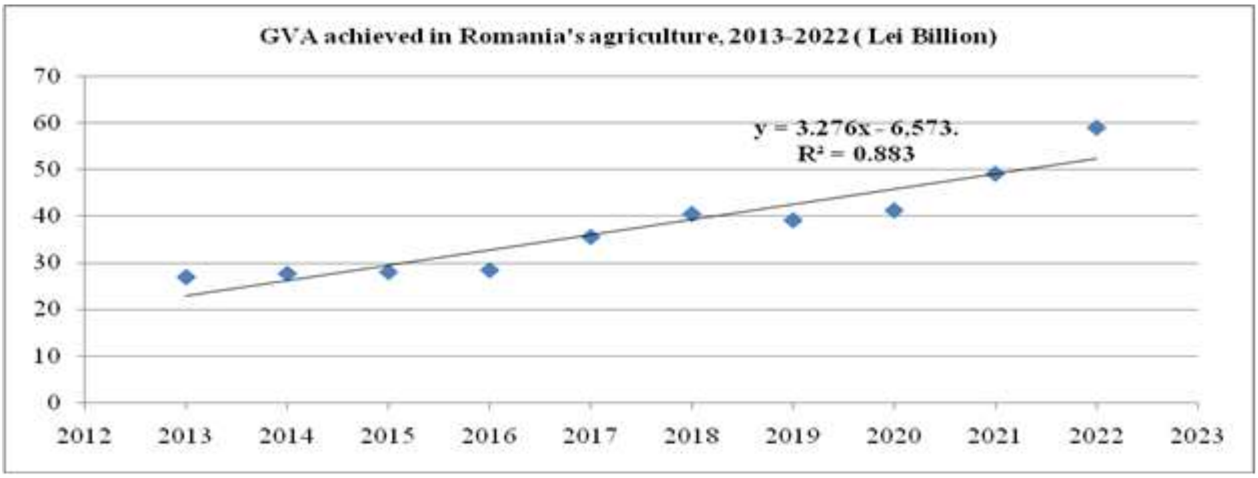

Fig. 7. Evolution of GVA in Romania's agriculture, 2013-2022 (Lei Billion)
Source: Own design based on the data from NIS, 2023 [17].

The share of GVA achieved in agriculture in Romania's GVA varied from 4.8% in 2013 and 4.6% in 2022, which reflects that its level is very small than in the field of services, industry and constructions.

The share of GVA in Romania's GDP followed an ascending tendency from 88% in 2013 to 90.9 % in 2022, while the share of GVA produced in agriculture in GDP of agriculture also increased from 78.3% in 2013 to 93.5% in 2022.

Gross Fixed Capital Formation (GFCF)

GFCF is a component of the expenditure on GDP which reflects how much of new value added is invested than consumed. It measures the value of the fixed assets either existing or new bought by government, business sector and households minus fixed assets availability.

GFCF in Romania raised from Lei 162.9 Billion in 2013 to Lei 377,2 Billion in 2022, meaning a surplus of +131.55% in the whole interval (Fig. 8).

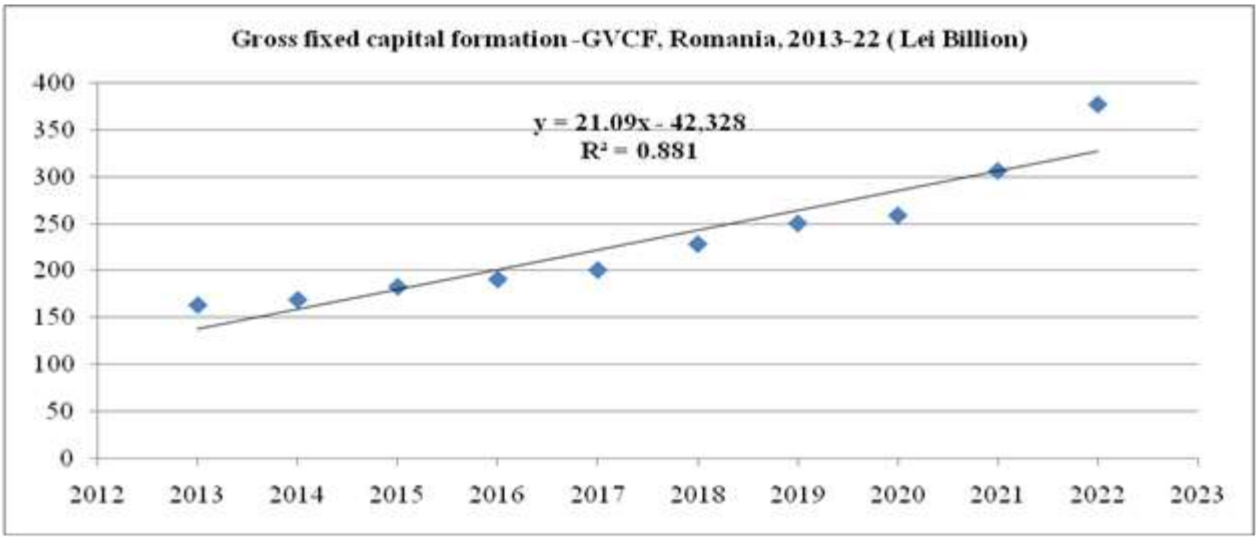

Fig. 8. Evolution of GFCF in Romania's economy, 2013-2022 (Lei Billion)
Source: Own design based on the data from NIS, 2023 [17].

In agriculture, GFCF is very small, but it also recorded an upward trend from Lei 1.43 Billion in 2013 to Lei 2.65 Billion in 2022 (Fig. 9).

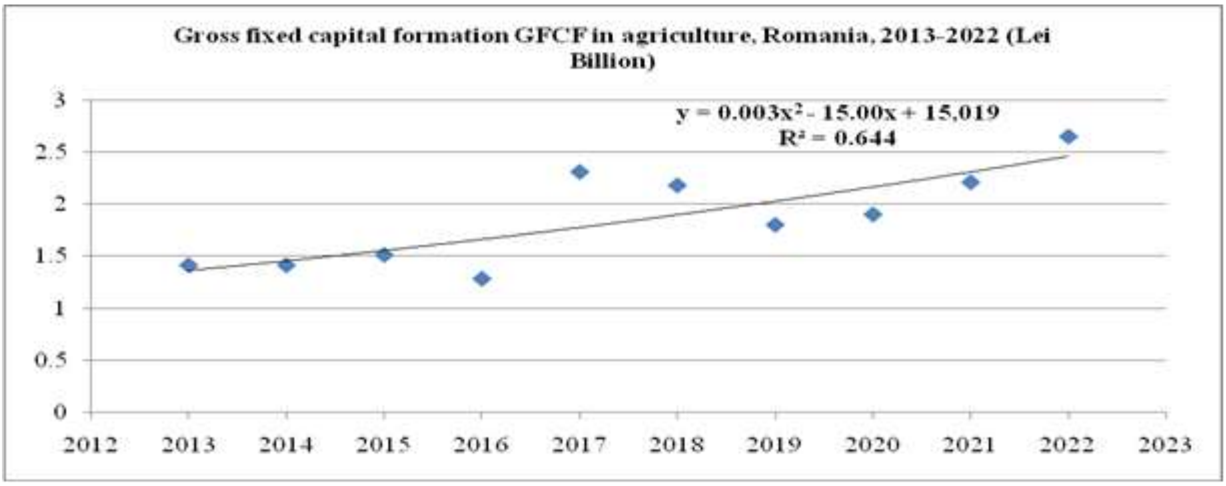

Fig. 9. Evolution of GFCF in Romania's agriculture, 2013-2022 (Lei Billion)
Source: Own design based on the data from NIS, 2023 [17].

The share of GFCF belonging to agriculture in GFCF in the national economy is very small and ranged between 0.87% in 2013 to 0.70% in 2022.

Net Investment Rate (NIR)

This indicator reflects how much money were spent on capital assets minus costs of the depreciation for those assets.

It reflects the efficiency of GVA as its calculation formula is the ratio between GFCF and GVA. At the national level, NIR was 28.1% in 2013 and 27.4% in 2022, with the lowest level of 23.5% registered in 2018 (Fig. 10).

In agriculture, NIR is very small and varied between 4.3% in 2013 and 4.5% in 2022. In industry NIR is 6 times higher, while in the field of services it is 12.1 times higher that the level registered in agriculture.

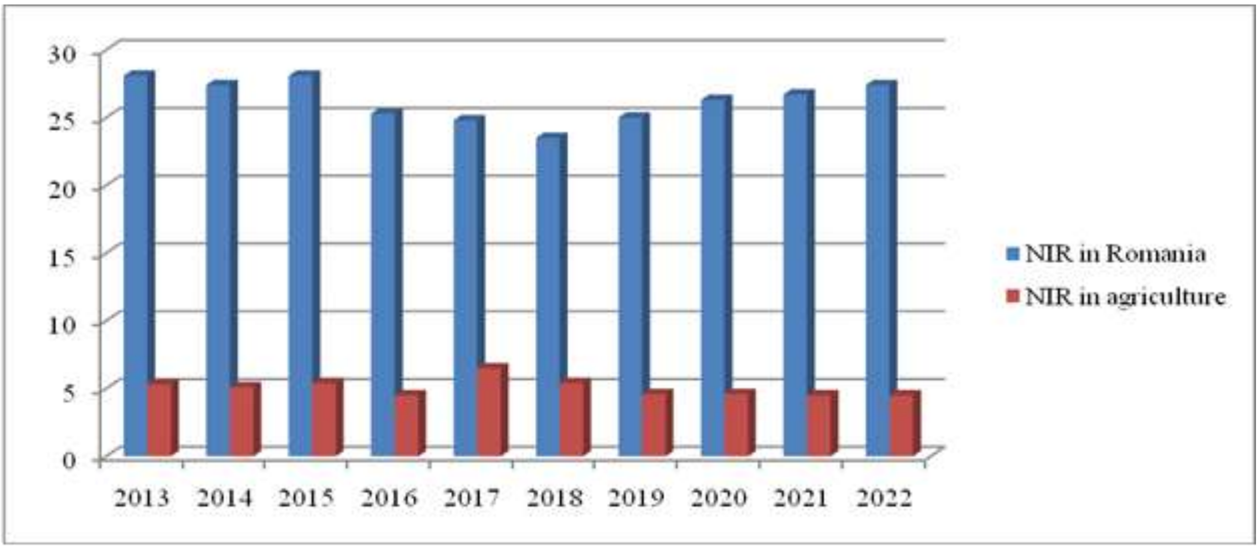

Fig. 10. Net Investment Rate, NIR in Romania and in its agriculture, 2013-2022 (%)
Source: Own calculation based on NIS data, 2023 [17].

Employment

The number of employees in Romania's economy registered an important decline from 8,549 thousand persons in 2013 to 7,806 thousand persons in 2022, meaning a reduction by 8.7%.

In agriculture, the number of employees suffered a more severe decrease, accounting for 65.7%, from 2,557 thousand persons in 2013 to 878 thousand persons in 2022 (Fig. 11).

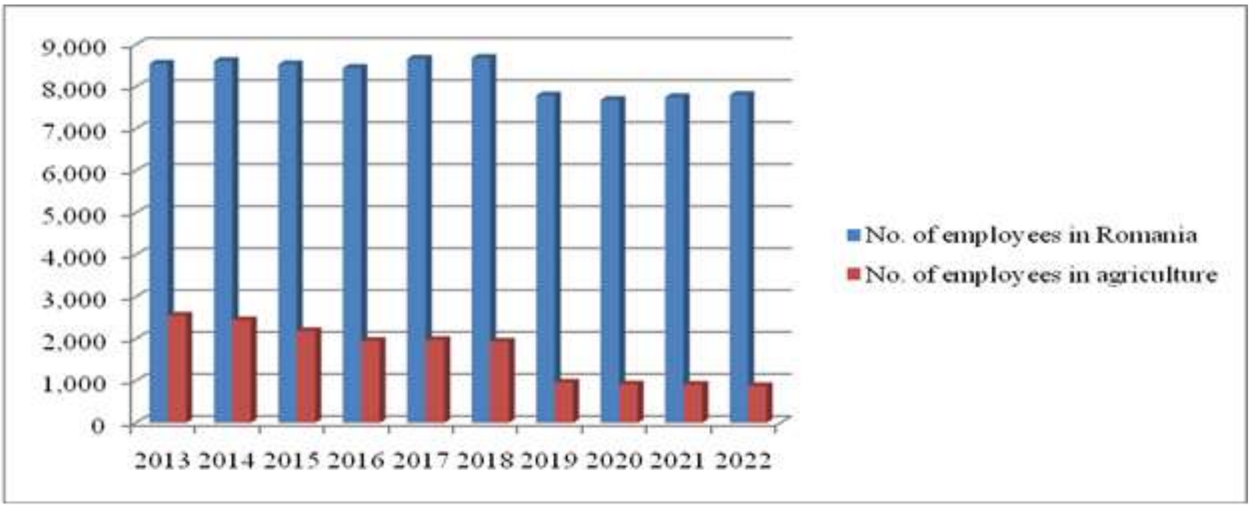

Fig. 11. Evolution of the number of employees in Romania's economy and in its agriculture, 2013-2022 (Thousand persons)
Source: Own design based on NIS data, 2023 [17].

As a result, the share of the number of employees in agriculture from the total number of employed persons in Romania declined from 29.9% in 2013 to 11.25 in 2022 (-18.7 pp).

The highest share of employees is in the field of services where it increased from 41.8% in 2013 to 56% in 2022. Also, in industry, the number of employees increased its share in total employees at the national level from 20.9% in 2013 to 23% in 2022.

In the field of constructions, the share of the number of employees is smaller than in the sectors mentioned above and it ranged between 7.3 % in 2013 to 9.8% in 2022, reflecting an increase of 2.5 percentage points.

Romania's external trade with commodities and agri-food trade

Export

Romania intensified its external trade on international market and especially with the EU.

The value of the all exported commodities increase in the analysed interval from Euro 49,562 Million in 2013 to Euro 91,953 Million in 2022, when it resulted a surplus of +85.53%.

At the same time, the agro-food export value raised by +126.32% from Euro 5,284.4 Million in 2013 to Euro 11,960 Million in 2022 (Fig. 12).

The share of agro-food export in total export registered an upward trend from 10.75 in 2013 to 13% in 2022, meaning +2.3 pp.

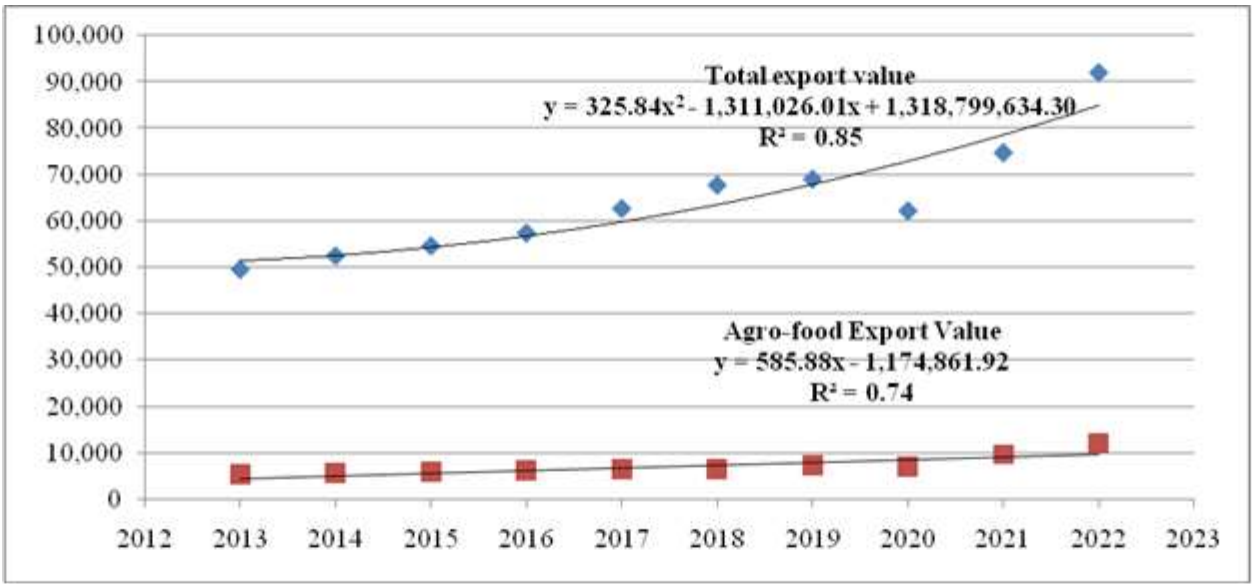

Fig. 12. Evolution of Romania' export value and of agro-food export value, 2013-2022 (Euro Million)
Source: Own design based on NIS data, 2023 [17].

Import

Romania's total import value increased by +127.87% in the studied interval from Euro 55,317 Million in 2013 to Euro 126,054 Million in 2022.

At the same time, the value of agro-food import recorded an ascending trend from Euro 4,952 Million in 2013 to Euro 13,248.6 Million in 2022, meaning +167.54% (Fig. 13).

Therefore, the share of agro-food import value in total import of Romania also went up from 8.9% in 2013 to 10.5% in 2022.

Trade balance

Romania's trade balance for all the commercialized goods registered a substantial decline, a deficit whose level was higher and higher by each year. In 2022, the deficit of the country trade balance accounted for Euro -34,191 Million, being 5.92 times higher than Euro - 5,755 Million in 2013.

The balance of agro-food products was positive in the years 2013 and 2014, but since 2015, it started to register a deficit, whose value was Euro -137 Million in 2015 and at the end of the interval, in 2022, the deficit accounted for Euro -1,288.6 Million (Table 1).

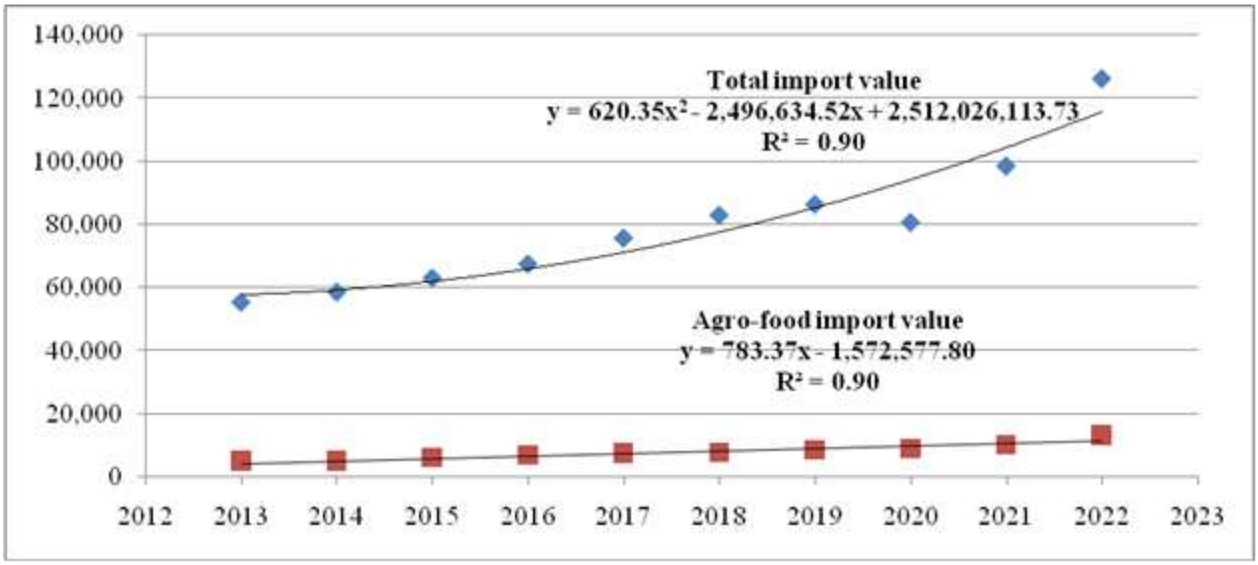

Fig. 13. Evolution of Romania' import value and of agro-food import value, 2013-2022 (Euro Million)
Source: Own design based on NIS data, 2023 [17].

Table 1. Evolution of trade balance for all goods and for agro-food products, Romania, 2013-2022 (Euro Million)

	Total trade balance	Agro-food trade balance
2013	-5,755	332.4
2014	-6,056	456.0
2015	-8,361	-137
2016	-9,972	-619.9
2017	-12,960	-1,016.5
2018	-15,166	-1,133.5
2019	-17,295	-1,246.1
2020	-18,397	-1,938.4
2021	-23,700	-543.1
2022	-34,101	-1,288.6

Source: Own calculations based on NIS data, 2023 [17].

CONCLUSIONS

This study emphasized the role played by agriculture in Romania's economy based on the analysis of the main selected macroeconomic indicators mentioned in the national accounts systems.

In the period 2013-2022, Romania's had a 2.21 times higher GDP, which accounted for Lei 1,409 Billion in 2022.

Agriculture produced Lei 63.04 Billion GDP in 2022, when it was by +83.14% higher than in 2013.

The contribution of agriculture to Romania's GDP is smaller than in the field of services and industry and declined from 5.4% in 2013 to 4.5% in 2022.

GVA increased 2.28 times in the economy from Lei 561.5 Billion in 2013 to Lei 1,282.3 Billion in 2022.

Agriculture produced a much smaller GVA, but it raised by 118.6% accounting for Lei 58.98 Billion in 2022. Agriculture contributed to GVA in the economy in a very small proportion, ranging between 4.8% in 2013 and 4.6% in 2022. GFCF raised in the economy by +131.55% accounting for Lei 377,2 Billion in 2022. In agriculture, GFCF is very small, but it also increased from Lei 1.43 Billion in 2013 to Lei 2.65 Billion in 2022.

At the national level, NIR was 28.1% in 2013 and 27.4% in 2022, while in agriculture it varied between 4.3% in 2013 and 4.5% in 2022, being much smaller than in the field of services and industry. The number of employees decreased substantially in the analysed decade, both at the national level and mainly in agriculture. In 2022, there were 7,806 thousand persons employed in the economy, by 8.7% less than in 2013, while in agriculture, remained just 878 thousand employees, the reduction being of 65.7% versus 2013. The causes of this situation are the period of the pandemic of Covid 19, which disturbed all the economic activities and in agriculture in addition to the migration of rural young people to cities or abroad for better paid jobs. External trade of Romania was intensified, imports are higher than exports, resulting a negative trade balance which reflects that Romania is a net importing country.

In 2022, Romania's exports were by 85.53% higher in 2022, accounting for Euro 91,953 Million.

The agro-food export value raised by +126.32% and reached Euro 11,960 Million in 2022, which means that agriculture contributes by about 13% to Romania's exports.

Romania's total import value reached Euro 126,054 Million in 2022, while the contribution of agriculture increased by +167.54%, accounting for Euro 13,248.6 Million.

Taking into consideration the dynamics of export and import, the fact that the import value exceeded export value both in case of all commodities and in case of agri-food products, the trade balance was negative, recording a deficit higher and higher from a year to another, which in 2022 accounted for Euro -34,101 Million and, respectively for Euro -1,288.6 Million, Romania being a net importing country.

In conclusion, we may affirm that even though agriculture registered a better situation concerning its contribution to GDP and GVA, it has still gap regarding GFCF and net investment rate in comparison with industry and services. Without a better technical endowment and higher investment, agriculture cannot apply modern technologies to increase production and sustain internal market and export and to diminish imports.

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REFERENCES

[1]Ana, I.M., Stoica, A.F., 2017, Abordari. tendinte si perspectve privind rolul agriculturii in realizarea obiectivelor de economie sociala in Romania si UE-28, ECOSTUDENT - Revistă de cercetare ştiinţifică a studenţilor economişti, Nr. 9/2017, Universitatea de Petrol si Gaze Ploiesti, 35-41.

[2]Arias, J., 2016, The contribution of agriculture to development, Inter-American Institute for Cooperation in Agriculture, https://iica.int/en/press/news/contribution-agriculture-development, Accessed on November 25, 2023.

[3]Beckman, J., Countryman, A.M., 2021, The Importance of Agriculture in the Economy: Impacts from COVID-19, Am J Agric Econ. 2021 Oct; 103(5): 1595–1611.

[4]Blandford, D., The Contribution of Agriculture to Green Growth, https://www.oecd.org/greengrowth/sustainable-agriculture/48258861.pdf, Accessed on November 10 , 2023.

[5]Caratus-Stanciu, M, 2018, Analysis of the behaviour and motivation of consumers toward short food supply chains, Scientific Papers Series Management, Economic Engineering in agriculture and Rural Development, Vol.18(4), 73-78.

[6]De Sormeaux, A., 2011, Factors influencing Agriculture's contribution to GDP: Latin America sand Carribean, AgEcon Search, 1- 13.

[7]Ene, C, Matei, M., New dimensions of food security in Romania from the European perspective, 135-140.

[8]European Commission, The European Green Deal-Striving to be the first climate-neutral continent, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[9]European Commission, 2013, At a glance: Romania's CAP Strategic plan.,

[10]Eurostat Statiscs Explained, 2023, Performance of the agricultural sector, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Performance_of_the_agricultural_sector#:~:text=Agriculture%20contributed%201.4%20%25%20to%20the%20EU's%20GDP%20in%202022.&text=Agricultural%20income%20per%20annual%20work,the%20index%20level%20in%202015, Accessed on November 10, 2023.

[11]Eurostat, 2023, Population and employment. https://ec.europa.eu/eurostat/databrowser/view/nama_10_pe/default/table?lang=en, Accessed on November 10, 2023.

[12]Ionitescu, S., Popescu, A., Gudanescu, N.-L., Cristea, A., 2023, Digitalization and agriculture-Impact on human resources in the European Union and Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.23(3), pp.363-372.

[13]Ionitescu, S., Popescu, A., Ionitescu, E., Ene, D., Gudanescu, N.-L., 2023, Models for agricultural production optimization, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.23(3), 373-385.

[14]Ionitescu, S., 2023, A linear simulation model for optimizing crop structure in order to maximize income in a vegetal agricultural farm, Scientific Papers Series

Management, Economic Engineering in Agriculture and Rural Development, Vol.23(3), 305-313.

[15]Jitendra Kumar, S., 2019, Influence of technologies on the growth rate of GDP from agriculture: A case study of sustaining economic growth of the agriculture sector in Bihar, 233/SJI-180436, Statistical Journal of the IAOS, Vol. 35(2), 277-287.

[16]McEvoy, O., GDP of the European Union 2011-2022, Statista, 2023, https://www.statista.com/statistics/279447/gross-domestic-product-gdp-in-the-european-union-eu/#:~:text=In%202022%20the%20gross%20domestic,economic%20strength%20of%20a%20country., Accessed on November 5, 2023.

[17]National Institute of Statistics, 2023, Tempo Online data base.

[18]Paz, J., Benavides, H., Arias, J., 2009, Measuring agricultural GDP performance: a technical note, Comun*IICA* Fifth Year, January-APRIL, 66-75.

[19]Popescu, A., 2015, Analysis of the dynamics of Gross Domestic Product and of its main factors of influence in Romania's agriculture, Proceedings of 25th IBIMA Conference Innovation Vision 2020: from Regional Development Sustainability to Global Economic Growth, Amsterdam, The Netherlands, May 7-8, 2015, pp.1379-1393.

[20]Popescu, A., 2016, Research on the Relationship between GDP, Unemployment and Employment in the EU-28, Proceedings of 27th IBIMA International Conference on Education Excellence and Innovation Management Vision 2020: from Regional Development Sustainability to Global Economic Growth, Milan, Italy, May 4-5, 2016, pp.686-695.

[21]Popescu, A., 2017a, Convergence of Regional Development in Romania in Terms of Gross Domestic Product, Proceedings of 29th IBIMA on Education Excellence and Innovation Management Vision 2020: from Regional Development Sustainability to Global Economic Growth, May 4-5, Vienna, May 4-5, 2017, pp.1279-1293.

[22]Popescu, A., 2017b, The Intra-Industry Trade in Agro-Food Products - The Case of Romania, Proceedings of 29th IBIMA International Conference on Education Excellence and Innovation Management Vision 2020: from Regional Development Sustainability to Global Economic Growth, Vienna, May 4-5, 2017, pp.1261-1278

[23]Popescu, A., 2017c, Trends and correlations in Romania's agro-food foreign trade in the period 2007-2016, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development,Vol.17(4)293-304.

[24]Popescu, A., 2018, The Influence of Final consumption on Gross Domestic Product in Romania, Proceedings of 31st IBIMA International Conference on Vision 2020: Education Excellence and Management of Innovations through Sustainable Economic Competitive Advantage, Milan, April 25-26, 2018, pp.2411-2423

[25]Popescu, A., 2020, Contribution of Agriculture to Romania's Gross Domestic Product, Proceedings of 36th IBIMA International Conference on Vision 2025: Education Excellence and Management of Innovations through Sustainable Economic Competitive Advantage, November 4-5, 2020, Granada, Spain, pp.2207-2220.

[26]Popescu, A., 2022, The importance of production and import for ensuring food availability in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.22(1), 533-548.

[27]Popescu, A., David, L., 2015, The use of the Cobb-Douglas production function to analyze the relationship between GDP, Fixed assets and Employment in Romania's Agriculture, Proceedings of 25th IBIMA Conference Innovation Vision 2020: from Regional Development Sustainability to Global Economic Growth, Amsterdam, The Netherlands, May 7-8, 2015, pp. 1366-1378,

[28]Popescu, A., 2016, Research on the Correlation between Economic Growth, Unemployment and Employment. A case study-Romania, Proceedings of 27th IBIMA International Conference on Education Excellence and Innovation Management Vision 2020: from Regional Development Sustainability to Global Economic Growth, Milan, Italy, May 4-5, 2016, pp.697-706.

[29]Popescu, A., David, L., 2017, The Relationship between GDP and its Resources in Romania's Economy, Proceedings of 30th IBIMA International Conference, Madrid, November 8-9, 2017, pp.449-468

[30]Popescu, A., Serban, V., 2021, Dynamics of Concentration in Gross Domestic Product achieved in Romania's Agriculture, Proceedings of 38th IBIMA International Conference, Sevilla, Spain, November 23-24, 2021, pp.6972-6981.

[31]Popescu, A., Dinu, T., A., Stoian, E., Şerban, V., 2021, Efficiency of labor force use in the European Union's agriculture in the period 2011-2020, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.21(3), 659-672.

[32]Popescu, A., Tindeche, C., Marcuta, A., Marcuta, L., Hontus, A., Angelescu, C., 2021, Labor force in the European Union agriculture - Traits and tendencies, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.21(2), 475-486.

[33]Popescu, A., Dinu, T.A, Stoian, E., Serban, V., 2022a, Population occupied in agriculture and agricultural production value in Romania, 2008-2020, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.22(1), 503-514.

[34]Popescu, A., Dinu, T.A, Stoian, E., Serban, V., 2022b, Romania's agro-food foreign trade concentration with the European Union countries, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.22(2), 565-578.

[35]Rivera, D., 2023, Agriculture sector remains lowest GDP contributor,

https://www.philstar.com/business/2023/06/20/2275068/agriculture-sector-remains-lowest-gdp-contributor, Accessed on November 10, 2023.

[36]Stanciu, M., 2009, The role of ecotourism in sustainable rural development, Scientific Paper, Series D., Vol.59, 323-328.

[37]Stanciu, M., 2013, The attitude and motivation of buyers of traditional/local.bio products in the context of biotourism in Sibiu County, Romania, Scientific Papers Series Management, Economic Engineering in agriculture and Rural Development, Vol.13(4), 273-278.

[38]Stanciu, M., Popescu, A., Rasvan, R,-I., 2022, Short food supply chains and young people's attitude toward health eating, Scientific Papers Series Management, Economic Engineering in agriculture and Rural Development, Vol.22(1), 625-635.

[39]Stanciu, M., Popescu, A., Stanciu, C., Popa, S., 2022, Local gastronomic points as part of sustainable agritourism and young people's perception of it. Case study, Sibiu county, Romania, Scientific Papers Series Management, Economic Engineering in agriculture and Rural Development, Vol.22(4), 697-705.

[40]Stanciu, M., Popescu, A., Stanciu, C., 2023, Rural tourism, agrotourism and ecotourism: current research status and future trends, Scientific Papers Series Management, Economic Engineering in agriculture and Rural Development, Vol.23(1), 745-757.

[41]van Arendonk, A., 2015, The development of the share of agriculture in GDP and employment. A case study of China, Indonesia, the Netherlands and the United States, Wageningen university, https://edepot.wur.nl/342795, Accessed on November 20, 2023.

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ANALYSIS OF THE COST AND PROFITABILITY OF IMPORTANT FIELD CROPS IN ISPARTA PROVINCE, TURKIYE

Mehmet IŞIK[1], Mevlüt GÜL[2]

[1]Isparta Provincial Directorate of Agriculture and Forestry, 32070, Isparta, Türkiye, E-mail: isikmehmet@tarimorman.gov.tr
[2]Isparta University of Applied Sciences, Faculty of Agriculture, Department of Agricultural Economics, 32260, Isparta, Türkiye, E-mail: mevlutgul@isparta.edu.tr

Corresponding author: isikmehmet@tarimorman.gov.tr

Abstract

In this study, it was aimed to examine the changes in the cost and profitability of rose (oil), wheat, barley and chickpea, which are important agricultural products in Isparta province. In this context, statistical data of Isparta Provincial Directorate of Agriculture and Forestry and TURKSTAT were utilized. According to the findings of the research, in 2022, rose (oilseed) kg cost was 10.57 TL, relative profit 1.58; wheat kg production cost 6.11 TL, relative profit 1.51; barley kg production cost 4.54 TL, relative profit 1.31 and chickpea kg production cost 14.78 TL, relative profit 1.25. There was a general upward trend in the production costs of the products analyzed. The increase in factors such as diesel, fertilizer, pesticides and harvest labor costs cauzed the cost of the products to increase. In addition, due to the nature of agriculture, changes in yield with the effect of the climate factor also affected the income of farmers. This reduces the profit margin of producers.

Key words: *cost of production, profitability, absolute profit, relative profit, Isparta*

INTRODUCTION

Cost is the sacrifice made to obtain a benefit or interest or a certain amount of money disposed of in return for a good [36]. According to another definition, cost is the sum of the expenditures made on the means of production used in the production of a particular good or service [3]. Although the methods used in calculating the costs of agricultural products are similar to each other, even small differences between these similarities cause significant changes in the results. It is seen that there are significant differences especially in interest rates, calculation of costs and distribution of costs to production branches [35] [6]. The cost of agricultural products varies according to the type of product in line with the objectives of the institutions and individuals making the calculation [6]. In agricultural enterprises engaged in mixed production, it is impossible to make plans about the enterprise without business accounting records. Because it is necessary to know the accounting records in order to explain the reasons why the factors of production used in input costs are used in which ratios and how they affect the result. It will be more effective to find out which production factors provide more effective returns to which production line and to turn to that production line. In addition, the production costs, profitability status and rationality degrees of the enterprise can contribute to production planning more effectively with the help of accounting records [34].
Cost calculations have been made for various products in Isparta province. For example, there are studies on apple by Gül [15]; Gül [16]; Gül et al., [18]; Gül et al., [19]; Demircan et al., [9]; Yılmaz et al., [39]; Bayav and Karlı [4]; on cherry by Gül et al., [17]; Gül et al., [20]; Demircan et al., [8]; on wheat by Gül et al. [12]. There are studies on lavender by Gül et al. [27]; on seedling product by Büyükarıkan and Gül [5]; on bread by Gül et al. [13]. On the other hand, Gül [14], Demircan [7]; Gül et al. [25] conducted studies on oil rose. In addition, there are studies on cost analysis conducted in neighbouring provinces with similar climate

and soil conditions to the research region. These studies include potato production in Afyonkarahisar province [31], almond production [38], grape production [11], tobacco in Uşak province [26] and chickpea [23], tomato production [30], sugar beet production [32], green bean [28], fennel production [29], and anise production in Burdur province [37], thyme production in Denizli province [21] [33], buckwheat production [22], carrot production in Konya province [1] and eggplant production in Antalya province [24].

In Isparta province, wheat (20%) and chickpea (86%) cultivation area decreased while barley (18%) and oil rose planting area (116%) increased between 2003-2022. Especially in recent years, oil rose production has become attractive for producers due to the increase in the demand for oil rose products of companies.

According to 2003 data, 107,045 tonnes of wheat is produced on 52,193 hectares, 93,059 tonnes of barley on 34,215 hectares, 23,814 tonnes of chickpea on 22,657 hectares and 6,073 tonnes of rose on 1,584 hectares in Isparta. As of the end of 2022, wheat production decreased by 5% to 101,755 tonnes, barley production increased by 7% to 99,566 tonnes, chickpea production decreased by 84% to 3,797 tonnes and rose production increased by 179% to 16,932 tonnes (Table 1).

Table 1. Development of cultivation area and production of the crops analysed in Isparta province

Years	Wheat		Barley		Chick pea		Rose oil	
	Cultivated Area (ha)	Production (tonnes)	Cultivated Area (ha)	Production (tonnes)	Cultivated Area (ha)	Production (tonnes)	Cultivated Area (ha)	Production (tonnes)
2003	52,193	107,045	34,215	93,059	22,657	23,814	1,584	6,073
2004	48,529	113,274	38,121	107,714	26,397	32,241	1,591	7,539
2005	46,108	113,309	39,998	120,988	23,510	25,976	1,894	9,971
2006	38,951	97,109	39,393	116,258	22,566	24,396	1,903	10,056
2007	39,669	66,862	41,608	76,185	18,968	12,335	1,905	7,085
2008	39,298	94,805	36,210	107,247	19,545	18,833	1,955	8,420
2009	42,321	101,392	41,938	104,279	20,249	21,327	1,850	8,510
2010	44,166	95,706	44,228	106,324	19,531	16,098	1,850	7,863
2011	46,705	96,587	44,218	113,567	18,846	19,339	1,955	8,895
2012	46,197	96,388	41,240	103,273	14,672	16,570	2,235	7,935
2013	46,199	106,073	41,204	112,681	16,431	17,315	2,017	8,481
2014	51,828	96,030	46,779	114,809	15,920	16,972	2,049	8,382
2015	50,291	110,627	47,908	114,526	16,233	18,078	2,055	7,251
2016	49,624	105,577	46,263	101,260	15,175	17,346	2,300	10,022
2017	47,014	96,696	40,519	98,875	13,441	14,048	2,616	10,900
2018	46,224	90,149	41,470	91,786	12,692	12,567	2,744	12,332
2019	42,898	79,885	42,117	86,474	6,378	6,461	3,146	14,097
2020	47,927	92,894	41,250	84,237	5,072	4,951	3,318	15,343
2021	44,758	62,282	43,787	52,343	5,204	5,361	3,317	15,259
2022	41,522	101,755	40,236	99,566	3,266	3,797	3,427	16,932
Index (2003=100)								
2003	100	100	100	100	100	100	100	100
2004	93	106	111	116	117	135	100	124
2005	88	106	117	130	104	109	120	164
2006	75	91	115	125	100	102	120	166
2007	76	62	122	82	84	52	120	117
2008	75	89	106	115	86	79	123	139
2009	81	95	123	112	89	90	117	140
2010	85	89	129	114	86	68	117	129
2011	89	90	129	122	83	81	123	146
2012	89	90	121	111	65	70	141	131
2013	89	99	120	121	73	73	127	140
2014	99	90	137	123	70	71	129	138
2015	96	103	140	123	72	76	130	119
2016	95	99	135	109	67	73	145	165
2017	90	90	118	106	59	59	165	179
2018	89	84	121	99	56	53	173	203
2019	82	75	123	93	28	27	199	232
2020	92	87	121	91	22	21	209	253
2021	86	58	128	56	23	23	209	251
2022	80	95	118	107	14	16	216	279

Source: TURKSTAT, 2023.

In this study, it was aimed to examine the changes in the cost and profitability of rose (oil), barley, wheat and chickpea, which are important agricultural products in Isparta province.

MATERIALS AND METHODS

The main material of the research is the statistical data of Isparta Provincial Directorate of Agriculture and Forestry. The data used in the important agricultural product costs of the province cover the period 2015-2022. In addition, TURKSTAT and FAO statistical data were also utilized. In the study, absolute profit, relative profit and gross profit indicators were calculated. Absolute profit is the difference between income and expenses. The main purpose of the business is to make profit and to seek ways to maximize this profit. The difference between gross production value (GPV) and production cost is called absolute profit or net profit [2]. Relative profit is the ratio of gross value of production to the cost of production. It shows proportionally how superior one option is to the other. This profit better measures the return of production activities [35].

In the products subject to the research, the proportional shares of the cost elements in total costs were calculated and their weights in total costs were determined. In addition, product production cost and profitability and their changes over the years were analyzed by simple index. Cost and profitability values were converted into real values using the Producer Price Index (PPI; 2003=100) calculated by TURKSTAT.

RESULTS AND DISCUSSIONS

Wheat

Taking 2015 as the base year for wheat costs for Isparta province, there was a significant increase in harvesting, marketing and land rent in wheat production (Table 2). Especially in recent years, with the effect of Covid-19 and the Ukraine-Russia war, there has been a serious increase in input costs and accordingly, there has been a serious increase in costs. The foreign dependence on inputs used in agricultural production in Türkiye is also one of the important factors that increase costs. It can be said that the reason why the sowing costs were lower in the periods considered compared to 2015 was that the majority of the producers preferred the seed they separated from their own production due to the high prices of certified seed. In this context, [12] determined that 48% of the producers used their own seed in their study on the use of wheat seed in agricultural enterprises.

Table 2. Change in wheat production costs in real prices per hectare (2015=100)

Cost Elements	2015	2016	2017	2018	2019	2020	2021	2022
Soil cultivation	100	100	85	68	68	137	102	98
Sowing	100	93	50	42	47	63	51	48
Fertilisation	100	96	69	56	73	66	73	70
Agrochemical	100	96	80	104	77	99	84	81
Harvest	100	96	99	86	73	198	163	156
Marketing	100	77	119	219	106	134	126	121
Revolving fund interest	100	95	72	67	64	102	85	81
Variable costs	100	95	72	67	64	102	85	81
General administrative expenses	100	95	72	67	64	102	85	81
Provision for land rent	100	96	88	72	78	82	115	110
Fixed costs	100	96	86	71	76	85	110	105
Production costs	100	95	74	67	66	99	89	85

Source: Own calculation on the basis of data from Isparta Provincial Directorate of Agriculture and Forestry data base 2015-2022.

When the shares of detailed cost elements covering the years 2015-2022 in total production costs of wheat production in Isparta province were analyzed; 23.77% of total wheat production costs were fixed costs and 76.23% were variable costs. The largest item of fixed costs was land rent provision with a proportional share of 18.11 percent in total production costs.

Table 3. The share of the items of wheat production cost (%)

Cost Elements	2015	2016	2017	2018	2019	2020	2021	2022
Soil cultivation	21.18	22.26	24.07	21.42	21.82	29.24	24.27	24.27
Sowing	27.76	27.00	18.58	17.32	19.64	17.55	15.76	15.76
Fertilisation	14.12	14.21	13.08	11.80	15.67	9.36	11.59	11.59
Agrochemical	5.18	5.21	5.55	7.97	6.05	5.15	4.89	4.89
Harvest	8.24	8.29	10.99	10.48	9.12	16.38	15.03	15.03
Marketing	2.94	2.37	4.71	9.57	4.76	3.98	4.17	4.17
Revolving fund interest	3.97	3.97	3.85	3.93	3.85	4.08	3.79	3.79
Variable costs	83.38	83.30	80.83	82.49	80.91	85.73	79.50	79.50
General administrative expenses	2.50	2.50	2.42	2.47	2.43	2.57	2.39	2.39
Provision for land rent	14.12	14.21	16.75	15.04	16.66	11.70	18.11	18.11
Fixed costs	16.62	16.71	19.17	17.51	19.09	14.27	20.50	20.50
Production costs	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Own calculation on the basis of data from Isparta Provincial Directorate of Agriculture and Forestry data base 2015-2022.

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Among the variable cost items, the largest items are ploughing, sowing and harvesting costs. The proportional shares of these items in production costs were calculated as 24.27%, 15.76% and 15.03%, respectively (Table 3). While wheat production costs per hectare was 4,403.41 TRY in 2003 (in 2021 real prices), it increased approximately 2.5 times to 10,940 TRY in 2022. The highest value in the 2003-2022 period analyzed was reached in 2012 with 16,131.15 TRY per hectare. There is a direct and statistically significant correlation between wheat production cost and yield (Fig. 1).

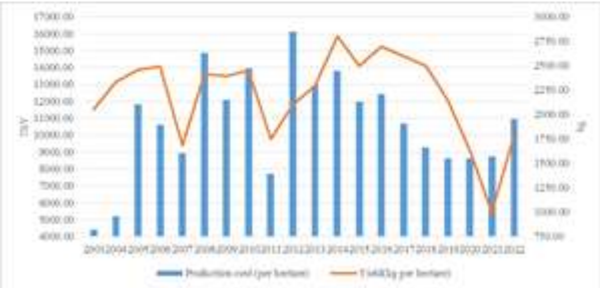

Fig. 1. The evolution of the production cost and yield of wheat production per hectare
Source: Own calculation.

The relative profit in wheat production was calculated as 3.00 in 2003 and 1.51 in 2022. Relative profit showed a decreasing trend from 2003 to 2009. After this year, it showed an increasing trend until 2015, while it was at the level of 1.50 in 2016-2020, it decreased to 0.91 in 2021 and reached 1.51 in 2022. In 2007, 2008, 2009 and 2021, wheat producers suffered losses from this production (Fig. 2).

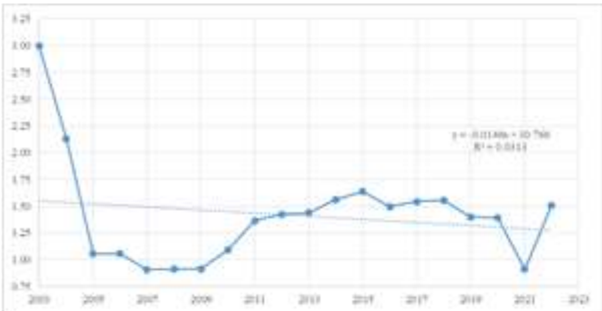

Fig. 2. The evolution of the relative profitability of wheat production
Source: Own calculation.

Wheat yield per hectare in Isparta province varied according to years. The main reason for this variability is climatic factors. In this context, the production cost of 1 kg of wheat produced in 2021 was the highest with 8.75 TRY. In the years examined, the cost of 1 kg of wheat had the second highest value in 2012 with 7.68 TRY, the third highest value in 2008 with 6.26 TRY and the fourth highest value in 2022 with 6.11 TRY. In 2003 and 2004, it was determined that the lowest kg wheat production costs were 2.15 TRY and 2.23 TRY. The years when the cost of 1 kg wheat was below 5 TRY were 2003, 2004, 2005, 2006, 2011, 2014, 2015, 2016, 2017, 2018 and 2019. There is a direct and statistically significant correlation between kg production cost of wheat and kg sales price. In 2007, 2008, 2009, 2021, costs were above the selling price (Fig. 3).

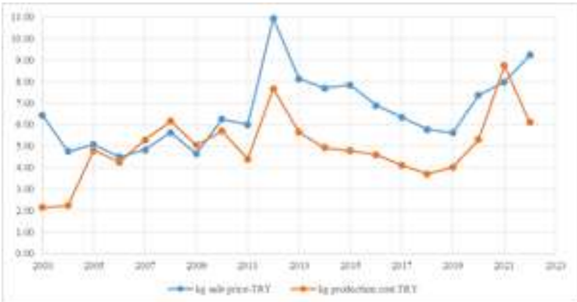

Fig. 3. The evolution of the real sale price and cost per kg of wheat production
Source: Own calculation.

Barley

When we analyzed the changes in barley production costs, which we calculated by converting to real prices between 2015 and 2022, based on 2015, it was found that the cost items with the highest increases were harvesting (58%), ploughing (10%) and land rent provision (10%). In the same period, the highest decrease in production cost items was in the cost elements of agricultural control (41%), planting (37%) and fertilization (34%). The reason for the decrease in cost items, especially in fertilizer and pesticides, can be said to be the producers' decision to reduce the use of fertilizers and pesticides due to increasing input prices. In addition, the reason for the decrease in the cost of sowing can be said to be the tendency to use their own seeds instead of using certified seeds from outside.

Table 4. Change in barley production costs in real prices per hectare (2015=100)

Cost Elements	2015	2016	2017	2018	2019	2020	2021	2022
Soil cultivation	100	101	93	73	76	154	115	110
Sowing	100	98	77	71	97	88	66	63
Fertilisation	100	84	26	53	52	77	69	66
Agrochemical	100	89	81	99	96	78	62	59
Harvest	100	110	99	86	73	198	165	158
Marketing	100	96	110	87	99	92	73	70
Revolving fund interest	100	81	64	62	68	96	76	73
Variable costs	100	95	75	73	79	113	89	85
General administrative expenses	100	95	75	73	79	113	89	85
Provision for land rent	100	112	102	87	83	99	115	110
Fixed costs	100	109	98	85	83	101	111	106
Production costs	100	98	79	75	80	111	93	89

Source: Own calculation on the basis of data from Isparta Provincial Directorate of Agriculture and Forestry data base 2015-2022.

In barley production in 2022, the share of variable costs in production costs per hectare was 79.48% and the share of fixed costs was 20.52%. Among the production costs, ploughing had the highest share with 24.30% and general administrative expenses had the lowest share with 2.38%. The share of ploughing cost element in total barley production costs varied between 19.27% and 24.30% in the years analyzed. The share of sowing cost element varied between 15.41% and 26.21%. The share of land rent cost element varied between 13.13 per cent and 18.96 per cent. The share of harvesting cost element varied between 7.83% and 15.23% (Table 5).

Table 5. Barley production costs (%)

Cost Elements	2015	2016	2017	2018	2019	2020	2021	2022
Soil cultivation	19.63	20.21	23.06	19.27	18.72	27.36	24.30	24.30
Sowing	21.60	21.66	21.01	20.56	26.21	17.07	15.41	15.41
Fertilisation	15.71	13.48	5.13	11.09	10.21	10.94	11.69	11.69
Agrochemical	7.12	6.50	7.28	9.42	8.51	5.03	4.71	4.71
Harvest	8.59	9.63	10.76	9.85	7.83	15.32	15.23	15.23
Marketing	5.52	5.41	7.69	6.42	6.81	4.60	4.35	4.35
Revolving fund interest	4.62	3.85	3.75	3.83	3.91	4.02	3.78	3.78
Variable costs	82.79	80.73	78.67	80.46	82.21	84.34	79.48	79.48
General administrative expenses	2.48	2.42	2.36	2.42	2.47	2.53	2.38	2.38
Provision for land rent	14.73	16.85	18.96	17.13	15.32	13.13	18.13	18.13
Fixed costs	17.21	19.27	21.33	19.55	17.79	15.66	20.52	20.52
Production costs	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Own calculation on the basis of data from Isparta Provincial Directorate of Agriculture and Forestry data base 2015-2022.

Barley production costs per hectare, which we calculated with real prices between 2003 and 2022, had the lowest value in 2003-2004. The year with the highest cost was 2012. In the same period, barley yield per hectare was the highest in 2010 with 3,200 kg and the lowest in 2021 with 1,195 kg. It can be said that climatic factors are the most important reasons for the variability of barley yield over the years. Especially the lack of periodic precipitation significantly reduced the yield. There was a positive correlation between chickpea production cost per hectare and yield values. However, this relationship was not statistically significant (Fig. 4).

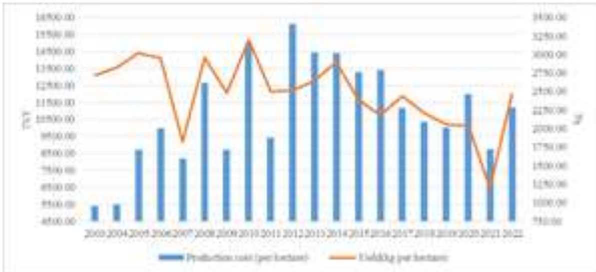

Fig. 4. The evolution of the production cost and yield of barley production
Source: Own calculation.

Relative profit in barley production reached its highest value of 2.38 in 2004 and its lowest value of 0.86 in 2021. Relative profit showed a decreasing trend between 2004-2007 and 2017-2021. It was determined that there was a constant trend between 2013-2016. In 2007 and 2021, barley producers suffered losses from this production (Fig. 5).

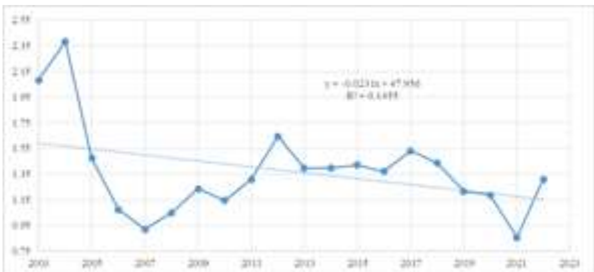

Fig. 5. The evolution of the relative profitability of barley production
Source: Own calculation.

When the barley production cost per kilogram and the barley selling price per kg, which we determined as a result of our calculations with real prices for barley production, were analyzed; kg barley production cost was the highest in 2021 with 7.32 TRY. In 2004 and 2003, the barley production cost per kg was the lowest (1.93 TRY and 1.98 TRY, respectively). The selling price per kg was below the cost of barley production in 2007 and 2021, and therefore barley producers suffered losses in these years. In general, there was an increasing trend in the selling price per kg and the cost of production per kg of barley. The highest barley selling price per kg was 10.53 TRY in 2012. There were fluctuations in barley sales price per kg and production cost. It can be said that these fluctuations were caused by agricultural frost events and low rainfall due to climatic factors in Isparta province. We found a positive correlation between the farmers' barley selling price per kg and barley production cost per kg calculated in real prices. This relationship was statistically significant (Fig. 6).

Fig. 6. The evolution of the real sale price and cost per kg of barley production
Source: Own calculation.

Chickpea

When the changes in real prices of cost elements of chickpea production in Isparta province in the period covering the years 2015-2022 were analyzed; it was found that total production costs decreased by 22% compared to 2015. The cost elements of chickpea production also decreased by 47% and 13% compared to the base year. Only the cost element of land rent provision increased by 10 per cent. It can be said that the reason for the decrease in production costs is that producers have reduced the amount of input use due to the increase in input prices in recent years (Table 6). As a matter of fact, [10] reported in their study conducted in Kütahya province that chickpea producers used less inputs in chickpea farming.

Table 6. Change in chickpea production costs at real prices per hectare (2015=100)

Cost Elements	2015	2016	2017	2018	2019	2020	2021	2022
Soil cultivation	100	100	89	71	64	62	58	65
Sowing	100	101	98	81	73	98	70	87
Fertilisation	100	105	96	67	59	57	60	53
Agrochemical	100	104	109	109	89	89	65	78
Harvest	100	110	99	86	79	79	59	76
Marketing	100	111	103	98	99	101	73	100
Revolving fund interest	100	103	97	82	73	78	63	73
Variable costs	100	103	97	82	73	78	63	73
General administrative expenses	100	103	97	82	73	78	63	73
Provision for land rent	100	112	102	87	83	102	80	110
Fixed costs	100	111	101	86	82	98	78	105
Production costs	100	105	98	82	74	81	66	78

Source: Own calculation on the basis of data from Isparta Provincial Directorate of Agriculture and Forestry data base 2015-2022.

For the year 2022, 22.38% of production costs consist of fixed costs and 77.62% of variable costs. The biggest cost items among the variable cost items are sowing (20.05%), ploughing (16.86%), pest control (11.85%) and fertilizer cost (10.30%). In the years analyzed, the land rent provision accounted for 14.26% and 20.05% of the total production costs. The share of sowing in total production costs was 17.42% and 21.72% (Table 7).

Table 7. Chickpea production costs (%)

Cost Elements	2015	2016	2017	2018	2019	2020	2021	2022
Soil cultivation	20.44	19.59	18.48	17.67	17.74	15.64	18.13	16.86
Sowing	18.07	17.42	18.07	17.67	17.74	21.72	19.13	20.05
Fertilisation	15.21	15.24	14.86	12.40	12.06	10.71	13.91	10.30
Agrochemical	11.89	11.76	13.25	15.79	14.19	13.03	11.80	11.85
Harvest	8.32	8.71	8.43	8.65	8.87	8.11	7.45	8.02
Marketing	5.35	5.66	5.62	6.39	7.10	6.66	5.96	6.84
Revolving fund interest	3.96	3.92	3.94	3.93	3.89	3.79	3.82	3.70
Variable costs	83.24	82.29	82.66	82.49	81.59	79.66	80.21	77.62
General administrative expenses	2.50	2.47	2.48	2.47	2.45	2.39	2.41	2.33
Provision for land rent	14.26	15.24	14.86	15.04	15.97	17.95	17.39	20.05
Fixed costs	16.76	17.71	17.34	17.51	18.41	20.34	19.79	22.38
Production costs	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Own calculation on the basis of data from Isparta Provincial Directorate of Agriculture and Forestry data base 2015-2022.

It was determined that chickpea production costs per hectare between 2013-2022 showed significant variability between years. The main reason for this variability is that chickpea agriculture is directly affected by climatic factors. In this context, the cost of chickpea per hectare was the highest in 2010 with 24,904.45 TRY. It was found to be the lowest in 2021 with 10,761.11 TRY. Chickpea yield was the highest in 2010 with 1

300 kg and the lowest in 2021 with 420 kg. Production costs remained below 10,000 TRY per hectare between 2004 and 2006, while it was in an increasing trend between 2007 and 2010, it decreased in 2011, it was above 15,000 TRY between 2012-2019 and remained below 13,000 TRY in 2021 and onwards. There was a positive correlation between farmers' chickpea production costs per hectare and their yields in real prices, which was statistically significant (Fig. 7).

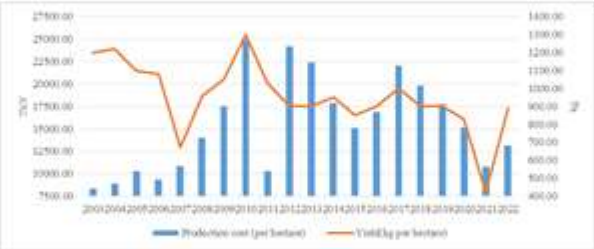

Fig. 7. The evolution of the production cost and yield of chickpea production
Source: Own calculation.

The relative profit in chickpea production was the highest in 2003 with a rate of 2.62. In 2020, which was also the year of the pandemic, it took its lowest value with a rate of 0.77. Producers made losses in 2009, 2020 and 2021. The years with the best profit margins were 2003, 2004, 2005, 2006, 2006, 2011, 2014, 2015, 2016, 2017 and 2018. In these years, profit margins were above 60% (Fig. 8).

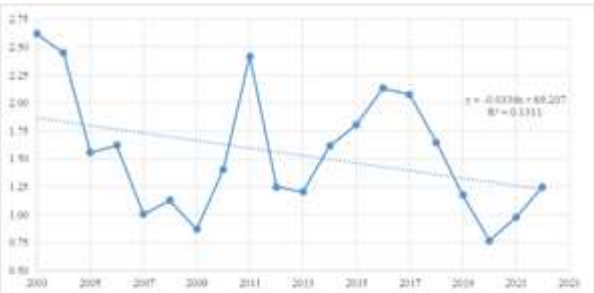

Fig. 8. The evolution of the relative profitability of chickpea production
Source: Own calculation.

In 2003, the real selling price of chickpea was 18.17 TRY per kilogram, while the production cost was 6.94 TRY. In 2022, the selling price per kilogram increased to 18.47 TRY and the production cost increased to 14.78 TRY. In 2007, 2009, 2020 and 2021, the selling price per kg was below the production cost per kg. Therefore, producers suffered losses in these years. The selling price per kg chickpea of farmers was in an increasing trend until 2018. After this year, it decreased and took its lowest value during the pandemic (2020). Farmers' production cost per kg of chickpea had an increasing trend (except for 2011 and 2022). In real prices, there is a positive correlation between farmers' kg chickpea selling price and kg production cost values, which is statistically significant (Fig. 9).

Fig. 9. The evolution of the real sale price and cost per kg of chickpea production
Source: Own calculation.

Oil Rose

When the real prices of oil rose costs and the changes between 2015 and 2022 are analysed, it was found that the production cost items with the highest increase were pest control, fertilization and harvesting when 2015 was taken as reference.

Table 8. Change in production costs of oil rose in real prices per hectare (2015=100)

Cost Elements	2015	2016	2017	2018	2019	2020	2021	2022
Soil cultivation	100	107	92	80	68	64	53	51
Channel-digging	100	84	103	98	83	78	65	62
Pruning	100	110	114	119	127	119	99	95
Fertilisation	100	107	100	137	152	143	119	114
Agrochemical	100	121	148	165	153	144	120	115
Hoe-drilling	100	102	99	78	70	66	55	53
Harvest	100	104	110	109	148	139	116	111
Marketing	100	105	137	124	114	107	90	86
Revolving fund interest	100	106	114	117	126	119	99	95
Variable costs	100	106	114	117	126	119	99	95
General administrative expenses	100	106	114	117	126	119	99	95
Interest on land capital	100	120	124	114	100	94	78	75
Depreciation of fixed plant	100	105	116	99	87	81	68	65
Fixed facility interest	100	105	116	99	90	84	70	67
Fixed costs	100	107	117	102	90	85	71	68
Production costs	100	107	115	109	107	101	84	81

Source: Own calculation on the basis of data from Isparta Provincial Directorate of Agriculture and Forestry data base 2015-2022

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It can be said that the reason why ploughing and trenching costs were low in the period under consideration was due to the fact that the producers restricted the use of mechanization in soil tillage in order to be less affected by the increasing fuel costs in recent years.

Considering the year 2022, it was calculated that while variable costs were 55.79% of production costs, fixed costs were 44.21%. The highest share in production cost items is depreciation of fixed plant with 23.55%, harvesting with 18.09%, fixed plant interest with 12.21%, fertilization with 10.32% and pest control with 9.91%. The share of harvesting costs varied between 12.56% and 18.09% over the years. The share of fertilization showed an increasing trend between 6.33% and 10.32%. The share of depreciation of fixed plant showed a decreasing trend between 23.55% and 29.30%. The share of fixed plant interest showed a decreasing trend between 12.21% and 14.59% (Table 9).

Table 9. Rose (oil) production costs (%)

Cost Elements	2015	2016	2017	2018	2019	2020	2021	2022
Soil cultivation	3.28	3.27	2.62	2.40	2.07	2.07	2.07	2.07
Channel-digging	2.92	2.29	2.62	2.61	2.26	2.26	2.26	2.26
Pruning	2.55	2.62	2.51	2.79	3.01	3.01	3.01	3.01
Fertilisation	7.30	7.33	6.33	9.15	10.32	10.32	10.32	10.32
Agrochemical	6.93	7.85	8.89	10.46	9.91	9.91	9.91	9.91
Hoe-drilling	5.47	5.24	4.71	3.92	3.58	3.58	3.58	3.58
Harvest	13.13	12.76	12.56	13.07	18.09	18.09	18.09	18.09
Marketing	3.65	3.60	4.34	4.14	3.88	3.88	3.88	3.88
Revolving fund interest	2.26	2.25	2.23	2.43	2.66	2.66	2.66	2.66
Variable costs	47.50	47.21	46.80	50.97	55.79	55.79	55.79	55.79
General administrative expenses	1.42	1.42	1.40	1.53	1.67	1.67	1.67	1.67
Interest on land capital	7.30	8.18	7.85	7.63	6.78	6.78	6.78	6.78
Depreciation of fixed plant	29.19	28.80	29.30	26.58	23.55	23.55	23.55	23.55
Fixed facility interest	14.59	14.40	14.65	13.29	12.21	12.21	12.21	12.21
Fixed costs	52.50	52.79	53.20	49.03	44.21	44.21	44.21	44.21
Production costs	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Own calculation on the basis of data from Isparta Provincial Directorate of Agriculture and Forestry data base 2015-2022.

Although there was a negative correlation between production cost per hectare and yield per hectare of oil rose in real prices, there was no statistical relationship. The production cost had its highest value in 2009 with 106,954.93 TRY and its lowest value was in 2003 with 35,289.50 TRY. Rose yield per hectare followed a fluctuating course due to climatic factors. Rose yield per hectare was highest in 2006 with 5,553 kg and lowest in 2015 with 3,527 kg (Fig. 10).

Fig. 10. The evolution of the production cost and yield of oil rose production
Source: Own calculation.

The relative profit in oil rose production was 3.64 in 2003. It decreased 2.30 times over time and was found to have decreased to 1.58 in 2022. Relative profit showed a decreasing trend between 2003 and 2009. From 2009 to 2016, it was in an increasing trend. After 2016, it was determined that there was a decreasing slope until 2022. In the periods analysed, relative profit reached its highest value in 2003 with a ratio of 3.64 and its lowest value in 2009 with a ratio of 0.71. It can be said that farmers producing oil roses generally made a profit in all years except 2009 (Fig. 11).

Fig. 11. The evolution of the relative profitability of oil rose production
Source: Own calculation.

When the real selling price per kg and the cost of oil rose production were analysed between 2003 and 2022, there was a relationship between the two variables in the same direction but not statistically significant. There was a fluctuation in the rose yield due to agricultural frosts in Isparta province in some years during the periods considered. This fluctuation in the yield of oil rose affected the unit cost per kg and the selling price of rose. In real prices, the cost of oil rose had the lowest value in 2021 with 7.69 TRY per kg and the highest value in 2017 with 20.81 TRY. It was determined that in the year when the production cost of oil rose was the highest, the sales price was also high. In 2009, since the sales price was below the production cost, the producers suffered losses. The years 2015-2018 were the years in which farmers' sales prices of oil rose were historically the highest (Fig. 12).

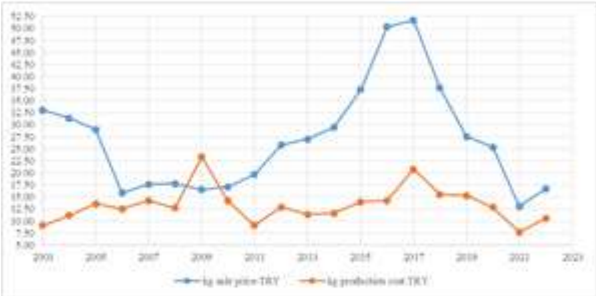

Fig. 12. The evolution of the real sale price and cost per kg of oil rose production
Source: Own calculation.

CONCLUSIONS

In this study, the changes in the cost and profitability of rose (oil), barley, wheat and chickpea, which are important agricultural products in Isparta province, were analyzed.
Statistical records of Isparta Provincial Directorate of Agriculture and Forestry were used as the main material of the research, together with the data obtained from TURKSTAT and FAO and relevant national and international research findings.
Cost items for rose (oil), barley, wheat and chickpea production, their proportional shares in total cost and profit were analyzed by years. Cost and profitability indicators were expressed in real values. Changes in profit and cost items over the years were analyzed and the main reasons for the changes were determined accordingly.
Considering the periods analyzed; there was a general upward trend in production costs. Diesel, fertilizer, agricultural expenses and harvest labor expenses, which are important inputs, cause the cost to increase. This reduces the profit margin of producers. In order to reduce the costs of the producers; Since the supports provided by the Ministry cannot reach the mass of producers sufficiently, there is not enough decrease in costs.
Especially in recent years, due to the developments in the supply chain after Covid-19, there has been an increase in costs due to input and supply problems. Türkiye's dependence on foreign inputs used in agricultural production can also be said to be one of the important factors that increase costs.

REFERENCES

[1]Acar, M., Gül, M., 2016, Carrot production-structure and profitability-cost analysis: the case of Konya province, Turkey. Custos e Agronegocio on line, 12(1), 73-88.
[2]Açıl, A.F., 1974, Calculation of Agricultural Product Costs and Developments in Agricultural Product Costs in Our Country (in Turkish). T.R. Ankara University, Faculty of Agriculture, Department of Agricultural Economics. Publication No: 567. Ankara.
[3]Aksoy, A. R., 1987, Cost of Milk and Factors Affecting Cost in Dairy Cattle Herd Operations in Ankara Region Conditions (in Turkish). Ankara University Department of Animal Science, Seminar No 2, 10 p., Ankara.
[4]Bayav, A., Karlı, B., 2020, The comparison of apple production costs in Isparta and Karaman provinces (in Turkish). Mustafa Kemal University Journal of Agricultural Sciences, 25(2), 225-236.
[5]Büyükarikan, U., Gül, M., 2014, Economic analysis of certified nursery producing enterprises in temperate climate fruits: a case of Isparta province. Custos e Agronegocio on line, 10(4), 60-72.
[6]Çakır, S., 2005, Evaluation of Agricultural Production Cost Calculation Methods of Agricultural Organizations in Adana Province (in Turkish). MSc. Thesis, Çukurova University Graduate School of Natural and Applied Sciences.
[7]Demircan, V., 2005, Rose production inputs, cost and determination of profitability in Isparta province (in Turkish). Süleyman Demirel University, Journal of the Institute of Science, 9 (3), 64-71.
[8]Demircan, V., Hatırlı, S. A., Aktaş, A. R., 2004, A research on determination of production inputs and cost of cherry in Isparta province (in Turkish). Çukurova University, Journal of the Faculty of Agriculture, 19(2), 55-64.
[9]Demircan, V., Yılmaz, H., Binici, T., 2005, Determination of apple production cost and income in Isparta province (in Turkish). Journal of Agricultural Economics; 11(2), 71-80.
[10]Erturk, A., Gül, M., 2018, Input usage and problems in chickpea production in Kütahya province. Scientific Papers Series-Management, Economic Engineering in Agriculture and Rural Development, 18(2), 171-178.
[11]Gargın, S., Akol, S., Ünal, A., Bayav, A., Göktaş, A., Öztürk, Y., Emre, M., Yılmaz, K., 2023, Economic analysis and determination of profitability of red globe grape varieties in three different training systems (in Turkish). Bahçe 52, 469-481.

[12]Gül, H., Gül, M., Acun, S., Türk Aslan, S., Öztürk, A., Kara, B., Akman, Z., 2015, Wheat germ use and problems in agricultural enterprises: Burdur and Isparta provinces example (in Turkish). Turkish Journal of Agriculture - Food Science and Technology, 3(9), 732-741.

[13]Gül, H., Gül, M., Şirikçi, B.S., Acun, S., Hayıt, F., 2015, Technical and economic evaluation of traditional and free type bread producing bakeries in Isparta province (in Turkish). Journal of Süleyman Demirel University Faculty of Agriculture, 10(2), 11-21.

[14]Gül, M., 2000, Current status of rose oil production and problems in Isparta (in Turkish). Süleyman Demirel Üniversitesi, Fen Bilimleri Enstitüsü Dergisi, 4 (1), 91-102.

[15]Gül, M., 2005, Technical efficiency and productivity of apple farming in Antalya province of Turkey. Pakistan Journal of Biological Sciences, 8, 1533-1540.

[16]Gül, M., 2006, Technical efficiency of apple farming in Turkey: A case study covering Isparta, Karaman and Nigde provinces. Pakistan Journal of Biological Sciences, 9(4), 601-605.

[17]Gül, M., Akpınar, M. G., Demircan, V., Bal, T., Yılmaz, H., Arıcı, Ş. E., Polat, M., Örmeci, K. M. Ç., Acar, M., 2020, Evaluation of economic structure of cherry growing in Turkey. Erwerbs-Obstbau, 62(1), 13-20.

[18]Gül, M., Akpınar, M. G., Demircan, V., Yılmaz, H., Bal, T., Arıcı, Ş. E., Polat M., Şan, B., Eraslan, F., Örmeci K. M. Ç., Gürbüz, D., Yılmaz, Ş. G., 2014, Economic analysis of early warning system in apple cultivation a Turkish case study. Custos e Agronegocio On Line, 10, 165-179.

[19]Gül, M., Akpınar, M. G., Demircan, V., Yılmaz, H., Bal, T., Arıcı Ş. E., Polat, M., Şan, B., Eraslan, İ. F., Örmeci, K. M. Ç., Gürbüz, D., Yılmaz, Ş. G., 2017, Economic analysis of integrated pest management adoption in apple cultivation: a Turkish case study. Erwerbs-Obstbau, 59(2), 147-154.

[20]Gül, M., Akpınar, M. G., Demircan, V., Yılmaz, H., Bal, T., Arıcı, Ş. E., Polat, M., Örmeci, K. M. Ç., Acar, M., 2016, Economic analysis of integrated pest management in cherry cultivation. Scientific Papers Series Management, Economic Engineering and Rural Development, 16 (2), 165-178.

[21]Gül, M., Aslan, O., Şirikçi, S.B., 2014, Determining the costs, production inputs and profit of thyme production enterprises in Denizli province of Turkey. Journal of Essential Oil Bearing Plants, 17(4), 562-569.

[22]Gül M., Birer, E., 2017, Socio-economic structure of buckwheat farms in Turkey. Columella, 4(1), 223-228.

[23]Gül, M., Bülbül, M., Kadakoğlu, B., Şirikçi B. S., 2022, Cost and profitability of chickpea production in Usak province, Turkey. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(1), 241-248.

[24]Gül, M., Değirmenci, N., Şirikçi B. S., Kadakoğlu, B., 2022, Cost and profitability analysis of greenhouse eggplant production: a case study of Antalya Province, Turkey. Custos e Agronegocio on line, 18(2), 440-457.

[25]Gül, M., Kazaz, S., Baydar, H., Sirikci, B. S., 2015, A study about technical economical situation problems and improvement of oil rose (*Rosa damascena* Mill) in Turkey. Journal of Essential Oil Bearing Plants, 18, 613-626.

[26]Gül, M., Köse, S., Şirikçi B. S., Kadakoğlu, B., 2022, Economic analysis of tobacco production in Turkey: The case of Usak province, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(4), 279-286.

[27]Gül, M., Örmeci Kart, M.C., Sirikci, B.S., 2016, Determining costs and profitability of lavender farms in Isparta province of Turkey. Journal of Essential Oil Bearing Plants, 19(3), 686-692.

[28]Gül, M., Parlak, H., 2017, Input usage and problems in green bean production: a case of Burdur province, Turkey. AgroLife Scientific Journal, 6(1), 133-140.

[29]Gül, M., Parlak, H., Öktem, H., 2017, The cost and profit of fennel production: A case study of Burdur province of Turkey. International Journal of Advances in Agricultural & Environmental Engg, 4(1), 2349-1531.

[30]Gül, M., Topçu, F., Kadakoğlu, B., Şirikçi B. S., 2021, Cost and profitability analysis of tomato production in the greenhouse in highland conditions: A case study of Burdur province, Turkey. Custos e Agronegocio on line, 17(3), 160-175.

[31]Kadakoğlu, B., Karlı, B., 2022, Economic analysis of potato production in Afyonkarahisar province (in Turkish). KSU Journal of Agriculture and Nature, 25(3), 581-588.

[32]Kadakoğlu, B., Karlı, B., Taşci, N., Özyürek, H., 2023, Sugar beet production cost and profitability analysis: The case of Burdur province (in Turkish). KSU Journal of Agriculture and Nature, 26(2), 385-392.

[33]Karlı, B., Demir, Z., Gül, M., Kadakoğlu, B., 2021, Economic analysis of thyme production: A case study of Denizli province, Turkey. International Journal of Agriculture, Forestry and Life Sciences, 5(1), 59-64.

[34]Kıral, T., 1970, Types and Comparison of Ledger Attitudes in Agricultural Enterprises (in Turkish). T.R. Ankara University, Faculty of Agriculture, Department of Agricultural Economics (Unpublished Doctoral Thesis).

[35]Kıral, T., Kasnakoğlu, H., Tatlıdil, F.F., Fidan, H., Gündoğmuş, E., 1999, Cost Calculation Methodology and Database Guidelines for Agricultural Products (in Turkish). Agricultural Economics Research Institute Publications. Project Report 1999-13. 143 pages. Ankara.

[36]Üstün, R., 1988, Cost Accounting: Principles and Practices (in Turkish). Bilim Teknik Publishing House, İstanbul.

[37]Yağız, O. F., Gül, M., 2022, Analysis of production cost and profitability of anise production in Burdur, Turkey. Scientific Papers: Management, Economic

Engineering in Agriculture & Rural Development, 22(3), 807-817.

[38]Yılmaz, A., Bayav, A., 2022, Determination of energy efficiency in almond production according to variety: A case study in Turkey. Erwerbs-Obstbau, 65(4), 971-979.

[39]Yılmaz H., Demircan V., Gül M., Örmeci K. M. Ç. 2015, Economic analysis of pesticides applications in apple orchards in west Mediterranean region of Turkey. Erwerbs-Obstbau, 57(3), 141-148.

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A DECADE OF CHANGE IN EUROPE'S TOMATO GREENHOUSES: INSIGHTS AND TRENDS

Ionuț Ovidiu JERCA[*], Cosmina SMEDESCU[**]

University of Agronomic Sciences and Veterinary Medicine Bucharest, *The Research Center for Studies of Food and Agricultural Products Quality, **Faculty of Management and Rural Development, 59 Marasti Blvd, District 1, 011464, Bucharest, Romania, E-mails: ovidiu.jerca@qlab.usamv.ro, smedescu.cosmina@managusamv.ro

Corresponding author: smedescu.cosmina@managusamv.ro

Abstract

In front of escalating resource limitations in agriculture, this study emphasizes the critical need for efficient crop cultivation. Focusing particularly on tomatoes, a staple in global diets, the research aims to sustenably enhance productivity. Recognizing productivity as a key economic indicator, the study highlights the pivotal role of energy-efficient practices in addressing challenges posed by climate change and depleting natural resources. By optimizing energy use in agricultural processes, this research not only improves economic efficiency but also positions the sector for resilience and innovation in a resource-constrained environment. Through an in-depth analysis of data from Eurostat covering the 2014-2022 period, we trace the trends in greenhouse tomato cultivation across Europe, evaluating changes in cultivation areas and productivity. This research offers insights into how different European countries have adapted their agricultural practices in response to environmental and economic pressures and in the same time, it underscores the need for continued innovation and adaptation in agricultural practices to meet the demands of a growing global population under increasingly constrained environmental conditions.

Key words**:** *agriculture, tomato production, crop efficiency, productivity, resource constraints, innovation*

INTRODUCTION

In the current context of agriculture, where resources are increasingly limited, the efficient cultivation of crops becomes a significant challenge [9]. Agriculture, as the foundation for providing sustenance to a growing population, necessitates the need for sustainable production [18]. Within this framework, emphasis on the efficient growth of crops, especially species like tomatoes, is essential to meet global food requirements in a sustainable and profitable manner [19].
rom an economic perspective, the tomato, as the most widely-cultivated vegetable globally, holds a significant position in the agricultural industry [2, 15, 17].
Productivity in agriculture serves as a very important indicator of economic success and long-term sustainability [8]. In this perspective, tomato production holds a prominent place in the agricultural industry, being a staple in many global diets [7]. Efficiently increasing productivity in this domain not only contributes to ensuring food security but also optimizes the utilization of natural resources [13].
In light of the ongoing challenges associated with climate change and the reduction of natural resources, prioritizing energy-efficient consumption has become a real necessity [6, 11]. The sustainable use of energy in agricultural processes not only enhances the economic efficiency of the entire production system but also enhances its adaptability to changes in the business environment [16]. In a period where resource efficiency and economic sustainability are becoming increasingly important, strategies focused on energy-efficient consumption are not only a necessity but also an opportunity to innovate and transform the agricultural sector into a more efficient and resilient one [1]. In few words, in order to boost yields and cost-efficiency in tomato production, it is important to extend cultivation in controlled environments like greenhouses [14]. Greenhouse-grown vegetables present a reliable solution for ensuring a continuous supply of fresh produce [10]. By employing

proven technologies, these controlled environments effectively address challenges posed by climate variability, enhancing the sustainability of the production system. Greenhouses allow for year-round cultivation, independent of external weather conditions, thus providing a consistent and dependable source of fresh vegetables [12]. This method not only meets consumer demand but also contributes to a more resilient agricultural system [3].

Such an expansion requires investments in modern agricultural setups that incorporate new farming technologies [15]. This approach can lead to an increase in production, meeting market demands more effectively while maintaining economic and environmental sustainability [5].

In this context, the purpose of the paper is emphasizes the need for an efficient cultivation of tomatoes for a sustainable increase of productivity using energy-efficient practices as a response to climate change and the depletion of natural resources.

MATERIALS AND METHODS

In conducting our study regarding the trends in European greenhouse tomato cultivation from 2014 to 2022, we sourced our data directly from Eurostat, the principal provider of statistical information in the European Union. This ensured that our analysis was grounded in reliable and comprehensive data. We then embarked on a meticulous process of standardizing this data, ensuring consistency across different countries and years. Our analysis involved calculating the percentage changes in cultivation areas for each country over the nine-year period, enabling us to paint a detailed picture of the evolving landscape of greenhouse tomato production in Europe, all grounded in the dependable data from Eurostat.

RESULTS AND DISCUSSIONS

Between 2014 and 2022, tomato production in Europe underwent some notable changes, with the focus being on the top 10 producing countries, which include Romania. Turkey was the leader in tomato production in Europe, with an initially cultivated area of approximately 183,000 hectares in 2014. However, over the period, the cultivated area decreased, reaching 159,000 hectares in 2022. Italy held the second place in tomato production, with an area that varied between 95,000 and 107,180 hectares in 2015, stabilizing at 97,610 hectares in 2022. Spain saw an initial increase in tomato production, reaching about 62,720 hectares in 2016, but later experienced a significant decrease, amounting to 45,150 hectares in 2022. Romania had significant fluctuations in its tomato production during this period. With an initial area of 24,430 hectares in 2014, there was a sharp decrease between 2018 and 2019. Since then, the cultivated area has remained relatively stable around 17,000 - 24,000 hectares. Portugal experienced fluctuations in tomato production, with a peak in 2016 of 20,850 hectares, but then stabilized around 16,580 hectares in 2022, while Greece recorded a steady decline in tomato production, from 17,260 hectares in 2014 to 9,430 hectares in 2022. Poland showed a steady downward trend in tomato production, decreasing from 13,500 hectares in 2014 to 6,700 hectares in 2022. France continued to maintain a relatively small tomato production, with an area that fluctuated between 5,650 and 6,260 hectares during this period, and Bulgaria had a relatively stable tomato production, varying between 3,000 and 5,000 hectares. Ranking last in the top 10 countries is Hungary, which had a small area for tomato production compared to the other countries, decreasing from 1,880 hectares in 2014 to 1,680 hectares in 2022.

Speaking in percentages, From 2014 to 2022, the landscape of European greenhouse tomato cultivation has shifted, with Turkey maintaining a dominant position despite a decline to 86.89% of its initial area. Italy nearly sustained its cultivation area, holding 94.67%, while Spain experienced a decrease to 82.47%. Romania and Greece faced significant reductions, with Romania at 70.28% and Greece at 54.63% of their respective starting figures. Poland's area saw a sharp fall to 49.63%. Contrastingly, France showed a slight increase, and Bulgaria and Hungary experienced modest declines. Overall, the EU 27's cultivation area contracted to 84.08%, indicating a region-wide trend of diminishing greenhouse space for tomatoes, prompting a push for more efficient production methods (Table 1).

Table 1. Top 10 European countries with the largest areas of tomatoes cultivated, 2014-2022 (1,000 ha)

COUNTRY	2014	2015	2016	2017	2018	2019	2020	2021	2022	2022/2014 %
Turkey	183.00	187.00	181.00	177.00	169.00	173.00	174.00	165.00	159.00	86.89
Italy	103.11	107.18	103.94	99.75	97.09	99.02	99.78	102.06	97.61	94.67
Spain	54.75	58.13	62.72	60.85	56.13	56.94	55.47	56.11	45.15	82.47
Romania	24.43	24.84	22.71	22.21	22.97	23.78	17.47	18.13	17.17	70.28
Portugal	18.46	18.66	20.85	20.87	15.83	15.89	15.04	17.78	16.58	89.82
Greece	17.26	15.25	14.01	13.32	16.02	15.01	15.82	13.14	9.43	54.63
Poland	13.50	13.80	12.42	12.64	13.11	13.50	7.80	7.70	6.70	49.63
France	5.83	5.69	5.65	5.75	5.74	5.66	6.26	6.19	5.89	101.03
Bulgaria	3.59	3.28	4.20	5.01	4.52	5.15	3.09	3.07	3.08	85.79
Hungary	1.88	2.26	2.08	2.19	2.50	2.41	1.82	1.94	1.68	89.36
EU 27 (from 2020)	247.89	254.20	253.95	247.95	239.48	242.52	227.89	231.33	208.43	84.08

Source: Eurostat, 2023 [4].

Analyzing the data from the table on areas cultivated with tomatoes in European countries between 2014 and 2022, the following concrete information can be observed: Turkey maintained the largest share of the total area cultivated with tomatoes in the European Union, with 73.82% in 2014, increasing to 76.28% in 2022. Italy remained in second place, with its share growing from 41.60% in 2014 to 46.83% in 2022, indicating an increase in its relative participation in tomato cultivation. Spain saw a slight decrease in its share, from 22.09% in 2014 to 21.66% in 2022, yet remained in the top three. Romania and Portugal recorded a reduction in their percentages, with Romania dropping from 9.86% to 8.24%, and Portugal from 7.45% to 7.95%. Greece experienced a significant reduction in its share, from 6.96% to 4.52%. Poland, France, Bulgaria, and Hungary show smaller figures and modest variations between the two years. At the EU 27 level (starting in 2020), there was a decrease in the total area cultivated with tomatoes from 247.89 in 2014 to 208.43 in 2022 (Tble 2).

Table 2. Share of tomato cultivation areas, comparison between the year 2014 and the year 2022

Country	% 2014	%2022
Italy	41.60	46.83
Spain	22.09	21.66
Romania	9.86	8.24
Portugal	7.45	7.95
Greece	6.96	4.52
Poland	5.45	3.21
France	2.35	2.83
Bulgaria	1.45	1.48
Hungary	0.76	0.81
EU 27 (from 2020)	100.00	100.00

Source: Own calculation based on data collected from Eurostat, 2023.

The analysis of the 2022 data on cultivated areas in the European Union highlights the need for diversification and optimization of agricultural practices, including through the use of protected spaces such as greenhouses, to meet market demand. This approach is relevant for both countries with large cultivated areas, such as Turkey, Italy, and Spain, as well as those with smaller areas, such as Denmark or Malta. The use of protected spaces allows for better control of environmental conditions, leading to the optimization of plant growth and increased production. This is vital to ensure a consistent and high-quality yield, regardless of climatic variations. Furthermore, greenhouses and other forms of controlled agriculture can contribute to extending the growing season, providing the opportunity to produce crops outside the usual season. For countries with smaller cultivated areas, this strategy is particularly important as it allows for maximizing production on the available land, thereby contributing to economic efficiency and food security. In the context of a continuously growing market demand and the challenges posed by climate change, the adoption of such innovative and sustainable methods in agriculture becomes essential for all member states of the European Union.

From 2014 to 2022, an analysis of tomato production in the leading European countries reveals a complex landscape of agricultural yields. Turkey remained at the forefront, with its tomato production figures showcasing a high degree of consistency, albeit with minor annual fluctuations. This trend indicates a sustained capacity for tomato cultivation at a large scale. Italy held firmly to its position as the second-largest producer, with an overall trajectory of increasing production. Notable within this period were the slight decreases in the years 2017 and 2018, succeeded by a subsequent recovery and an eventual peak in production in 2021, before a small decline in 2022.

Spain's production narrative unfolded with an initial period of growth, reaching a high point in 2016, after which a gradual decrease in tomato production was observed. By 2022, Spain's production had reduced significantly from its highest point. Portugal, Greece, and the Netherlands presented more variable patterns of production. Portugal's peak in 2017 was followed by a decrease, stabilizing in the later years. Greece saw a general decline over the period, suggesting a reduction in tomato cultivation. The Netherlands demonstrated a steady production until a slight decrease in the last two years.

The production figures from Poland, France, Romania, and Belgium illustrated smaller scales of cultivation. Poland and France maintained relatively stable production with minor annual variations. Romania, after experiencing a sharp decline in 2019, recovered somewhat but then fell significantly in 2022. Belgium, while the smallest among the top ten, indicated an upward trend in the latter years, potentially pointing towards a growing focus on tomato production.

The comparison of tomato production in the top European countries between 2014 and 2022 shows Turkey, Italy, and Belgium increasing their output over the eight years, while Spain, Greece, and Romania see significant declines. From 2021 to 2022, most countries, except for Belgium, which shows growth, experience a modest decrease in production (Table 3).

Table 3. Top 10 european countries with the largest tomato production - standard humidity, 2014-2022 (1,000 tonnes)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2022/2014 %	2022/2021 %
Turkey	11,850.00	12,615.00	12,600.00	12,750.00	12,150.00	12,842.00	13,204.00	13,095.00	13,000.00	109.70	99.27
Italy	5,598.08	6,410.25	6,437.57	6,015.87	5,798.10	5,777.61	6,247.91	6,644.79	6,136.38	109.62	92.35
Spain	4,888.88	4,832.70	5,233.54	5,163.47	4,768.60	5,000.56	4,312.90	4,754.38	3,651.94	74.70	76.81
Portugal	1,399.54	1,407.00	1,693.86	1,747.63	1,329.76	1,530.11	1,399.21	1,741.32	1,406.28	100.48	80.76
Greece	1,132.72	1,148.36	1,039.32	878.77	835.94	808.67	908.25	888.32	752.51	66.43	84.71
Netherlands	900.00	890.00	890.00	910.00	910.00	910.00	910.00	880.00	770.00	85.56	87.50
Poland	810.60	789.60	866.98	898.01	928.83	917.80	766.60	815.80	787.20	97.11	96.49
France	786.10	787.88	827.61	771.55	712.02	709.28	703.39	726.17	711.04	90.45	97.92
Romania	473.86	468.75	425.61	435.06	464.04	436.55	493.72	500.20	298.92	63.08	59.76
Belgium	249.25	253.05	259.54	255.96	258.68	270.14	311.50	282.67	298.80	119.88	105.71

Source: Eurostat, 2023 [4].

The data presented in Table 4, regarding tomato cultivation in greenhouses from 2014 to 2022 emphasizes the ongoing necessity of protected agriculture. Turkey currently leads with 25,000 hectares, signaling a robust approach to addressing market demands.

Spain and Italy, maintaining 16,040 and 6,820 hectares respectively, illustrate the critical role that greenhouse cultivation occupies in their agricultural output.

The observed decrease in Spain's greenhouse areas and the fluctuations in Italy's cultivation space highlight the challenges these countries face in meeting the year-round market demand. Particularly from September to May, when there is a notable market shortfall, the need for produce grown in controlled environments becomes even more pressing.

Poland's reduction in greenhouse tomato area to 1,200 hectares might limit its capacity to contribute to market supply during the off-season. Conversely, Romania's steady increase to 1,900 hectares in 2022, and the Netherlands' significant rebound to 1,820 hectares, indicate strategic enhancements to their protected cultivation practices, likely in response to the seasonal market deficit.

Portugal's and Bulgaria's cultivation trends, with the former peaking at 1,400 hectares in 2020 and 2021 and then descending to 1,240 hectares, and the latter maintaining a stable cultivation area, underscore the broader European movement towards optimizing greenhouse tomato production. The current cultivation data points to the essential need for continued and increased investment in greenhouse infrastructure across Europe to secure a consistent supply of tomatoes, thus addressing the market deficits that are most pronounced from September to May.

Table 4. Top 10 European countries with the largest areas of tomatoes cultivated in greenhouses, 2014-2022 (1,000 ha)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	Evolution
Turkey	23.00	25.00	26.00	28.00	28.00	28.00	26.00	28.00	25.00	
Spain	21.13	19.41	19.98	18.95	18.97	17.80	16.79	16.27	16.04	
Italy	7.15	7.44	7.16	7.08	7.23	7.61	7.61	7.35	6.82	
Poland	3.10	3.10	3.25	3.23	3.25	3.20	1.50	1.80	1.20	
Greece	3.06	2.82	2.59	2.67	2.70	2.61	2.67	3.11	2.71	
France	2.07	2.03	2.21	2.09	2.14	2.15	2.17	2.17	2.15	
Netherlands	1.78	1.76	1.78	1.79	1.79	0.91	0.91	0.88	1.82	
Romania	1.62	1.65	1.73	1.66	1.84	1.83	1.79	1.78	1.90	
Portugal	0.93	0.98	0.96	1.00	1.01	0.93	1.40	1.40	1.24	
Bulgaria	0.56	0.59	0.58	0.64	0.61	0.50	0.51	0.64	0.59	

Source: Eurostat, 2023 [4].

Table 5. Top 10 european countries with the largest tomato production in greenhouses, 2014-2022 (1,000 tonnes)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	Tredline
Turkey	3,203.00	3,315.00	3,522.00	3,796.00	3,889.00	3,989.00	4,045.00	4,369.00	4,104.00	
Spain	2,112.02	1,835.31	2,027.86	1,827.11	1,836.19	1,623.43	1,553.19	1,475.06	1,450.44	
Netherlands	900.00	890.00	890.00	910.00	910.00	910.00	910.00	880.00	770.00	
France	580.10	589.32	625.18	560.36	522.86	524.27	486.59	521.17	504.25	
Poland	538.70	553.20	606.59	643.46	675.84	677.30	571.30	654.40	615.70	
Italy	498.61	516.29	447.05	442.56	465.94	524.93	513.66	536.50	485.92	
Greece	384.19	340.77	321.72	309.66	328.38	293.28	344.62	397.46	337.03	
Germany	84.50	80.92	85.29	96.56	103.27	106.69	102.12	101.77	102.18	
Romania	75.93	79.41	98.52	76.55	87.14	76.33	68.79	67.56	71.21	
Austria	56.97	55.38	54.75	53.90	57.80	57.99	58.24	59.34	56.46	

Source: Eurostat, 2023 [4].

Turkey's greenhouse tomato production consistently increased, reaching a high in 2021 with 4,369,000 tonnes before a minor drop to 4,104,000 tonnes in 2022 (Table 5).

Spain's output gradually declined over the years, ending at 1,450,440 tonnes. The Netherlands saw a steady production until a drop in the last two years, concluding with 770,000 tonnes. France and Poland both experienced fluctuations, with France ending at 504,250 tonnes and Poland decreasing after a peak in 2019 to 615,700 tonnes in 2022. Italy's production overall declined slightly to 485,920 tonnes. Greece showed recovery in 2021 but fell again to 337,030 tonnes in 2022.

Germany, Romania, and Austria had more stable production, with slight variations, ending the period near their starting figures (Table 5).

CONCLUSIONS

The landscape of tomato production in European greenhouses has displayed varied trends from 2014 to 2022, with some countries expanding their output and others facing declines. Increases in countries like Turkey, Italy, and Belgium contrast with the significant drops seen in Spain, Greece, and Romania, signaling diverse agricultural conditions and strategies across the continent. Yearly figures from 2021 to 2022 mostly show a downturn, except for Belgium, which notably improved its production.

The general decrease across the EU emphasizes the importance of adopting advanced agricultural technologies and sustainable practices to adapt to the shrinking cultivation spaces and to meet the ongoing demand for tomatoes. The future of European tomato production in greenhouses appears to hinge on integrating innovation and efficiency into the sector's practices, ensuring long-term sustainability and resilience.

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REFERENCES

[1]Becerril, H., De los Rios, I., 2016, Energy efficiency strategies for ecological greenhouses: experiences from Murcia (Spain). Energies, 9(11), 866.

[2]Capobianco-Uriarte, M. D. L. M., Aparicio, J., De Pablo-Valenciano, J., Casado-Belmonte, M. D. P., 2021, The European tomato market. An approach by export competitiveness maps. PloS one, 16(5), e0250867.

[3]Drăghici, E. M., Jerca, O. I., Cîmpeanu, S. M., Teodorescu, R. I., Şiu, J., Bădulescu, L., 2021, Study regarding the evolution of high-performance cultivation technologies in greenhouses and hight tunnels in Romania. Scientific Papers. Series B. Horticulture, 65(1).

[4]Eurostat, 2023, Crop production in EU standard humidity for tomatoes, https://ec.europa.eu/eurostat/databrowser/view/apro_cpsh1__custom_8748007/default/table, Accessed on September 2, 2023.

[5]Giucă, A. D., 2023, Trends on the tomato market in Romania in the period 2010-2021. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 23(3), 313-322.

[6]Iancu, T., Petre, I. L., Tudor, V. C., Micu, M. M., Ursu, A., Teodorescu, F. R., Dumitru, E. A., 2022, A Difficult Pattern to Change in Romania, the Perspective of Socio-Economic Development. Sustainability, 14(4), 2350.

[7]Ilić, Z. S., Kapoulas, N., Šunić, L., 2014, Tomato Fruit Quality from Organic and Conventional Production. InTech. doi: 10.5772/58239

[8]Kadakoğlu, B., Gül, M., 2023, Foreign trade structure of vegetable sector: development process in the world and Türkiye. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 23(3), 419-430.

[9]Keating, B. A., Carberry, P. S., Bindraban, P. S., Asseng, S., Meinke, H., Dixon, J., 2010, Eco-efficient agriculture: Concepts, challenges, and opportunities. Crop science, 50, S-109.

[10]LaPlante, G., Andrekovic, S., Young, R. G., Kelly, J. M., Bennett, N., Currie, E. J., Hanner, R. H., 2021, Canadian greenhouse operations and their potential to enhance domestic food security. Agronomy, 11(6), 1229.

[11]Maja, M. M., Ayano, S. F., 2021,The impact of population growth on natural resources and farmers' capacity to adapt to climate change in low-income countries. Earth Systems and Environment, 5, 271-283.

[12]Pardossi, A., Tognoni, F., Incrocci, L., 2004, Mediterranean greenhouse technology. Chronica horticulturae, 44(2), 28-34.

[13]Parry, M. A., Hawkesford, M. J., 2010, Food security: increasing yield and improving resource use efficiency. Proceedings of the nutrition Society, 69(4), 592-600.

[14]Peet, M. M., Welles, G., 2005, Greenhouse tomato production. In Tomatoes (pp. 257-304). Wallingford UK: CABI Publishing.

[15]Popescu, A., 2016, Some considerations on vegetables and tomatoes production and consumption in Romania in the period 2007-2014. Scientific Papers Series Management, Economic Engineering in Agriculture & Rural Development, 16(3), 277-284.

[16]Pretty, J., 2008, Agricultural sustainability: concepts, principles and evidence. Philosophical Transactions of the Royal Society B: Biological Sciences, 363(1491), 447-465.

[17]Pretty, J., Bharucha, Z. P., 2014, Sustainable intensification in agricultural systems. Annals of botany, 114(8), 1571-1596.

[18]Shankara, N., Van Dam, B., Goffau, M., Van L.J.J, 2005, Cultivation of Tomato: Production, Processing and Marketing, Agrodok;17. Agromisa/CTA, Wageningen, The Netherlands.

[19]Timsina, J., 2018, Can organic sources of nutrients increase crop yields to meet global food demand?. Agronomy, 8(10), 214.

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IMAGING ANALYSIS IN CROP MANAGEMENT. CASE STUDY IN SOYBEAN

Andreea Lidia JURJESCU[1], Florin SALA[1,2]

[1]Agricultural Research and Development Station Lovrin, Lovrin, 307250, Romania, andreealidia19@gmail.com, florin_sala@usvt.ro
[2]University of Life Sciences "King Michael I" from Timisoara, Timișoara, 300645, Romania Emails: florin_sala@usvt.ro

Corresponding author: florin_sala@usvt.ro

Abstract

The study used imaging analysis to describe and characterize a soybean crop, in terms of plant uniformity and the presence of weeds, with the formulation of intervention decisions for crop management. Images were taken in digital format (cell phone camera), which were analyzed for spectral information (RGB) and fractal geometry (D). Based on the obtained data, normalized values (rgb), different ratios (R/G, R/B, G/R, G/B, B/R, B/G), specific indices (NDI – normalized difference index, INT - intensity) and degree of vegetation cover (DVC, %), as green canopy cover. A flow diagram was developed for the study carried out in the assessment of soybean culture. From the correlation analysis, the values of the correlation coefficient (r) were obtained, in conditions of statistical safety. The regression analysis led to obtaining some equations that described the variation of DVC in relation to the considered parameters. Very high levels of precision and safety were recorded based on the R/G ratio, the corrected g value (R^2=0.998, p<0.001), followed immediately by the equations based on the G/R ratio and the NDI index (R^2=0.997, p <0.001). 3D models and in the form of isoquants described the variation of DVC in relation to the considered parameters. According to PCA, PC1 explained 95.997% of variance, and PC2 explained 3.9978% of variance. Cluster analysis led to the grouping of the variants based on similarity, highlighting the variants with a high degree of weeding (s8, s9), the variant with a normal state (s7) and the other experimental variants.

Key words*: *decision support, imaging analysis, models, soybean crop, weeds

INTRODUCTION

The management of agricultural crops, from sowing to harvesting, requires permanent knowledge of the vegetation state of the plants, the performance of the works foreseen by the culture technologies, and appropriate interventions, in real time, in relation to aspects identified during periods of vegetation [16, 27, 30]. Knowledge of the vegetation and the evolution of crops by growth stages require information in real time, regarding the status of plants in relation to biotic and abiotic factors and culture technologies [14, 19].

Obtaining information can be done through direct observation, based on satellite, aerial or terrestrial images, and different investigation systems, which capture the reality of plants and agricultural crops [1, 7, 36]. Satellite images have the advantage of large-scale coverage of terrestrial and agricultural areas, with variable image resolutions and related costs [9, 35].

Aerial images (UAV) have a smaller scale coverage (plots) but at a better resolution, with very high dynamics for moving the work technique in the field, and the facility to work at different photographing heights for analysis and crop evaluation [3, 6, 25]. At the same time, images taken with cameras or mobile devices (at high resolutions) allow obtaining localized, punctual images in areas of a culture ascertained from observations on the ground to be normal areas, or areas with variable plant density (gaps in the row of plants), weedy areas (presence of different weed species), or affected by diseases, pests or nutrient deficiency [18, 24, 33, 34]. The images taken, accompanied by recorded observations (notes, data, measurements, etc.) represent an information base that needs to be analyzed, processed in order to obtain additional, more precise information and on the basis of which the culture can be characterized, or maybe be generated intervention decisions / corrections on the crops [5, 21, 24]. These interventions can target the entire culture (plot, soil) or only certain areas of the culture depending on the identified problem. In this way, localized interventions have immediate, high efficiency and low costs, compared to a generalized intervention, on the scale of the entire crop plot [25]. Different types of image analysis can be used to analyze data in the form of images related to plants or agricultural crops. Some methods are based on spectral information and specific indices [9, 10, 19, 22], and others are based on fractal analysis [23, 29].

The present study used imaging analysis to study soybean culture in terms of plant growth, uniformity and development and the degree of weeding, in order to formulate characterization models and attention to some intervention works.

MATERIALS AND METHODS

The study analyzed the soybean crop with imaging methods in relation to the uniformity of the plants in a row and the presence of weeds in the crop. Soybean crop was organized within SCDA Lovrin, under non-irrigated crop conditions. The soybean crop was analyzed in stage 5 BBCH code (Principal growth stage). In relation to the purpose of the study, images were taken in digital format (cell phone camera SM-N910C model, 2,988 x 5,312 pixels, 24 bit depth, jpg format) to capture areas with appropriate density, and areas with gaps (missing plants). Also, images were taken in areas of culture with weeds. Examples of images are shown in Photo 1.

Photo 1. Aspects of soybean crop considered in the study
Source: Original photos made by authors.

Imaging analysis was used to obtain information in the form of data [20, 29].

To describe the fractal geometry was determined for each image total pixels (TP), foreground pixels (FP), fractal dimension (D, and Mean^D). For the fractal analysis, binarized images were used, Photo 1 (s7 binary). Based on the RGB color parameters, the normalized rgb values were calculated [12], equations (1), (2), (3). The ratios between the color parameters (R/G, R/B, G/R, G/B, B/R, B/G) were calculated. In addition, the NDI [15], equation (4) and INT [2], equation (5) indices were calculated.

$$r = \frac{R}{R+G+B} \quad (1)$$

$$g = \frac{G}{R+G+B} \quad (2)$$

$$b = \frac{B}{R+G+B} \quad (3)$$

$$NDI = \frac{(r-g)}{(r+g+0.01)} \quad (4)$$

$$INT = \frac{R+G+B}{3} \quad (5)$$

The degree of vegetation cover (DVC, %), as green canopy cover, was determined [17]. Through the regression analysis, the DVC variation was evaluated in relation to the imaging analysis parameters considered.

The obtained data through imaging analysis and results through calculations were analyzed to evaluate the statistical safety (p, R^2, RMSEP), the level of interdependence between the considered parameters. Distribution and similarity of variants, PCA, Cluster Analysis were evaluated [8, 11, 31].

The study was conducted based on the designed flow diagram, represented in Figure 1.

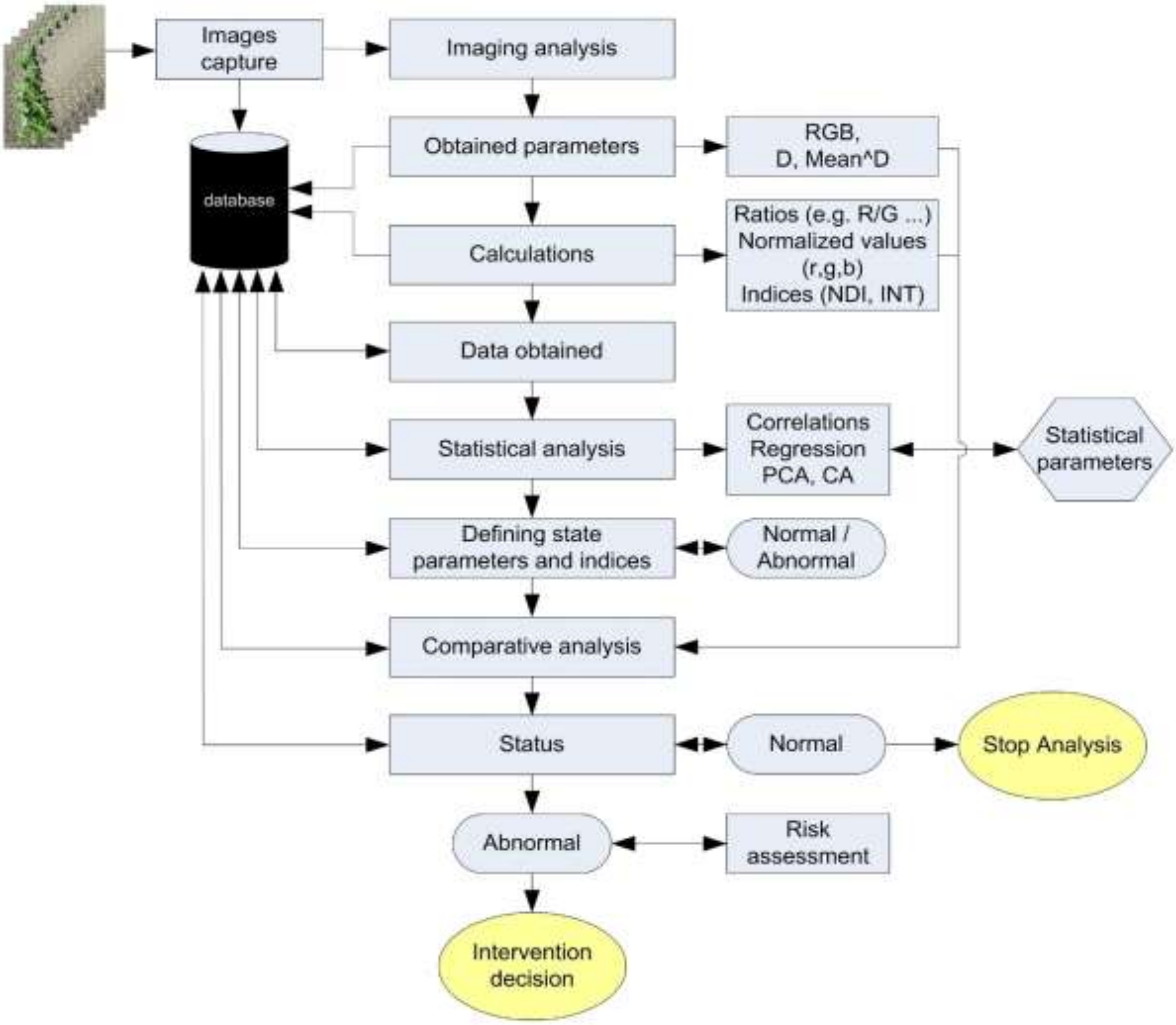

Fig. 1. Flow chart for the soybean crop study
Source: Original figure.

RESULTS AND DISCUSSIONS

For the characterization of soybean crop, information was obtained from the analysis of digital images in the form of data regarding total pixels (TP), foreground pixels (FP), fractal dimension (D, Mean^D), degree of vegetation cover (DVC), and color parameters in the RGB system (R,G,B). The values resulting from the imaging analysis are presented in Table 1. The TP parameter has the same value for each image, the images having the same size (2,988 x 5,312 pixels; Width, Height). In the case of foreground pixels (FP), different values were recorded, depending on the composition of each image, composition given by the component elements, respectively soil, soybean plants, and weeds. The fractal dimension (D) varied between 1.827 in the case of the s9 variant and 1.886 in the case of the s5 variant. Degree of vegetation cover (DVC) had values between DVC=0.00% in the case of variant s1 (land without vegetation) and DVC=78.25% in the case of variant s9 with a high percentage of weeds. RGB color parameters show values between 101.52 and 150.51 in the case of the R parameter; 129.62 and 152.36 in the case of parameter G; respectively between 67.27 and 127.70 in the case of parameter B.

Starting from the primary recorded data, table 1, the ratios between color parameters (RGB) were calculated, the normalized values (rgb) were calculated, according to equations (1), (2), (3) and the NDI indices were calculated and INT, according to equations (4) and (5). The values resulting from the calculations are presented in Table 2.

Table 1. Data on imaging analysis parameters for image samples, soybean crop

Trials	TP	FP	D	Mean^D	DVC	R	G	B
s1	15872256	5550575	1.916	1.882	0.00	140.32	129.62	117.07
s2	15872256	5828698	1.915	1.876	6.16	139.51	134.64	115.70
s3	15872256	5584039	1.915	1.873	9.21	150.51	149.61	127.70
s4	15872256	5614623	1.918	1.882	13.02	152.31	152.36	126.68
s5	15872256	6357696	1.920	1.886	15.86	128.53	131.39	106.37
s6	15872256	6056106	1.922	1.873	18.56	145.86	152.25	125.23
s7	15872256	6430957	1.916	1.862	22.51	136.26	144.25	112.83
s8	15872256	6491138	1.905	1.842	37.49	124.05	139.18	99.02
s9	15872256	6428950	1.827	1.755	78.25	101.52	134.06	67.27

Source: Original data.

Table 2. Normalized values, ratios and indices calculated for image samples, soybean crop

Trials	R/G	R/B	G/R	G/B	B/R	B/G	r	g	b	NDI	INT
s1	1.0825	1.1986	0.9237	1.1072	0.8343	0.9032	0.3626	0.3349	0.3025	0.0391	129.00
s2	1.0362	1.2058	0.9651	1.1637	0.8293	0.8593	0.3579	0.3454	0.2968	0.0175	129.95
s3	1.0060	1.1786	0.9940	1.1716	0.8484	0.8536	0.3518	0.3497	0.2985	0.0030	142.61
s4	0.9997	1.2023	1.0003	1.2027	0.8317	0.8315	0.3531	0.3532	0.2937	-0.0002	143.78
s5	0.9782	1.2083	1.0223	1.2352	0.8276	0.8096	0.3509	0.3587	0.2904	-0.0109	122.10
s6	0.9580	1.1647	1.0438	1.2158	0.8586	0.8225	0.3445	0.3596	0.2958	-0.0211	141.11
s7	0.9446	1.2077	1.0586	1.2785	0.8280	0.7822	0.3464	0.3667	0.2869	-0.0281	131.11
s8	0.8913	1.2528	1.1220	1.4056	0.7982	0.7115	0.3424	0.3842	0.2733	-0.0567	120.75
s9	0.7573	1.5091	1.3205	1.9929	0.6626	0.5018	0.3352	0.4427	0.2221	-0.1364	100.95

Source: Original data.

From the correlation analysis, the values of the correlation coefficient (r) resulted, which expressed different levels of intensity of correlations, and types of correlations (positive, negative) between considered parameters, under conditions of statistical

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certainty. The obtained data are presented in Figure 2, as correlation matrix plot.

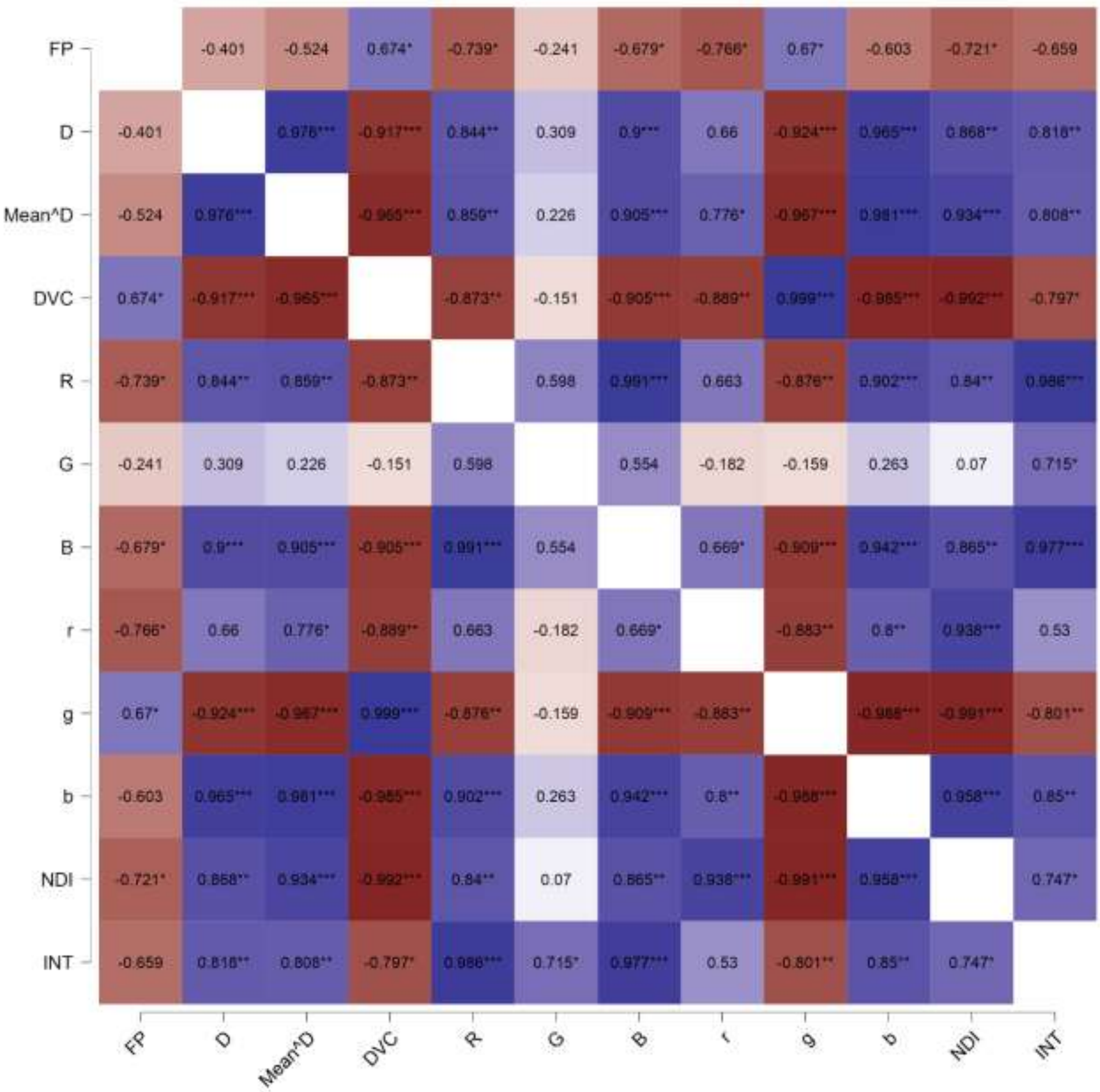


Fig. 2. Correlation matrix plot between analyzed parameters for the characterization of soybean crop
Source: Original figure, generated by analysis.

The main aspect of the study was to evaluate the soybean crop from the perspective of the crop uniformity (rows with plants, without gaps) and the presence of weeds, based on the calculated parameters and indices. Based on the simple regression analysis, the DVC variation was evaluated in relation to each parameter determined from the imaging analysis, and the results are presented in Table 3 in the form of equations, and the statistical confidence level (R^2, p).

From the analysis of the data presented in table 3, it was found that a very high level of precision and statistical certainty in the description of the DVC variation was recorded in the case of using the R/G ratio (R^2=0.998), the parameter g (normalized values) (R^2=0.998), followed by the cases of using the G/R values (R^2=0.997), and the NDI index values (R^2=0.997), and followed by the case where the values of the G/B ratio (R^2=0.996) and the B ratio were used/G (R^2=0.995).

The multiple regression analysis facilitated the description of the DVC variation in relation to the different parameters considered in the analysis, as a direct and interaction effect, according to equation (23).

Table 3. Equations and statistical safety parameters for the description of the DVC variation in relation to different parameters

Parameter	Equations	Eq. No.	R^2	p
FP	$DVC = 5.2588E-11x^2 - 0.0005934x + 1681$	(6)	0.485	0.136
D	$DVC = -4389x^2 + 1.572E04x - 1.399E04$	(7)	0.846	0.0036
Mean^D	$DVC = -1033x^2 + 3206x - 2368$	(8)	0.934	<0.001
R	$DVC = 0.03299x^2 - 9.722x + 726.6$	(9)	0.899	0.0010
G	$DVC = -0.1963x^2 + 55.19x - 3842$	(10)	0.189	0.531
B	$DVC = 0.01729x^2 - 4.521x + 305.6$	(11)	0.891	0.0012
R/G	$DVC = 398.7x^2 - 975.8x + 588.9$	(12)	0.998	<0.001
R/B	$DVC = -83.38x^2 + 432.7x - 384.4$	(13)	0.862	0.0026
G/R	$DVC = 90.21x^2 - 1.856x - 76.26$	(14)	0.997	<0.001
G/B	$DVC = -64.67x^2 + 289x - 240.8$	(15)	0.996	<0.001
B/R	$DVC = 382.2x^2 - 948x + 539.3$	(16)	0.862	0.0025
B/G	$DVC = -196.8x + 177$	(17)	0.995	<0.001
r	$DVC = 1.252E05x^2 - 8.992E04x + 1.615E04$	(18)	0.950	<0.001
g	$DVC = 737.7x - 247.7$	(19)	0.998	<0.001
b	$DVC = -5318x^2 + 1845x - 69.16$	(20)	0.981	<0.001
NDI	$DVC = 939.1x^2 - 360.6x + 11.97$	(21)	0.997	<0.001
INT	$DVC = 0.05524x^2 - 15.05x + 1036$	(22)	0.861	0.0026

Source: Original data resulted by calculations.

The values of the coefficients of equation (23) depending on the considered parameters are presented in Table 4. Examples of the graphic distribution of DVC values, in 3D and isoquants form, depending on the considered parameters, are presented in Figures 3and 4.

$$DVC = ax^2 + by^2 + cx + dy + exy + f \qquad (23)$$

where: DVC – degree of vegetation cover (%); *x*, *y* – parameters considered in the analysis (table 4); a, b, c, d, e, f – coefficients of the equation (23), Table 4.

Table 4. Values of the coefficients of the equation (23) in the description of the DVC variation in the soybean crop

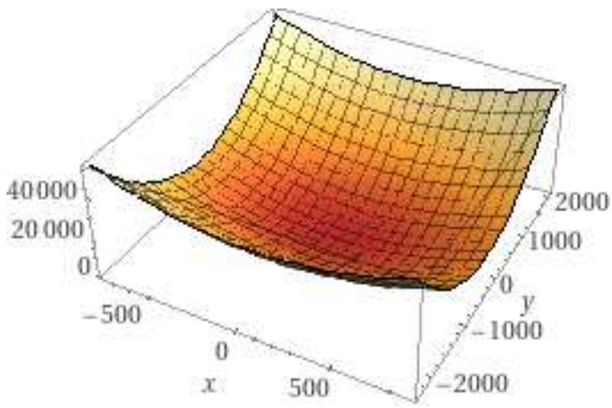
Coefficients of equation (23)	Indexes used					
	x=R *y*=G	*x*=R *y*=B	*x*=G *y*=B	*x*=r *y*=b	*x*=g *y*=b	*x*=FP *y*=D
a	0.02129543	-0.79747437	0.01271909	-3972.37229158	0.01271909	2.05E-11
b	0.00859978	-0.67424189	0.00369149	-723.41469798	0.00369149	3786.77644459
c	-2.92364198	46.17134462	-0.16037879	1916.03732249	-0.16037879	0.00211460
d	3.13743287	-54.80744364	0.24541609	-521.07927517	0.24541609	-6929.62610279
e	-0.03081279	1.51534052	-0.01796363	454.45390935	-0.01796363	-0.00122121
f	0	0	0	0	0	0
R^2	0.999	0.949	0.998	0.999	0.998	0.980
p	<0.001	0.024	<0.001	<0.001	<0.001	0.0059
RMSEP	0.87658	7.08707	1.01070	0.96286	1.0107	4.38567

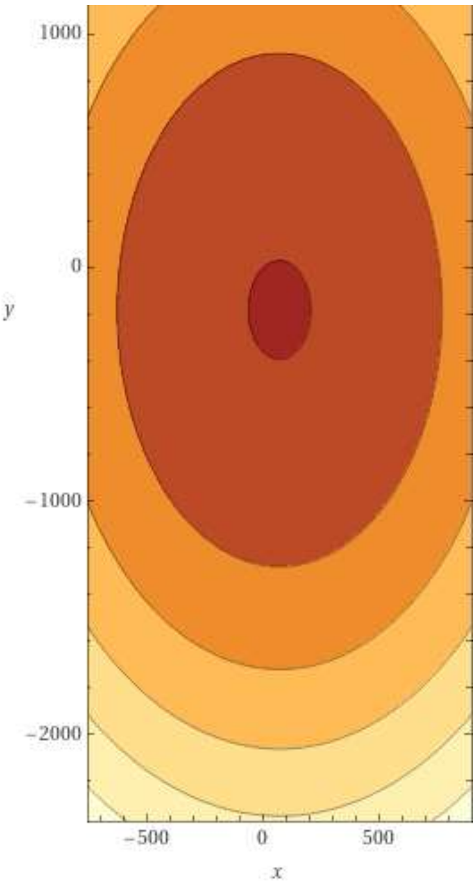
Source: Original data resulted by calculations.

Under the conditions of the present study, trial s7 presented the normal state of soybean crop, at stage 5 BBCH code, Principal growth stage. From the imaging analysis, this state was characterized by the values of the considered parameters presented in Table 1 and Table 2.

According to PCA, based on the values of the calculated ratios, the diagram in figure 6 was generated, in which the variants were distributed in relation to the values considered in the analysis. Variant s1 (land without plants) was positioned independently, in quadrant IV, associated with R/G, B/G ratios.

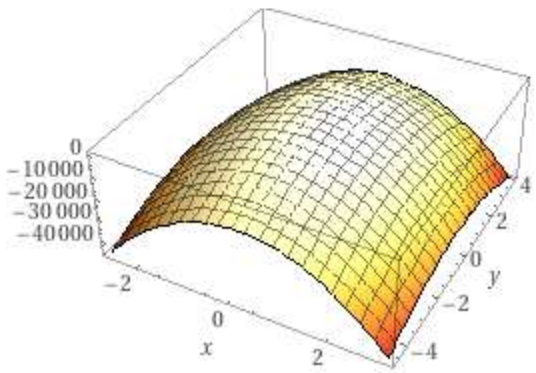
The s7 variant, which represented the normal state of the culture at the time of the study, was associated with the B/R ratio (quadrant II). Variants s2 – s6, weed-free culture, with variable number of plants per row, were positioned grouped, quadrant III and IV, associated with R/G, B/G, B/R ratios.

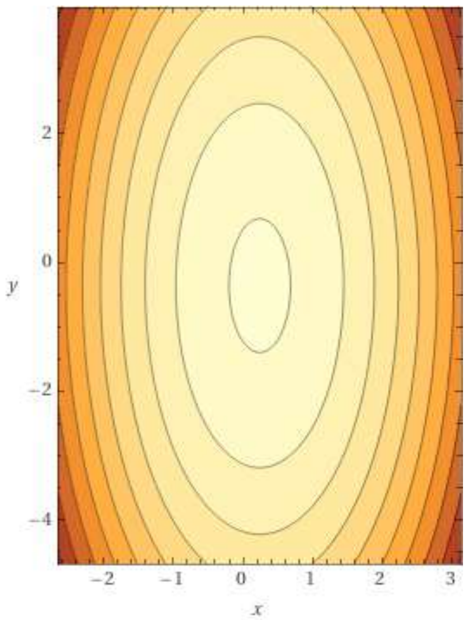




(a) (b)

Fig. 3. Distribution of DVC values in relation to R and G in soybean crop; (a) 3D format, (b) isoquants format
Source: Original figure.





(a) (b)

Fig. 4. Distribution of DVC values in relation to r and b in soybean crop; (a) 3D format, (b) isoquants format
Source: Original figure.

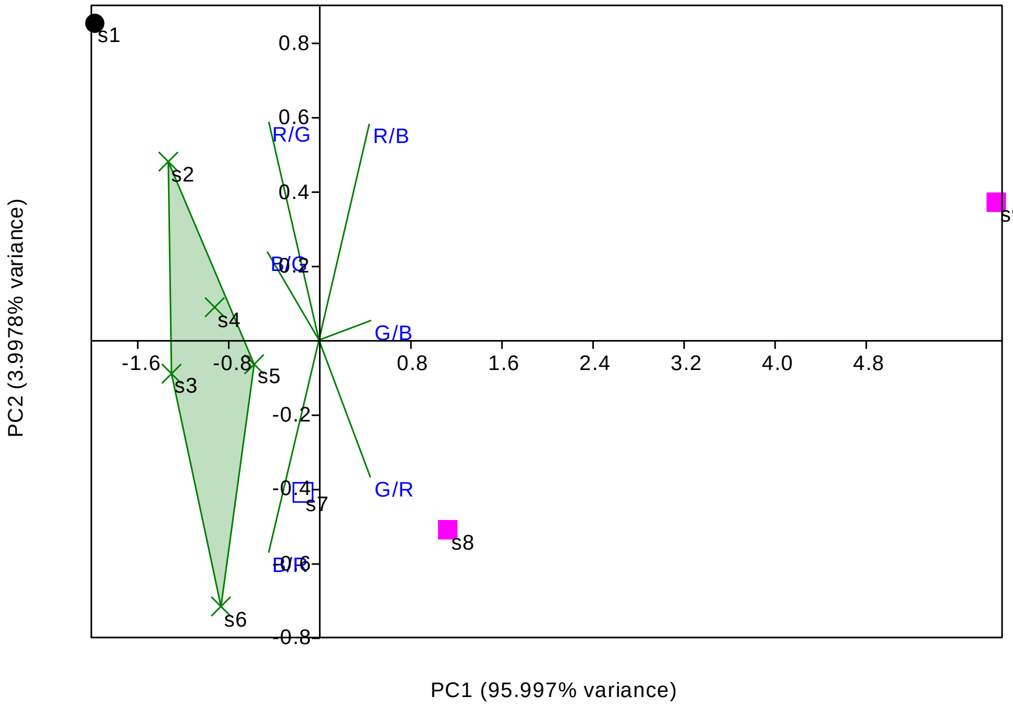


Fig. 5. PCA diagram in the analysis of soybean crop
Source: Original figure.

Variants s8 and s9, with variable degree of weeds, were placed associated with G/R ratios (s8) quadrant II, and G/B, R/B (s9) ratios, quadrant I. PC1 explained 95.997% of variance, and PC2 explained 3.9978% of variance.

The cluster analysis led to the dendrogram in Figure 6, under conditions of Coph.corr.= 0.978, in which the variants were grouped based on Euclidean distances.

The independent positioning of variant s9 (high degree of weeds) and close to variant s8 (both variants with weeds) was found. Within a sub-cluster C1, variant s1 (plant front, empty land) was placed independently.

The other variants, s2 to s7 (without weeds, with variable number of plants) were positioned grouped in two sub-clusters, in relation to the growing number of plants per row. Thus, on the basis of similarity, the variants (s2(s3,s4)) were grouped within a sub-cluster, and the variants ((s5,s6),s7) within another sub-cluster.

The calculated SDI values confirmed the association and grouping of the variants (SDI=0.07122 in the case of s7 with s5; SDI=0.09348 in the case of s7 with s6; SDI=0.72824 in the case of s9 with s8; SDI=1.1553 in the case of s1 with s9, the highest value SDI).

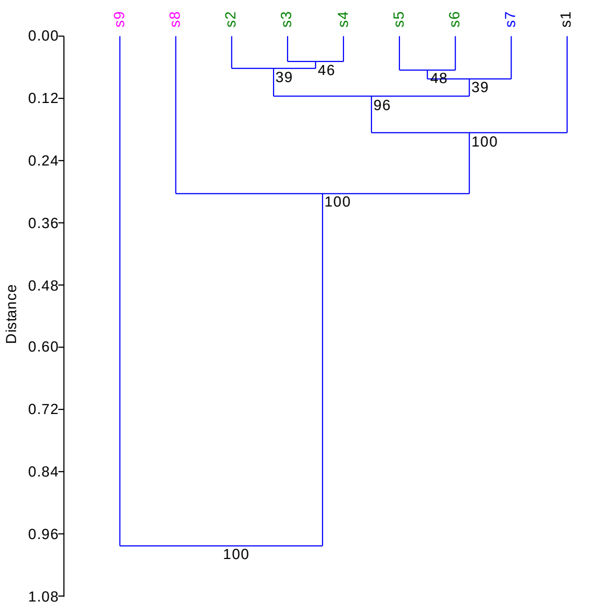


Fig. 6. Dendrogram of variants grouping based on Euclidean distances
Source: Original figure.

The imaging analysis used in the present study facilitated the description of the soybean culture in relation to aspects regarding the uniformity of the culture, the degree of coverage of the land with soybean plants, but also in relation to the presence of weeds. Imaging methods are very frequently used for crop control, crops mapping, plant density, plant nutrition and health status [26, 28].

Imaging analysis has given very good results in studies of identification and analysis of weeds in different agricultural crops [13, 32]. The identification of weeds in real time in agricultural crops presents high advantages for the differentiated application of herbicides, only on the affected areas, thus ensuring a precise dosage of treatments, sustainable technologies for agricultural crops and environmental protection [4, 13].

The present study contributes to the development of the database and information regarding the evaluation of agricultural crops in terms of uniformity and the presence of weeds, through methods based on imaging analysis, and proposes some models for describing the degree of land cover based on some color parameters (RGB), calculated reports and specific indices.

CONCLUSIONS

Imaging analysis based on digital images (cell phone camera) facilitated obtaining information in the form of color parameters (RGB, rgb), calculated ratios (e.g. R/G, R/B), specific indices (NDI, INT) and degree of vegetation cover (DVC), for the analysis and characterization of the soybean culture in terms of uniformity and weeds degree.

The correlation analysis facilitated the identification of the degree of interdependence between the parameters considered in the characterization and analysis of the soybean crop.

The regression analysis facilitated the description by equations (linear and polynomial) of the degree of vegetation cover (DVC) variation according to each considered parameter, under statistical safety conditions. A high level of precision and safety efforts were recorded in the case of the equations based on the R/G ratio, of the corrected value g (R^2=0.998, p<0.001), immediately followed by the equations based on the G/R ratio and the NDI index (R^2= 0.997, p<0.001). 3D models and in the form of isoquants were generated to describe the variation of DVC in relation to considered parameters, as a direct and interaction effect.

According to PCA, a distribution diagram of the variants was generated in relation to the considered parameters, as biplot; PC1 explained 95.997% of variance, and PC2 explained 3.9978% of variance in the case of analysis based on calculated ratios (RGB).

Cluster analysis led to the grouping of the variants based on similarity, highlighting the variants with a high degree of weeding (s8, s9), the variant with a normal state (s7) and the other experimental variants.

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REFERENCES

[1]Ahmad, I.S., Reid, J.F., 1996, Evaluation of color representations for maize images, J. Agric. Eng. Res., 63(3):185-195.

[2]Ahmad, U., Nasirahmadi, A., Hensel, O., Marino, S., 2022, Technology and data fusion methods to enhance site-specific crop monitoring, Agronomy, 12:555

[3]Bouguettaya, A., Zarzour, H., Kechida, A., Taberkit A.M., 2022, Deep learning techniques to classify agricultural crops through UAV imagery: a review, Neural Comput & Applic., 34:9511-9536.

[4]Burgos-Artizzu, X.P., Ribeiro, A., Guijarro, M., Pajares, G., 2011, Real-time image processing for crop/weed discrimination in maize fields, Comput. Electron. Agric., 75(2):337-346.

[5]Espinosa-Herrera, J.M., Macedo-Cruz, A., Fernández-Reynoso, D.S., Flores-Magdaleno, H., Fernández-Ordoñez, Y.M., Soria-Ruíz, J., 2022, Monitoring and identification of agricultural crops through multitemporal analysis of optical images and machine learning algorithms, Sensors (Basel), 22(16):6106.

[6]Fan, C., Lu, R., 2021, UAV image crop classification based on deep learning with spatial and spectral features, IOP Conf. Ser. Earth Environ. Sci., 783:012080.

[7]Halstead, M., Ahmadi, A., Smitt, C., Schmittmann, O., McCool, C., 2021, Crop agnostic monitoring driven by deep learning, Front. Plant Sci., 12:786702.

[8]Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001, PAST: Paleontological Statistics software package for education and data analysis, Palaeontol. Electron., 4(1):1-9.

[9]Hsiou, D.-C., Huang, F., Tey, F.J., Wu, T.-Y., Lee, Y.-C., 2022, An automated crop growth detection method using satellite imagery data, Agriculture, 12:504.

[10]Huete, A.R., 1988, A soil-adjusted vegetation index (SAVI), Remote Sens. Environ., 25(3):295-309.

[11]JASP Team, 2022, JASP (Version 0.16.2) [Computer software].

[12]Lee, K.-J., Lee, B.-W., 2013, Estimation of rice growth and nitrogen nutrition status using color digital camera image analysis, Eur. J. Agron., 48:57-65.

[13]Li, Y., Al-Sarayreh, M., Irie, K., Hackell, D., Bourdot, G., Reis, M.M., Ghamkhar, K., 2021, Identification of weeds based on hyperspectral imaging and machine learning, Front. Plant Sci., 11:611622.

[14]Madec, S., Irfan, K., Velumani, K., Baret F., David E., Daubige G., Samatan L.B., Serouart ., Smith D., James C., Camacho F., Guo W., De Solan B., Chapman S.C., Weiss M., 2023, VegAnn, Vegetation Annotation of multi-crop RGB images acquired under diverse conditions for segmentation, Sci. Data, 10:302.

[15]Mao, W., Wang, Y., Wang, Y., 2003, Real-time detection of between-row weeds using machine vision, ASAE Annual Meeting, 2003:031004.

[16]Mesías-Ruiz, G.A., Pérez-Ortiz, M., Dorado, J., de Castro, A.I., Peña, J.M., 2023, Boosting precision crop protection towards agriculture 5.0 via machine learning and emerging technologies: A contextual review, Front. Plant Sci., 14:1143326.

[17Patrignani, A., Ochsner, T.E., 2015, Canopeo: A powerful new tool for measuring fractional green canopy cover, Agron. J., 107(6):2312-2320.

[18Pei, H., Sun, Y., Huang, H., Zhang, W., Sheng, J., Zhang, Z., 2022, Weed detection in maize fields by UAV images based on crop row preprocessing and improved YOLOv4, Agriculture, 12:975.

[19]Radočaj, D., Šiljeg, A., Marinović, R., Jurišić, M., 2023, State of major vegetation indices in precision agriculture studies indexed in Web of Science: A Review, Agriculture, 13:707.

[20]Rasband, W.S., 1997, Image J. U. S. National Institutes of Health, Bethesda, Maryland, USA, p. 1997-2014.

[21]Rivera, A.J., Pérez-Godoy, M.D., Elizondo, D., Deka, L., del Jesus, M.J., 2022, Analysis of clustering methods for crop type mapping using satellite imagery, Neurocomputing, 492:91-106.

[22]Rouse, J.W.Jr., Haas, R.H., Schell, J.A., Deering, D.W., 1974, Monitoring vegetation systems in the Great Plains with ERTS. Third Earth Resource Technology Sattelite - 1 Symposium, NASA SP-351(I):309-317.

[23]Sala, F., Iordănescu, O., Dobrei, A., 2017, Fractal analysis as a tool for pomology studies: case study in apple, AgroLife Sci. J., 6(1):224-233.

[24]Sala, F., Popescu, C.A., Herbei, M.V., Rujescu, C., 2020, Model of color parameters variation and correction in relation to “Time-View” image acquisition effects in wheat crop, Sustainability, 12(6):2470.

[25]Shahi, T.B., Xu, C.-Y., Neupane, A., Guo, W., 2023, Recent advances in crop disease detection using UAV and Deep Learning techniques, Remote Sens., 15:2450.

[26]Shirzadifar, A., Maharlooei, M., Bajwa, S.G., Oduor, P.G., Nowatzki, J.F., 2020, Mapping crop stand count and planting uniformity using high resolution imagery in a maize crop, Biosyst. Eng., 200:377-390.

[27]Thomas, R.J., O’Hare, G., Coyle, D., 2023, Understanding technology acceptance in smart agriculture: A systematic review of empirical research in crop production, Technol. Forecast. Soc. Change, 189:122374.

[28]Vong, C.N., Conway, L.S., Feng, A., Zhou, J., Kitchen, N.R., Sudduth, K.A., 2022, Corn emergence uniformity estimation and mapping using UAV imagery and deep learning, Comput. Electron. Agric., 198:107008.

[29]Voss, R., 1985, Random fractal forgeries. In: Earnshaw R. (Ed.) Fundamental algorithms for computer graphics, Springer Verlag, Berlin, pp. 805-835.

[30]Vrchota, J., Pech, M., Švepešová, I., 2022, Precision agriculture technologies for crop and livestock production in the Czech Republic, Agriculture, 12:1080.

[31]Wolfram, Research, Inc., Mathematica, Version 12.1, Champaign, IL (2020).

[32]Wu, Z., Chen, Y., Zhao, B., Kang, X., Ding, Y., 2021, Review of weed detection methods based on Computer Vision, Sensors (Basel), 21(11):3647.

[33]Yin, H., Huang, W., Li, F., Yang, H., Li, Y., Hu, Y., Yu, K., 2023, Multi-temporal UAV imaging-based mapping of chlorophyll content in potato crop, PFG – J. Photogramm. Rem. 91:91-106.

[34]Yu, F., Jin, Z., Guo, S., Guo, Z., Zhang, H., Xu, T., Chen, C. 2022, Research on weed identification method in rice fields based on UAV remote sensing, Front. Plant Sci., 13:1037760.

[35]Zhang, C., Marzougui, A., Sankaran, S., 2020, High-resolution satellite imagery applications in crop phenotyping: An overview, Comput. Electron. Agric., 175:105584.

[36]Zhu, Y., Cao, Z., Lu, H., Li, Y., Xiao, Y., 2016, In-field automatic observation of wheat heading stage using computer vision, Biosyst. Eng., 143:28-41.

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TURKISH OLIVE OIL: HOW CAN ITS GLOBAL COMPETITIVENESS BE INCREASED?

Bektaş KADAKOĞLU, Bahri KARLI

Isparta University of Applied Sciences, Faculty of Agriculture, Department of Agricultural Economics, Isparta-Türkiye, Phone: +902462146240, Fax: +902462146399, Emails: bektaskadakoglu@isparta.edu.tr; bahrikarli@isparta.edu.tr

Corresponding author: bektaskadakoglu@isparta.edu.tr

Abstract

This study aims to examine the development of olive oil production and trade, analyze the competitiveness, and develop recommendations to increase competition. Although world olive oil production has followed a fluctuating course in the last two decades, it has been determined to be in an increasing trend. Approximately 3.3 million tons of olive oil are produced in the world every year. Türkiye ranks fifth in world olive oil production with a share of 7.12%. Although Türkiye's olive oil production has been increasing over the years, there are approximately 200-250 thousand tons of products every year. In 2021, world olive oil exports amounted to 8.58 billion dollars and imports to 8.75 billion dollars. Türkiye ranks sixth in the world regarding the amount and value of olive oil exports. Türkiye's olive oil export market is concentrated in the United States of America (USA) and European Union (EU) countries. In 2021, Türkiye's olive oil exports were 27.98% to the USA and 20.63% to EU countries. In the study, the competitiveness analysis of olive oil was calculated for the years 2010-2021, and Balassa's Revealed Comparative Advantage Index (RCA), Vollrath's Relative Export Advantage Index (RXA), and Laursen's Revealed Symmetric Comparative Advantage Index (RSCA) were used in the analysis. The average index values obtained for Türkiye are calculated as 2.06 for RCA, 2.09 for RXA, and 0.278 for RSCA. It was determined that although Türkiye's competitiveness in olive oil exports is at a low level, it has the potential to compete with rival countries. In the study, some suggestions were developed for Türkiye to increase its competitiveness. The main recommendations are to improve the quality of olive oil production by differentiating it through tools such as geographical indication registration and to liberalize trade by removing practices that restrict foreign trade (such as quotas and taxes) through agreements between countries.

Key words: *olive oil, competitiveness analysis, revealed comparative advantage, relative export advantage, revealed symmetric comparative advantage, geographical indication*

INTRODUCTION

Olive oil is one of the nutrients that play an essential role in human nutrition and maintaining a healthy life. Therefore, olive oil production and consumption are increasing yearly [14].

In 2020, 3.37 million tons of olive oil were produced worldwide. Türkiye ranks fourth in world olive oil production after Spain, Tunisia and Italy, with 240 thousand tons of olive oil production [8]. Moreover, Türkiye earns an average foreign trade contribution of 125 million dollars (olive oil exports value – olive oil imports value) every year through olive oil foreign trade.

Both internal and external factors influence international competition. Gain a continuous and stable competitive advantage in global markets, depending on production control, good organization and foreign trade policies [18]. In addition, there is a need for studies in which competitiveness analyses are conducted to reveal the current situation of countries in international trade and to determine the policies to be implemented in foreign trade [12]. This study aims to examine the development of olive oil production and trade, an essential product in Türkiye's agricultural production and foreign trade, and to develop suggestions to increase competition by analyzing competitiveness.

MATERIALS AND METHODS

Data on the main material of the study were obtained from the Food and Agriculture Organization of the United Nations and the

International Trade Center. In addition, sector reports prepared by relevant institutions and organizations and academic studies published in national and international fields were used. The production data analyzed within the scope of the study covers the period 2000-2020, and foreign trade data covers the period 2001-2021. The Olive oil data index was calculated, and the production, exports and imports development process over the years was analyzed.

In the competitiveness analysis of olive oil foreign trade, the Revealed Comparative Advantage Index (RCA) developed by Balassa [2], the Relative Export Advantage Index (RXA) developed by Vollrath [20] and the Revealed Symmetric Comparative Advantage Index (RSCA) developed by Laursen [15] were used.

Balassa's Revealed Comparative Advantage Index is shown in equation 1.

$$RCA_j^i = \frac{x_j^i / \Sigma x^i}{\Sigma x_j^w / \Sigma x^w} \quad (1)$$

where:

RCA_j^i is the Revealed Comparative Advantage Index of country i in product j,

x_j^i: the export value of product j of country i,

Σx^i: the total export value of country i,

Σx_j^w: the total export value of world product j,

Σx^w: the total export value of the world.

Vollrath's Relative Export Advantage Index is shown in equation 2.

$$RXA_j^i = \frac{x_j^i / \Sigma x^i}{\Sigma x_j^w / \Sigma x^w} \quad (2)$$

where:

RXA_j^i: the Relative Export Advantage Index of country i in product j,

x_j^i: the export value of product j of country i,

Σx^i: the total export value of country I,

Σx_j^w: subtracting the export value of product j of country i from the total export value of product j of the world,

Σx^w: subtracting the export value of country i from the total world export value.

RCA and RXA values are close to each other. This is because, when calculating the RXA value, the double calculation is avoided by subtracting the export values of the relevant country and product from the total product and total country export values [12].

Laursen's Revealed Symmetric Comparative Advantage Index is shown in equation 3.

$$RSCA_j^i = \frac{(RCA - 1)}{(RCA + 1)} \quad (3)$$

where:

$RSCA_j^i$: the Revealed Symmetric Comparative Advantage Index of country i in product j,

RCA is the countries' Revealed Comparative Advantage Index for the relevant product.

Countries with an RCA value in the range of 0-1 have no comparative advantage and comparative disadvantage, countries with an RCA value in the range of 1-2 have a weak comparative advantage, countries with an RCA value in the range of 2-4 have a moderate comparative advantage and countries with an RCA value greater than 4 have a high degree of comparative advantage [10]. Countries with an RXA value greater than 1 have a competitive advantage for the relevant product, while countries with an RXA value less than 1 have a competitive disadvantage for the relevant product [9]. RSCA value takes a value between -1 and 1. Countries with a positive RSCA value have a competitive advantage for the related product, while countries with a negative RSCA value have a competitive disadvantage for the related product [15].

RESULTS AND DISCUSSIONS

Developments in olive oil production and trade

When the developments in olive oil production in the world between 2000 and 2020 are evaluated, olive oil production, which was 2 million 731 thousand tons on average between 2000 and 2004, increased by 23.55% to 3 million 374 thousand tons in the

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period under review. Spain ranks first in world production with a share of 40.20%. Spain was followed by Tunisia (11.06%), Italy (9.81%), Greece (9.13%) and Türkiye (7.12%). During the period under review, olive oil production increased 3.52 times in Algeria, 2.99 times in Portugal, 2.97 times in Tunisia, 2.93 times in Morocco and 1.89 times in Türkiye. It decreased by 45.77% in Italy, 13.89% in Greece and 9.22% in Syria (Table 1).

Table 1. Development of olive oil production in the world

Countries	2000-2004		2005-2009	2010-2014	2015-2019	2020		Index (2000-2004 = 100)
	Tons	Percent (%)	Tons	Tons	Tons	Tons	Percent (%)	
Spain	1,133,187	41.50	1,106,753	1,244,091	1,366,155	1,356,411	40.20	119.70
Tunisia	125,400	4.59	180,000	169,560	229,720	373,100	11.06	297.53
Italy	610,178	22.34	594,658	466,613	364,995	330,879	9.81	54.23
Greece	357,693	13.10	344,682	306,110	318,250	308,000	9.13	86.11
Türkiye	127,000	4.65	127,960	180,160	207,320	240,100	7.12	189.06
Morocco	56,000	2.05	77,320	131,120	156,640	164,600	4.88	293.93
Syrian Arab Republic	152,250	5.58	159,658	164,432	143,543	138,217	4.10	90.78
Algeria	32,218	1.18	34,981	51,420	82,480	113,600	3.37	352.60
Portugal	35,708	1.31	49,170	70,153	119,066	107,000	3.17	299.66
Others	101,113	3.70	116,304	186,683	255,919	241,975	7.17	239.31
World	2,730,746	100.00	2,791,485	2,970,342	3,244,088	3,373,882	100.00	123.55

Source: [8].

World olive oil exports increased from an average of 1 million 195 thousand tons between 2001 and 2005 to 2 million 187 thousand tons in 2021. During this period, olive oil exports increased by 82.93%. In the period under review (2001-2005), olive oil export value increased by 148.37% from 3 billion 454 million dollars to 8 billion 580 million dollars. Regarding olive oil export value, Spain ranked first with a share of 45.17%. It is followed by Italy (20.22%), Portugal (9.67%), Greece (7.83%), Tunisia (6.93%) and Türkiye (1.98%). Türkiye's olive oil exports decreased by 17.86% during the period analyzed. Türkiye's share of total olive oil exports decreased from 5.62% in 2001-2005 to 2.52% in 2021. The export value increased by 9.95% between the same periods (Table 2).

Table 2. Export quantities and values of leading olive oil exporting countries

Countries	2001-2005		2006-2010	2011-2015	2016-2020	2021		Index (2001-2005 = 100)
	Export Quantity (Tons)							
	Tons	Percent (%)	Tons	Tons	Tons	Tons	Percent (%)	
Spain	559,867	46.84	610,131	822,597	993,212	1,061,871	48.56	189.66
Italy	297,013	24.85	305,756	364,073	324,389	343,979	15.73	115.81
Portugal	20,588	1.72	38,968	105,913	158,650	216,209	9.89	1,050.17
Tunisia	95,536	7.99	152,173	154,745	190,645	180,517	8.26	188.95
Greece	87,873	7.35	97,481	128,124	143,336	157,556	7.21	179.30
Türkiye	67,191	5.62	29,991	32,875	48,284	55,194	2.52	82.14
Syrian Arab Republic	20,211	1.69	42,712	16,540	45,547	46,408	2.12	229.62
Argentina	7,627	0.64	15,936	20,812	23,534	26,323	1.20	345.13
USA	2,728	0.23	6,440	10,212	11,600	12,948	0.59	474.63
Others	36,667	3.07	56,829	155,939	88,509	85,526	3.91	233.25
World	1,195,302	100.00	1,356,419	1,811,831	2,027,705	2,186,531	100.00	182.93
Countries	Export Value							Index (2001-2005 = 100)
	Thousand dollars	Percent (%)	Thousand dollars	Thousand dollars	Thousand dollars	Thousand dollars	Percent (%)	
Spain	1,478,373	42.80	2,398,519	2,849,813	3,550,671	3,875,172	45.17	262.12
Italy	1,005,144	29.10	1,500,502	1,646,703	1,625,135	1,734,505	20.22	172.56
Portugal	67,014	1.94	178,899	413,565	607,912	829,836	9.67	1,238.30
Greece	253,642	7.34	395,999	501,128	567,235	671,964	7.83	264.93
Tunisia	240,739	6.97	499,255	480,033	574,506	594,865	6.93	247.10
Türkiye	154,766	4.48	109,081	114,061	156,430	170,158	1.98	109.95
Syrian Arab Republic	104,477	3.02	145,624	44,328	113,365	125,881	1.47	120.49
Argentina	24,799	0.72	58,768	71,259	82,752	97,459	1.14	393.00
France	17,826	0.52	36,661	46,306	60,424	70,049	0.82	392.96
Others	107,681	3.12	224,995	329,420	401,962	409,889	4.78	380.65
World	3,454,461	100.00	5,548,303	6,496,616	7,740,392	8,579,778	100.00	248.37

Source: [11].

World olive oil imports increased from an average of 1 million 312 thousand tons between 2001 and 2005 to 2 million 47 thousand tons in 2021. In the same period, olive oil imports increased by 56.07%. The value of olive oil imports increased by 144.09% from 3 billion 584 million dollars to 8 billion 748 million dollars. Italy ranked first in olive oil import value with a 21.53% share. It is followed by the USA (17.08%), France (6.52%), Spain (6.40%), Brazil (5.03%) and Portugal (4.97%). In the analyzed period, olive oil import value increased 5.88 times in Brazil, 4.92 times in Spain, 3.11 times in Portugal, 2.68 times in Germany and 2.47 times in the USA (Table 3).

Table 3. Import quantities and values of leading olive oil importing countries

Countries	2001-2005		2006-2010	2011-2015	2016-2020	2021		Index (2001-2005 = 100)
	Export Quantity							
	Tons	Percent (%)	Tons	Tons	Tons	Tons	Percent (%)	
Italy	510,517	38.92	497,469	557,624	546,265	539,769	26.37	105.73
USA	202,917	15.47	250,329	291,990	338,934	365,916	17.87	180.33
France	96,710	7.37	108,839	115,023	124,930	137,909	6.74	142.60
Portugal	55,007	4.19	73,574	102,270	114,085	134,202	6.56	243.97
Brazil	23,613	1.80	40,567	67,544	79,348	97,210	4.75	411.68
Germany	43,632	3.33	56,692	67,556	70,872	81,733	3.99	187.32
United Kingdom	57,619	4.39	62,413	68,609	72,887	61,990	3.03	107.59
Japan	31,317	2.39	32,112	49,191	61,377	59,141	2.89	188.84
Canada	26,524	2.02	33,340	38,663	47,785	51,222	2.50	193.12
Others	263,866	20.12	374,384	516,607	595,190	518,157	25.31	196.37
World	1,311,724	100.00	1,529,718	1,763,552	2,051,672	2,047,249	100.00	156.07
Countries	Import Value							Index (2001-2005 = 100)
	Thousand dollars	Percent (%)	Thousand dollars	Thousand dollars	Thousand dollars	Thousand dollars	Percent (%)	
Italy	1,267,592	35.37	1,686,205	1,718,311	1,811,044	1,883,407	21.53	148.58
USA	605,022	16.88	971,454	1,084,760	1,398,968	1,494,276	17.08	246.98
France	266,278	7.43	435,685	436,942	526,392	570,324	6.52	214.18
Spain	113,699	3.17	198,080	288,000	444,388	559,621	6.40	492.20
Brazil	74,858	2.09	200,384	328,698	374,408	440,293	5.03	588.17
Portugal	139,803	3.90	246,702	303,910	359,727	434,923	4.97	311.10
Germany	147,793	4.12	278,889	297,121	343,319	395,839	4.52	267.83
Japan	120,680	3.37	176,412	248,681	301,625	277,759	3.17	230.16
United Kingdom	139,856	3.90	254,997	240,208	266,244	234,184	2.68	167.45
Others	708,531	19.77	1,395,115	1,765,949	2,145,287	2,457,865	28.09	346.90
World	3,584,112	100.00	5,843,923	6,712,579	7,971,402	8,748,491	100.00	244.09

Source: [11].

Türkiye's olive oil exports were 170 million 158 thousand dollars in 2021 and these exports were realized at 27.98% to the USA, 15.52% to Spain and 7.53% to Japan. These countries account for about half of Türkiye's total olive oil exports (51.03%) (Table 4).

Table 4. The main countries to which Türkiye exports olive oil

Countries	2001-2005		2006-2010	2011-2015	2016-2020	2021		Index (2001-2005 = 100)
	Thousand dollars	Percent (%)	Thousand dollars	Thousand dollars	Thousand dollars	Thousand dollars	Percent (%)	
USA	26,879	17.37	24,027	25,971	48,711	47,607	27.98	177.12
Spain	26,186	16.92	3,974	13,290	28,913	26,401	15.52	100.82
Japan	1,551	1.00	7,934	9,731	7,430	12,805	7.53	825.81
Israel	693	0.45	635	167	2,675	9,652	5.67	1,393.59
Saudi Arabia	4,384	2.83	6,367	12,797	16,642	9,240	5.43	210.79
United Arab Emirates	1,755	1.13	3,153	2,857	2,996	7,205	4.23	410.45
Iran	293	0.19	909	5,208	4,538	6,623	3.89	2,258.87
Germany	645	0.42	1,651	2,227	2,506	4,303	2.53	666.72
Jordan	77	0.05	130	19	221	3,161	1.86	2,435.29
Others	92,304	59.64	60,301	41,794	41,797	43,156	25.36	46.75
World	154,766	100.00	109,081	114,061	156,430	170,158	100.00	109.95

Source: [11].

Türkiye's olive oil imports were 67 million 556 thousand dollars in 2021 and almost all of these imports were from Syria. Syria's share in olive oil imports is 95.90% (Table 5). Türkiye's olive oil imports have increased in the last three years (2019-2021). Although imports have risen recently, Türkiye's olive oil export price per kg was higher than its import price. In other words, Türkiye exports olive oil at high prices and imports it at low prices.

Table 5. The main countries to which Türkiye import olive oil

Countries	2001-2005		2006-2010	2011-2015	2016-2020	2021		Index (2011-2015 = 100)
	Thousand dollars	Percent (%)	Thousand dollars	Thousand dollars	Thousand dollars	Thousand dollars	Percent (%)	
Syrian Arab Republic	84	7.28	-	196	26,426	64,789	95.90	245.17
Spain	917	79.81	-	304	337	1,484	2.20	440.88
Tunisia	-	0.00	-	1,692	1,009	317	0.47	31.41
Italy	2	0.16	-	84	125	224	0.33	178.63
Cyprus	79	6.84	4	54	-	203	0.30	375.93
France	-	0.00	-	30	39	133	0.20	337.56
Germany	-	0.00	-	1	88	105	0.16	119.05
Greece	-	0.00	-	3	92	98	0.15	106.99
United Kingdom	-	0.00	-	1	4	75	0.11	2,083.33
Others	68	5.92	33	469	557	127	0.19	22.78
World	1,149	100.00	37	2,835	28,678	67,556	100.00	235.57

Source: [11].

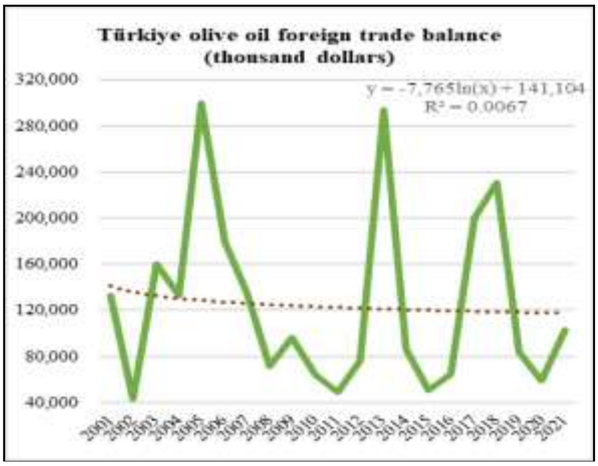

Fig. 1. Türkiye olive oil foreign trade balance (thousand dollars)
Source: Own calculation from [11] data.

Türkiye's foreign trade balance in olive oil has fluctuated over the years. Türkiye had a foreign trade surplus of 132 million 620 thousand dollars in 2001. In 2021, it decreased by 22.63% and a foreign trade surplus of 102 million 602 thousand dollars was realized. In the analyzed period, the foreign trade surplus ranged between 42 million and 300 million dollars, averaging 119 million dollars (Fig 1).

Competitiveness analysis in olive oil

According to the RCA index, Tunisia, Greece, Spain, Portugal and Italy have had a high comparative advantage. The average RCA values of these countries were calculated as 84.01, 39.07, 26.28, 20.46 and 8.28, respectively. It was determined that Argentina and Türkiye have a moderate comparative advantage, while France does not have any comparative advantage (Table 6).

Table 6. Revealed comparative advantage index (RCA)

RCA	Tunisia	Greece	Spain	Portugal	Italy	Argentina	Türkiye	France
2010	53.96	34.03	28.73	12.47	9.41	1.81	1.62	0.20
2011	50.82	36.38	27.37	15.95	9.90	2.72	1.16	0.22
2012	72.46	39.03	27.43	19.11	10.13	2.08	1.65	0.23
2013	82.84	50.71	23.53	20.19	9.30	2.88	5.11	0.22
2014	45.43	25.78	30.62	20.69	8.70	1.71	1.43	0.24
2015	150.61	55.49	23.68	19.55	7.84	4.43	0.93	0.26
2016	63.89	50.10	26.75	17.73	7.92	2.22	1.05	0.24
2017	61.08	36.07	28.38	19.49	7.02	5.60	2.72	0.25
2018	116.05	40.18	23.82	23.42	6.95	2.78	3.28	0.25
2019	82.72	27.57	25.88	24.29	7.30	2.68	2.11	0.31
2020	135.00	36.84	23.66	24.20	7.45	2.51	1.75	0.30
2021	93.30	36.69	25.51	28.42	7.43	3.23	1.95	0.32
Average	84.01	39.07	26.28	20.46	8.28	2.89	2.06	0.25

Source: Own calculation.

According to the RXA index, Tunisia, Spain, Greece, Portugal and Italy were found to have a comparative advantage. The average RXA values of these countries were calculated as 91.43, 47.50, 42.27, 22.01 and 10.58, respectively. France was found to be at a

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competitive disadvantage in olive oil exports (Table 7).

Table 7. Relative export advantage index (RXA)

RXA	Tunisia	Spain	Greece	Portugal	Italy	Argentina	Türkiye	France
2010	57.26	53.42	36.22	12.96	12.66	1.82	1.62	0.20
2011	53.44	49.08	38.92	16.78	13.46	2.74	1.16	0.21
2012	77.59	47.63	42.10	20.27	13.62	2.09	1.66	0.22
2013	89.47	37.98	56.08	21.58	12.16	2.90	5.30	0.21
2014	47.30	62.57	27.06	22.17	11.18	1.71	1.44	0.23
2015	172.79	38.76	61.25	20.85	9.75	4.48	0.93	0.25
2016	67.51	50.21	54.80	18.83	9.99	2.23	1.05	0.23
2017	64.20	56.16	38.54	20.86	8.55	5.69	2.77	0.24
2018	127.87	40.78	43.68	25.63	8.42	2.79	3.34	0.24
2019	88.51	47.55	29.14	26.51	8.97	2.70	2.13	0.30
2020	151.02	40.21	39.69	26.36	9.19	2.52	1.76	0.29
2021	100.17	45.69	39.72	31.36	9.06	3.25	1.97	0.31
Average	91.43	47.50	42.27	22.01	10.58	2.91	2.09	0.25

Source: Own calculation.

According to the RSCA index, Tunisia, Greece, Portugal, Spain, Italy, Argentina and Türkiye were determined to have a competitive advantage in olive oil exports. France, on the other hand, was found to have a competitive disadvantage (Table 8).

Table 8. Revealed symmetric comparative advantage index (RSCA)

RSCA	Tunisia	Greece	Portugal	Spain	Italy	Argentina	Türkiye	France
2010	0.964	0.943	0.852	0.933	0.808	0.289	0.236	-0.664
2011	0.961	0.946	0.882	0.930	0.817	0.463	0.075	-0.641
2012	0.973	0.950	0.901	0.930	0.820	0.351	0.245	-0.627
2013	0.976	0.961	0.906	0.918	0.806	0.484	0.673	-0.642
2014	0.957	0.925	0.908	0.937	0.794	0.262	0.178	-0.613
2015	0.987	0.965	0.903	0.919	0.774	0.631	-0.035	-0.590
2016	0.969	0.961	0.893	0.928	0.776	0.379	0.025	-0.615
2017	0.968	0.946	0.902	0.932	0.751	0.697	0.463	-0.605
2018	0.983	0.951	0.918	0.919	0.749	0.470	0.532	-0.605
2019	0.976	0.930	0.921	0.926	0.759	0.457	0.356	-0.529
2020	0.985	0.947	0.921	0.919	0.763	0.430	0.273	-0.541
2021	0.979	0.947	0.932	0.925	0.763	0.527	0.321	-0.519
Average	0.973	0.948	0.903	0.926	0.782	0.453	0.278	-0.599

Source: Own calculation.

In a study [5], Türkiye was superior to Morocco according to the RCA and RXA indices and Portugal according to the RXA index. Except for these countries, Türkiye's international competitiveness was significantly lower than other countries.

Another study [3] found that Türkiye does not have an international competitive advantage over the leading countries in olive oil production and exports.

A study determined that countries such as Tunisia, the USA, Canada, Australia, Japan and Brazil have a higher competitive advantage than EU countries and Türkiye [18].

The EU imposes taxes and quotas on olive oil imports from some countries outside the community to protect its olive oil-producing member countries. Türkiye is one of these countries and is subjected to quotas and has to pay taxes on olive oil exports to the EU market. Therefore, Türkiye's olive oil competitiveness is lower than other countries.

Geographical indication in olive oil

Geographical indications highlight local products and increase their brand value. In addition, it creates new employment areas for producers and increases their incomes. People living and producing in rural regions have introduced the concept of geographical indication to benefit from these opportunities [13]. Countries differentiate and determine quality through branding to increase their competitiveness. One way to achieve this differentiation and quality is to trade products with geographical indications.

In addition, a geographical indication is an important tool for creating a market by providing product differentiation and competitive advantage [16] [6]. While defining geographical indications, the place of production, processing methods, microbiological, chemical and physical characteristics that contribute to the product's sensory and distinctive features are considered [4]. These definitions are as follows. Protected Designation of Origin-PDO: The products covered by this geographical indication have a particular production scheme and must be produced under appropriate environmental conditions without changing this production flow. It is possible to make it all over the world with the proper production scheme [1]. Protected Geographical Indication-PGI: In the products that receive this geographical indication, there is a geographical situation that affects the microbiological, chemical, physical, aromatic and sensory properties of the products. These products can only be produced in that region [1]. In addition, these two geographical indications are also included in the quality guarantee certificates in the EU and increase competition in marketing [17].

In 12 different provinces of Türkiye, 11 different olive oils have been registered with the PGI, 6 olive oils have been registered with the PDO and a total of 17 different olive oils have received geographical indications from the Turkish Patent and Trademark Office (Table 9).

Table 9. Olive oils with geographical indication registered in Türkiye

Product name	Provinces	Registration date	Geographical label
Ayvalık olive oil	Balıkesir	2007	PDO
Nizip olive oil	Gaziantep	2012	PGI
Milas olive oil	Muğla	2016	PDO
Edremit olive oil	Balıkesir	2017	PDO
Mut olive oil	Mersin	2018	PDO
Aydın Memecik olive oil	Aydın	2020	PDO
Burhaniye olive oil	Balıkesir	2020	PDO
Ödemiş Çekişte olive oil	İzmir	2020	PDO
Geyikli olive oil	Çanakkale	2021	PDO
Tarsus Sarıulak olive oil	Mersin	2021	PDO
Akhisar Domat olive oil	Manisa	2022	PGI
Akhisar Uslu olive oil	Manisa	2022	PGI
Bayramiç olive oil	Balıkesir	2022	PDO
Ceyhan olive oil	Adana	2022	PGI
Derik Halkalı olive oil	Mardin	2022	PDO
Kilis olive oil	Kilis	2022	PGI
Osmaniye olive oil	Osmaniye	2023	PGI

PDO: Protected Designation of Origin
PGI: Protected Geographical Indication
Source [19].

In addition, Milas Olive Oil has been registered by the European Union. Registration applications were made for Kilis Olive Oil, Aydın Memecik Olive Oil and Edremit Olive Oil [7].

In the European Union, there are 138 extra virgin olive oils registered with the PDO and PGI from Italy (50), Spain (33), Greece (31), France (7), Croatia (7) and Portugal (6) (Table 10). It was determined that Türkiye lags behind Italy, Spain and Greece regarding the number of olive oils that have received geographic indication. This situation reduces the competitiveness of Türkiye in olive oil exports.

Table 10. Olive oils with geographical indication registered in European Community

Countries	PDO	PGI	Total
Italy	42	8	50
Spain	31	2	33
Greece	19	12	31
France	9	-	9
Croatia	6	-	6
Portugal	6	-	6
Slovenia	1	1	2
Hungary	-	1	1
EU Total	114	24	138

Source [7].

CONCLUSIONS

To increase Türkiye's competitiveness and exports in olive oil production, recommendations can be developed under the following headings;

Marketing Strategy: Turkish olive oil producers need to better promote their products in both domestic and international markets. Specifically, Turkish olive oil brands should develop a marketing strategy emphasizing the advantages they offer regarding quality and health.

Quality Control: Türkiye can potentially compete with other countries in producing high-quality olive oil. However, quality control should be tightened during production, and the technology used in production should be modernized.

R&D and Innovation: Turkish olive oil producers should invest more in R&D and innovation. Especially by optimizing the production process with new technologies, they can reduce costs and increase competitiveness. Geographical Indications: Olive oils produced in certain regions in Türkiye are protected by geographical indications. More effective use of these geographical indications can help Turkish olive oil producers build consumer trust in the quality and characteristics of their products.

Participation in International Fairs and Events: Turkish olive oil producers can participate more actively in international fairs and events. These events can provide opportunities for product promotion and export. Support for Exporters: Necessary financial and logistical support should be provided for Turkish olive oil producers to export their products. Such support can increase their export capacity and facilitate the delivery of products to foreign markets.

Bilateral Cooperation: It is recommended to eliminate restrictions on international trade, such as taxes and quotas, through agreements between countries, thus making trade more liberal. This will allow Türkiye to compete with other countries in olive oil exports and increase its revenue.

REFERENCES

[1]Anonymous, 2006, On the protection of geographical indications and designations of origin for agricultural products and foodstuffs. Council Regulation (EEC) No 510/2006.

[2]Balassa, B., 1965, Trade liberalization and “revealed” comparative advantage. The Manchester School of Economic and Social Studies, 33(2), 92-123. https://doi.org/10.1111/j.1467-9957.1965.tb00050.x.

[3]Çukur, F., Demirbaş, N., Gölge, E., 2017, International competitiveness of the Turkish olive oil sector. Selcuk Journal of Agriculture and Food Sciences, 31(3), 162-168. https://doi.org/10.15316/SJAFS.2017.50.

[4]Dikici, A., Koluman, A., Aktaş, R., 2013, Geographical labeling of foods (in Turkish). Journal of The Faculty of Veterinary Medicine Istanbul University, 39(1), 136-138.

[5]Durmuş, E., Dokuzlu, S., 2019, Competitiveness analysis of olive oil sector. Turkish Journal of Agriculture-Food Science and Technology, 7(9), 1354-1359. https://doi.org/10.24925/turjaf.v7i9.1354-1359.2604.

[6]Durmuş, E., Yüceer, S. E., Tan, S., 2022, Investigation of socio-economic effects of geographical indication registration: Bozcaada Çavuş Grape sample (in Turkish). Turkish Journal of Agricultural Economics, 28(1), 21-29.

[7]EU - Door, 2023, European Commision, Agriculture and Rural Development, Geographical Indications Database, http://ec.europa.eu/agriculture/quality/door/list.html?locale=en, Accessed on 05 April 2023.

[8]FAOSTAT, 2023, Food and Agriculture Organization of the United Nations. https://www.fao.org/faostat/en/#data/QCL, Accessed on 24 February 2023.

[9]Frohberg, K., Hartmann, M., 1997, Comparing Measures of Competitiveness. Institute of Agricultural Development in Central and Eastern Europe. Halle, Germany. Discussion Paper No: 2.

[10]Hinloopen, J., Van Marrewijk, C., 2001, On the Empirical Distribution of the Balassa Index. Weltwirtschaftliches Archiv 137(1), 1-35. doi.org/10.1007/BF02707598.

[11]ITC, 2023, Trade Map. https://www.trademap.org/, Accessed on 22 February 2023.

[12]Kadakoğlu, B., Karlı, B., Bayav, A., 2022, Development of fig production and global competitiveness analysis (in Turkish). Fruit Science, 9(2), 39-47. https://doi.org/10.51532/meyve.1184717.

[13]Kan, M., Gülçubuk, B., 2008, Geographical indications for recovery and local owned of rural economy (in Turkish). VIII. National Agricultural Economics Congress, June 25-27, Bursa, Türkiye, 301-312p.

[14]Karlı, B., Gül, M., Karadağ Gürsoy, A., 2018, Olive and olive oil export potential of Turkey (in Turkish), XIII. National Agricultural Economics Congress, September 12-14, Kahramanmaraş, Türkiye, Abstracts Book, 5p.

[15]Laursen, K., 2015, Revealed Comparative Advantage and the alternatives as measures of international specialization. Eurasian Business Review 5(1), 99-115. doi.org/10.1007/s40821-015-0017-1.

[16]Marie-Vivien, D., 2008, From plant variety definition to geographical indication protection: A search for the link between Basmati rice and India/Pakistan. The Journal of World Intellectual Property, 11(4), 321-344. https://doi.org/10.1111/j.1747-1796.2008.00341.x.

[17]Tunalıoğlu, R., 2010, Implementation of the olive oil food safety and quality assurance in the marketing system in Turkey and evaluation of developments (in Turkish). Tarım Ekonomisi Dergisi, 16(2), 59-66.

[18]Türkekul, B., Miran, B., Abay, C., Günden, C., 2010, Competitiveness of Mediterranean countries in the olive oil market. New Medit, 9(1), 41-46.

[19]Turkish Patent, 2023, Turkish Patent and Trademark Office, Republic of Türkiye Ministry of Industry and Technology. https://ci.turkpatent.gov.tr/cografi-isaretler/liste?il=&tur=&urunGrubu=&adi=zeytinya%C4%9F%C4%B1. Accessed on28 February 2023.

[20]Vollrath, T.L., 1991, A theoretical evaluation of alternative trade intensity measures of Revealed Comparative Advantage. Weltwirtschaftliches Archiv 127(2), 265-280. doi.org/10.1007/BF02707986.

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AMINO ACID COMPOSITION OF PEARL MILLET GRAIN AND HERBAGE

Sergey Ivanovich KAPUSTIN[1], Alexander Borisovich VOLODIN[1], Andrey Sergeevich KAPUSTIN[2], Nikolai Viktorovich SAMOKISH[3]

[1]North Caucasus Federal Agrarian Research Center, Nikonov str. 49, Mikhailovsk, Stavropol region, 356241, Russia, Phone: +79624512303; E-mail: sniish@mail.ru
[2]North Caucasus Federal University, Pushkin str. 1, Stavropol, 355017, Russia, Phone: +78652330291; E-mail: hpplus@bk.ru
[3]Stavropol State Agrarian University, Zootekhnicheskiy Lane 12, Stavropol 355017, Russia, Phone: +78652352282; E-mail: inf@stgau.ru

Corresponding author: hpplus@bk.ru

Abstract

Object of the research is 5 new lines of pearl millet. They were bred in the Federal State Budgetary Scientific Institution "North Caucasus FARC". The purpose of the research was to specify the presence of nutrients (protein, fat, fiber, NFE), the level of essential and other amino acids in these new lines. Their content in the feed determines its biological value. The highest content of crude protein (12.92%) in the dry matter, which was obtained during the studies in 2021-2022, was found in line No. 1. This parameter ranged from 10.51 to 11.52% in other varieties. As for the grain, lines No. 5 (16.47%), No. 3 (16.45%) and No. 1 (16.29%) had the highest content of crude protein. The standards of Siberian millet and proso millet had significantly lower content of protein. It was 13.45 and 11.32%, respectively. The grain of the new lines showed the highest levels of crude fat in lines No. 4 (7.34%) and No. 5 (7.09%). The amount of crude gluten in the grain and dry matter of pearl millet was relatively low. On average, the dry matter of pearl millet had lower levels of essential amino acids (0.36%) compared to non-essential ones (0.72%). The new lines No. 1 and No. 5 had the highest content of essential amino acids in the grain. The content of non-essential amino acids in the grain was significantly higher than in the dry matter, averaging 1.2% and 0.72% respectively. The new lines No. 4, No. 3, and No. 1 had the maximum content of these amino acids. In terms of amino acid content, pearl millet grain exceeded the standards of proso millet and Siberian millet grain.

Key words**:** *millet, amino acid content, protein, dry matter*

INTRODUCTION

Pearl millet (*Pennisetum thyphoideum* Richt) is a valuable crop that is grown for green fodder, hay, silage, grain and pastureland. It has a fibrous root system that penetrates deep into the soil. The stems are light green, erect. Nodes are thickened. The length is about 3 meters or more. The plant bushes well. The number of sprouts in the bush ranges from 3 to 10. The leaves are large, hard, and scabrous along the edges. The inflorescence is a dense spiked panicle from 10 to 30 cm long [6]. The digestibility of nutrients in grain is high: simple protein – 75, protein – 74, fat – 79, NFE – 79, fiber – 33, in herbage, respectively – 70, 60, 60, 70, 66, and in hay – 60, 55, 45, 71, 53 [9]. Pearl millet produces green fodder that is coarser than Sudan grass, but softer than sorghum [6, 8]. In order to produce hay and green fodder, they cut it down at a height of 12-15 cm 1-2 weeks before the inflorescence development. This ensures better growth of the aftermath and obtaining the second cut for green fodder [1].

African millet grain is used for fattening animals and poultry, as well as for human nutrition. It produces flour, cereals, cooking dietary dishes, cereals, cookies and bread. The vegetative mass is fed to animals in the form of hay, silage, green mass. The culture does not contain hydrocyanic acid.

African millet is grown by individual farms in the North Caucasus, the Lower Volga region and the arid regions of the Trans-Urals (Orenburg, Kurgan, Omsk and other regions). The annual sowing area is 25-27 thousand hectares. The yield of green mass is 35-50 t/ha, the grain yield is 2-2.5 t/ha. Accounting for African millet in Rosstat is not conducted, the data are given for the Stavropol Territory.

The use and cultivation technology of pearl millet have been widely studied. In order to develop new early-ripening and late-ripening varieties with herbage yield from 30 to 60 t/ha, selective breeding is being carried out at the Federal State Budgetary Scientific Institution “North Caucasus Federal Agricultural Research Center”. The quality characteristics of grain and herbage of these new samples are being specified now, which is the aim of our research.

The quality of feed is largely determined by the genetic traits of varieties [5, 10]. By applying genetic variation in studies, Tarik, A.S., Akram, Z., et al. have improved grain quality [11]. Content heterosis of sugar, crude protein and crude fat was established. Proteins show significant differences between the obtained hybrids and their parental forms. Nitrogen-free substances of the organic part of the feed include fat, fiber, NFE. Crude fat is a substance that dissolves only in organic solvents. It is a source of energy nutrition. Crude fiber determines the digestibility of the feed.

Grain fermentation increases the total amino acid content. The presence of essential amino acids increases to their total content. A number of literary sources [12] point to the role of histidine, serine, glutamic acid, and arginine, which form hydrogen bonds and stabilize binding of the sugar donor. The accumulation of free amino acids is less in seeds and seedlings with high content of tannin [3].

In feeding, protein cannot be replaced by any other nutrient. Approximately 20 unique amino acids participate in the synthesis of animal protein. Certain amino acids must be provided through feed. The biological quality of the feed is dictated by the concentration of these indispensable amino acids. Valine, leucine, isoleucine, threonine, histidine, lysine, phenylalanine, methionine are essential amino acids. Leucine regulates blood sugar level; phenylalanine is the starting material for insulin [7, 13]. Valine contributes to the regulation and reduction of neurological diseases. Histidine prevents atherosclerosis, hypertension, and heart attacks. Isoleucine is necessary for wound healing and hemoglobin synthesis. Together with threonine, they enhance immunity.

Non-essential amino acids that can be synthesized by the body include aspartic and glutamic acids, arginine, tyrosine, alanine, proline, glycine, serine. They also play an important role. Aspartic acid is important for the proper functioning of the endocrine and nervous systems. It promotes the production of testosterone. Along with alanine, this acid activates the antibody production, which strengthens the immune system. Glutamic acid is found in the brain and spinal cord, the fluid part of the muscles. It promotes the production of new cells and prevents early aging. Arginine activates the production of hormones, insulin.

Various sources of germ plasm with high nutrient density are used in crossbreeding programs for including this trait in the breeding process in order to improve nutritional quality [2]. As a result of a derangement of redox processes in the cytoplasm of pollen grains, their starches and fats are depleted. The composition and amount of amino acids change. The content of alanine in sterile anthers is higher than in fertile ones. There is also a difference in the content of proline and asparagine. Proline is actually found only in fertile anthers. Pollen grains in sterile forms are depleted in other amino acids and fats.

The aim of the research is to specify the presence of nutrients (protein, fat, fiber, NFE) in the dry matter and the content level of essential and other amino acids in 5 new varieties of pearl millet.

MATERIALS AND METHODS

The studies were carried out by the methods of field and laboratory experiments on the experimental field of the FSBSI “North Caucasus Federal Agricultural Research Center”, the soil cover of which was a typical black soil with 120 cm of humus horizon.

The sowing was carried out in 2021-2022. It was wide-rowed with row spacing of 70 cm. The area of the registration plot was 25 m2. The density of plants was 160 thousand per hectare. The parameters of feed analysis and amino acid composition of the dry mass were established in the certified laboratory "Feed and Metabolism" at the Stavropol State Agrarian University. Out of the 22 known amino acids, the content of 16 acids was specified. The protein content was determined by the Kjeldahl method (GOST 13496-4-93), fiber – by the Henneberg and Shtokman`s method (GOST 31675-2012), fat – by extractive method (GOST 13496-15-97), dry matter – by weight method (GOST 31640-2012).

The object of the study was 5 new lines of pearl millet, which were bred by the North Caucasus Federal Agricultural Research Center. Observations, records, and measurements were performed in accordance with the Methodology for State Testing of Agricultural Crops [4] and the Volgin`s Method [13].

RESULTS AND DISCUSSIONS

New lines of pearl millet do not get destroyed or have a reduced susceptibility to bacterial disease, smut and aphids. An important characteristic of the studied crop is the stable yield of herbage, the level of which varied from 30 to 60 t/ha. This was due to the long growing season, tall plants and the presence of other positive features.

According to the data in table 1, the quality of the obtained herbage and grain was assessed in the air-dry matter. Samples were taken during the mowing of pearl millet in milk-wax stage of herbage (1-4 varieties) and full ripeness (5-11 varieties). Crude protein is the total amount of nitrogen-containing substances in the feed. It contains proteins and amides. Proteins consist of amino acids, which are linked together by peptide bonds. In feeding, protein cannot be replaced by any other nutrient. Only a plant can form protein from non-protein compounds.

Table 1. Main parameters of pearl millet feed analysis (average for 2021-2022)

Experimental varieties		Crude protein, %	Crude fat, %	Crude fiber, %	Crude ash, %	NFE, %
Herbage	Line No. 1	12.92	2.83	26.48	7.79	52.98
	Line No. 2	10.51	2.48	30.03	9.08	47.89
	Line No. 3	11.41	1.01	30.54	9.66	47.37
	Line No. 4	11.52	0.74	30.17	10.07	47.50
Grain	Line No. 1	16.29	6.24	1.92	1.94	73.61
	Line No. 2	16.03	6.48	1.46	1.70	74.32
	Line No. 3	16.45	6.54	1.90	1.71	73.39
	Line No. 4	15.50	7.34	2.02	1.91	73.23
	Line No. 5	16.47	7.09	1.38	1.40	73.65
	Proso millet variety	11.32	4.31	9.82	3.67	70.87
	Siberian millet variety	13.45	3.89	10.29	3.40	69.07

Source: developed by the authors based on [4, 13].

The highest content of crude protein (12.92%) in the dry matter, which was obtained during the research, was found in line No. 1. As for other varieties, this parameter ranged from 10.51 to 11.52%. The highest content of crude protein in the grain was obtained in lines No. 5 (16.47%), No. 3 (16.45%) and No. 1 (16.29%). The content of protein in the standards of Siberian millet and proso millet was significantly lower (13.45 and 11.32%), respectively.

Nitrogen-free substances of the organic part of feed include fat, fiber, and NFE. The studied variants of dry matter had the best parameters of fat in lines No. 1 (2.83%) and No. 2 (2.48%). These varieties, in comparison with other numbers, had lower content of crude fiber (26.48-30.03%), crude ash (7.79-9.08%) and higher content of NFE (47.89-52.98%).

The maximum crude fat parameters in the grain of the new lines of pearl millet were established in No. 4 (7.34%) and No. 5 (7.09%). The standards of proso millet and Siberian millet had values of 4.31 and 3.89%. The presence of crude fiber in the grain of the studied lines (1.38-2.02%) and crude ash (1.40-194%) was significantly less than in the standards of proso millet and Siberian millet, in which their content was 9.82-10.29% and 3.40-3.67%, respectively. Crude fiber determines the digestibility of the feed. As far as our experience is concerned, the total content of crude fiber in the grain and dry matter of pearl millet was low.

The composition of essential and non-essential amino acids present in the dry matter of pearl millet (harvested during the milk-wax stage) and in the grain of this crop is displayed in Table 2.

Table 2. Amino acid composition of pearl millet grain and dry matter for the years 2021-2022

Varieties		Indispensable amino acids, %								Dispensable amino acids, %							
		Valine	**Leucine**	**Isoleucine**	**Threonine**	**Histidine**	**Lysine**	**Phenylalanine**	**Methionine**	**Aspartic acid**	**Arginine**	**Glutamic acid**	**Tyrosine**	**Alanine**	**Proline**	**Glycine**	**Serine**
Herbage	Line No. 1	0.59	1.04	0.47	0.46	0.22	0.53	0.48	0.16	1.46	0.64	1.84	0.29	0.86	0.87	0.56	0.63
	Line No. 2	0.38	0.63	0.29	0.31	0.15	0.28	0.32	0.09	0.93	0.37	1.24	0.18	0.61	0.54	0.46	0.42
	Line No. 3	0.43	0.56	0.29	0.33	0.12	0.40	0.32	0.10	1.74	0.46	0.90	0.17	0.54	1.23	0.42	0.48
	Line No. 4	0.35	0.54	0.29	0.27	0.15	0.39	0.30	0.09	1.51	0.44	0.79	0.15	0.55	0.95	0.39	0.42
	Average	**0.44**	**0.70**	**0.34**	**0.34**	**0.16**	**0.40**	**0.36**	**0.11**	**1.41**	**0.48**	**1.19**	**0.20**	**0.64**	**0.90**	**0.46**	**0.49**
	LSD_{05}, %	**0.020**	**0.031**	**0.015**	**0.016**	**0.007**	**0.018**	**0.017**	**0.006**	**0.067**	**0.022**	**0.057**	**0.009**	**0.029**	**0.044**	**0.021**	**0.023**
Grain	Line No. 1	0.77	1.67	0.62	0.49	0.55	0.47	0.78	0.26	1.29	0.74	3.40	0.38	1.30	1.04	0.53	0.76
	Line No. 2	0.68	1.70	0.59	0.49	0.33	0.42	0.71	0.38	1.28	0.70	3.65	0.42	1.33	1.09	0.48	0.81
	Line No. 3	0.75	1.75	0.58	0.56	0.37	0.43	0.71	0.29	1.40	0.74	3.79	0.42	1.37	1.15	0.51	0.87
	Line No. 4	0.57	1.53	0.50	0.48	0.34	0.42	0.60	0.28	1.21	0.71	3.20	0.38	1.24	0.92	0.48	0.75
	Line No. 5	0.73	1.83	0.62	0.57	0.37	0.42	0.77	0.33	1.40	0.70	3.86	0.44	1.41	1.15	0.50	0.86
	Average	0.70	1.70	0.58	0.52	0.39	0.43	0.71	0.31	1.32	0.72	3.58	0.41	1.33	1.07	0.50	0.51
	Proso millet – St	0.36	1.27	0.30	0.30	0.20	0.26	0.46	0.32	0.65	0.42	2.45	0.33	1.15	0.77	0.27	0.64
	Siberian millet – St	0.63	1.58	0.47	0.53	0.26	0.28	0.81	0.30	1.05	0.41	2.81	0.37	1.02	1.22	0.37	0.59
	LSD_{05}, %	**0.033**	**0.077**	**0.029**	**0.025**	**0.019**	**0.020**	**0.034**	**0.016**	**0.063**	**0.034**	**0.170**	**0.020**	**0.060**	**0.051**	**0.024**	**0.036**

Source: developed by the authors based on [4, 13].

The content of essential amino acids in the dry matter of pearl millet, on average (0.36%), was lower in comparison to non-essential ones (0.72%). Thus, methionine (0.11%) and histidine (0.16%) were contained in dry matter in very small quantities. As for essential amino acids, leucine (0.7%) and phenylalanine (0.81%) showed the highest amount. Line No. 1 exhibited the highest concentration of essential amino acids in the dry matter, while line No. 4 displayed the lowest.

The grain of pearl millet had an average content of 0.67% for these amino acids, which was significantly less than the non-essential amino acids at 1.22%. Among the essential amino acids, methionine (0.31%), histidine (0.39%), and lysine (0.43%) had the minimum presence in the grain, while leucine (1.7%) and phenylalanine (0.71%) had the highest. The highest content of essential amino acids in the grain was observed in the new lines No. 1 and No. 5.

Examination of the non-essential amino acids content revealed an average content of 0.72% in the dry matter and 1.22% in the grain. Tyrosine (0.20%), arginine (0.48%), glycine (0.46%) and serine (0.49%) had the lowest presence in the dry matter. At the same time, aspartic acid content was 1.41%, glutamic acid – 1.19%, proline – 0.9%. The highest content of non-essential amino acids was found in lines No. 1, No. 3 and No. 4. Their parameters exceeded the values of the grain of proso millet and Siberian millet standards.

The content of non-essential amino acids in the grain was significantly higher than in the dry matter and averaged 1.22 and 0.71%, respectively. The average superiority was 0.50%. The most significant content was found in glutamic acid – 3.58%, aspartic acid – 1.32%, alanine – 1.33% and proline –

1.07%. The content of remaining non-essential amino acids in the grain was 0.41-0.81%. The maximum content of these amino acids was established in new lines No. 5, No. 3 and No. 1. In terms of amino acid content, pearl millet grain exceeds the parameters of standard proso millet and standard Siberian millet grain.

CONCLUSIONS

The highest content of crude protein (12.92%) in dry matter was found in line No. 1. As for other varieties, this parameter ranged from 10.51 to 11.52%.

The concentration of essential amino acids in the dry substance of pearl millet, on average (0.36%), was lower compared to the concentration of non-essential amino acids (0.72%). Leucine (1.7%) and phenylalanine (0.71%) exhibited the highest levels among essential amino acids in the grain.

In terms of amino acid content, the grain of pearl millet was superior to the grain of standards – proso millet and Siberian millet.

REFERENCES

[1]Andreev, N.G., 1975, Meadow and arable fodder cropping. Moscow: Kolos, 504 p.

[2]Are, A.K., Srivastava, R.K., Mahalingam, G., Gorthy, S., Gaddameedi, A.,Kunapareddy, A., Kotla, A., Jaganathan, J., 2018, Application of plant breeding and genomics for improved sorghum and pearl millet grain nutritional quality. Sorghum and Millets: Chemistry, Technology, and Nutritional Attributes: 51-68. DOI: 10.1016/B978-0-12-811527-5.00003-4

[3]Chavan, J.K., Kadam, S.S., Salunkhe, D.K., 1981, Changes in Tannin, Free Amino Acids, Reducing Sugars, and Starch During Seed Germination of Low and High Tannin Cultivars of Sorghum. Journal of Food Science. 46(2): 638-639. DOI: 10.1111/j.1365-2621.1981.tb04930.x

[4]Fedin, M.A., 1985, Methodology of the State Variety Testing of Agricultural Crops. Moscow: Ministry of Agriculture of the USSR, 267 p.

[5]Impa, S.M., Perumal, R., Bean, S.R., John Sunoj, V.S., Jagadish, S.V.K., 2019, Water deficit and heat stress induced alterations in grain physico-chemical characteristics and micronutrient composition in field grown grain sorghum. Journal of Cereal Science. 86: 124-131. DOI: 10.1016/j.jcs.2019.01.013

[6]Kapustin, S.I., Volodin, A.B., 2022, Cultivation of sorghum and annual fodder crops in arid conditions in the south of Russia. Stavropol: Service School, 103 p.

[7]Kapustin, S., Volodin, A., Kapustin, A., Samokish, N., 2022, Feed Quality of New Sudan Grass Varieties. Journal of Agriculture and Nature, 25(2): 400-405. DOI: 10.18016/ksutarimdoga.vi.916295

[8]Kapustin, S.I., Volodin, A.B., Kapustin, A.S., Vlasova, O.I., Donets, I.A., 2021, Reaction of Sudan grass and sorghum-Sudan hybrids to salinity. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development. 21(3): 491-496.

[9]Medvedev, P.F., 1981, Forage plants of the European part of the USSR. Leningrad: Kolos, 336 p.

[10]Mishra, J.S., Thakur, N.S., Kewalanand, Sujathamma, P., Kushwaha, B.B., Rao, S.S., Patil, J.V., 2015, Response of Sweet Sorghum Genotypes for Biomass, Grain Yield and Ethanol Production under Different Fertility Levels in Rainfed Conditions. Sugar Tech. 17(2): 204-209. DOI: 10.1007/s12355-014-0315-4

[11]Tariq, A.S., Akram, Z., Shabbir, G., Khan, K.S., Mahmood, T., Iqbal, M.S., 2014, Heterosis and combining ability evaluation for quality traits in forage sorghum (*Sorghum bicolor* L.). Sabrao Journal of Breeding and Genetics, 46(2): 174-182.

[12]Thorsoe, K.S., Bak, S., Olsen, C.E., Imberty, A., Breton, C., Moller, B.L., 2005, Determination of catalytic key amino acids and UDP sugar donor specificity of the cyanohydrin glycosyltransferase UGT85B1 from Sorghum bicolor. Molecular modeling substantiated by site-specific mutagenesis and biochemical analyses. Plant Physiology. 139(2): 664-673. DOI: 10.1104/pp.105.063842

[13]Volgin, V.I., Romanenko, L.V., Prokhorenko, P.N., 2008, The method of calculating the metabolizable energy in feed based on the content of raw nutrients. Dubrovitsy: Publishing House of the Research Institute of Animal Husbandry of the Russian Agricultural Academy, 252 p.

EFFICIENCY AND ECONOMIC EVALUATION OF DIFFERENT METHODS OF IRRIGATION IN GROWING CORN (*ZEA MAYS* L.)

Vira KONOVALOVA[1], Serhii ROI[1], Andrii TYSHCHENKO[1], Viktor SHARII[1], Olena TYSHCHENKO[1], Volodymyr KONOVALOV[2], Nadiia REZNYCHENKO[1], Kateryna FUNDIRAT[1]

[1]Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, 24 Mayatska doroga Street, sett. Khlybodarske, Odesa district, Odesa region, 67667, Ukraine, E-mails: vera_konovalova_1990@ukr.net, roysergey11@gmail.com, tischenko_andriy@ukr.net, viktor.sharii@ukr.net, elenat1946@ukr.net, nadezhda.reznichenko@ukr.net, kfundirat@gmail.com
[2]Askanian State Agricultural Research Station of the Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, Tavrichanka village, Kakhovka district, Kherson region, 74862, Ukraine, E-mail: konovalov.1991@ukr.net

Corresponding author: tischenko_andriy@ukr.net

Abstract

The paper aimed to study the effectiveness of corn cultivation under different irrigation methods on the experimental field of the Askanian State Agricultural Research Station, which is located in the semi-arid, steppe, arid climate zone of the Southern Steppe of Ukraine, in the Kakhovsky irrigated massif. The investigation pointed out the effectiveness and provided an economic assessment of the use of different irrigation methods in corn cultivation. Two methods of irrigation (sprinkling and subsoil drip irrigation) were studied, with the maintenance of the humidity of the soil layer 0–50 cm at the level of 80% LMC and corn hybrids of different maturity groups. Under subsoil drip irrigation, the irrigation rate was lower on average by 24% than when sprinkled, on the other hand, the yield was higher on average by 40.9%, which significantly affected the cost price of the obtained corn grain. Subsoil drip irrigation yielded a net profit of 62% higher than sprinkler irrigation. and the profitability accordingly increased by 78.8%.

Key words**:** *corn, hybrid, sprinkling, drip irrigation, yield*

INTRODUCTION

One of the most important tasks of the agricultural industry is to obtain the greatest profit, reduce the cost price and increase the profitability of growing agricultural crops. In contrast to this is the expansion of the area of agricultural land and the continuous intensification of agriculture, which leads to increasingly strong negative consequences for the ecology of the planet. Therefore, in today's context, one of the most promising ways to increase the profitability of agricultural production is the scientific development and wide implementation of resource-saving technologies [11, 14].

The south of Ukraine is the territory of risky agriculture, where due to lack of moisture, farmers can suffer significant losses, or even completely lose their harvest [8, 9]. Therefore, irrigation in this region is a necessary component for the sustainable development of agriculture. One of the main means of reducing cost, increasing productivity is possible due to the increase of irrigated areas under surface and subsoil drip irrigation, which is considered a resource-saving method of irrigation [4, 13].

The most widespread method of irrigation in the Southern region of the country is sprinkler irrigation. Drip irrigation is widely used in the cultivation of vegetable products, but the research results below have shown that this is a very promising method of irrigation for row crops as well [12]. In many countries of the world, instead of surface drip irrigation, when drip lines are located on the surface of the soil, underground drip irrigation is increasingly used. The peculiarity of this irrigation method is that water is brought to the field using perennial pipes with drippers, which are laid under the surface at a depth of 30-50 cm.

The impact of drip irrigation on the productivity of various corn hybrids has been studied in many countries of the world. Such experiments conducted in the experimental garden of the Faculty of Agriculture, Teuku Umar University, Meulaboh, West Aceh in Indonesia on various hybrids of sweet corn showed that the use of drip irrigation practically does not affect the plants in the first month of vegetation, but already on the 45th day such the watering method led to an increase in leaf length by almost 20% [5].

Studies of the influence of different watering intervals using drip irrigation on the yield and quality of corn silage conducted in Southeastern Anatolia region in Turkey indicate a positive effect of maximally frequent watering with a small irrigation rate [7].

Despite the fact that subsoil drip irrigation is a relatively new method of irrigation, it is quite widely covered in scientific works around the world. Lysimeter studies carried out on winter wheat plants indicate a decrease in evapotranspiration when using subsoil drip irrigation by 26% compared to traditional irrigation methods, and by 15% compared to surface drip irrigation [1, 10]. A field experiment conducted in Pals (Baix Ter, Girona, Spain) during the cultivation of Onice rice variety showed that when laying drip tapes at a depth of 0.15 m and carrying out two irrigations per day, the lowest water losses for percolation into the lower soil layers can be achieved [3].

Research carried out in the USA on the possibility of increasing the productivity of modern corn hybrids due to the use of subsoil drip irrigation together with increasing the density of plant stands showed high prospects for such an approach. However, the change in irrigation intensity had a minor effect on corn yield (within 2–3%) [6]. In India, a study was conducted with the possibility of evaluating the yield level of sweet corn under different irrigation water management strategies. Among the many considered parameters were various irrigation methods. The results of the study indicate that the use of subsoil drip irrigation allows to increase the yield of corn grain compared to sprinkling by 22.69% without the use of mulch, and by 8.47% with mulching [2].

With the aim of researching different irrigation regimes when growing corn on subsoil drip irrigation, a number of experiments were conducted at Haymana Research and Training Center of Agricultural Faculty at Ankara University, in Central Anatolia Region of Turkey. The results were quite predictable. With an increase in the irrigation rate, the yield of corn also increased significantly. However, when the irrigation rate was reduced by 30%, the grain yield decreased by only 10% [2].

The analysis of the results of recent studies showed that the influence of subsoil drip irrigation on the productivity of corn depends on the soils and climatic features of the place of the experiment. Therefore, for the conditions of the south of Ukraine, it is necessary to conduct detailed studies of this issue. The analysis of literary sources shows that Ukrainian scientists consider the economic efficiency of corn cultivation with sprinkler and drip irrigation. However, scientific and practical works on the study of the influence of subsoil drip irrigation on the economic efficiency of corn cultivation for the soil and climatic conditions of southern Ukraine were not conducted.

The aim of the study was to study, analyze and establish the effectiveness of the application of excellent methods of irrigation in the cultivation of corn for grain and to provide an economic assessment.

MATERIALS AND METHODS

The research was carried out at the experimental field of the Askanian Atate Agricultural Research Station in the village of Tavrychanka, Kherson region (46°33'12"N; 33°49'13"E; 39 m above sea level), located in the steppe zone of Southern Ukraine, Kakhovsky irrigated massif, during 2019–2020.

The soil on the site is dark chestnut. The humus horizon is dark gray up to 35 cm thick and has a lumpy granular structure. It contains a significant amount of root remains. The transitional horizon has a coarse-grained or lumpy-prismatic structure, light chestnut color. It contains carbonates in the form of white stars. The humus content is 2.3%. The content of the main nutrients: N (mineral) – 30–45 mg/kg, P_2O_5 – 45–55 mg/kg, K_2O – 400–550 mg/kg. The parent rock is represented by loess, which lies at a depth of about two meters.

Irrigation by sprinkling was calculated to maintain the humidity of the soil layer 0–50 cm at the level of 80% of the lowest soil moisture content (HB). On subsoil drip irrigation, soil moisture was maintained within 80% HB. The subsoil drip irrigation system had the following parameters: a drip tape with a diameter of 16 mm with a wall thickness of 16 mil laid at a depth of 35 cm. The distance between the tapes is 70 cm, the distance between the emitters is 25 cm. The output of the emitter is 1.1 l/h. Corn was sown with a seeder with a row spacing of 70 cm. The seeding rate was 82,000 pieces. per hectare. The rate of application of mineral fertilizers was $N_{120}P_{60}$ and was applied in two stages: the first – under cultivation in the form of amphos, the second - before sowing in the form of UAM.

Factor A in the experiment was the methods of irrigation: subsoil drip irrigation and sprinkling using a front sprinkler. Factor B - corn hybrids of different maturity groups: Stepovyy – FAO 190, Meotida – FAO 190, Khotyn – FAO 250, Askania – FAO 320, Getera – FAO 420 and Arabat – FAO 430.

Statistical processing of experimental data was carried out to help program security AgroSTAT, XLSTAT and Statistica (v. 13).

RESULTS AND DISCUSSIONS

The use of subsoil drip irrigation made it possible to reduce the irrigation rate in 2019 from 3,600 m^3/ha to 2,610 m^3/ha. In 2020, this figure for sprinkling was 2,700 m^3/ha, and for subsoil drip irrigation – 2,160 m^3/ha. This saving of irrigation water had a significant impact on the cost of the obtained corn grain.

The use of drip irrigation made it possible to significantly increase the productivity of corn, with the highest yield in the Getera hybrid - 14.17 t/ha, while with sprinkler irrigation - 9.69 t/ha (Table 1).

Table 1. Productivity and economic efficiency of corn cultivation on average for 2019-2020

Irrigation method (A)	Hybrid (B)	Yield, t/ha	The cost of the obtained products, €/ha	Expenses per 1 ha, €	Notional net profit, €/ha	Cost of 1 t of seeds, €	Profitability level, %
Sprinkling	Stepovyy	8.62	1,637.80	517.90	1,119.90	60.08	216.2
	Meotida	8.97	1,704.30	519.18	1,185.13	57.88	228.3
	Khotyn	9.07	1,723.30	518.78	1,204.53	57.20	232.2
	Askania	9.65	1,833.50	519.20	1,314.30	53.80	253.1
	Getera	9.69	1,841.10	519.28	1,321.83	53.59	254.6
	Arabat	9.33	1,772.70	517.75	1,254.95	55.49	242.4
	Average	**9.22**	**1,752.12**	**518.68**	**1,233.44**	**56.34**	**237.8**
Subsoil drip irrigation	Stepovyy	12.31	2,338.90	469.48	1,869.43	38.14	398.2
	Meotida	12.23	2,323.70	469.83	1,853.88	38.42	394.6
	Khotyn	12.50	2,375.00	469.85	1,905.15	37.59	405.5
	Askania	13.14	2,496.60	470.30	2,026.30	35.79	430.9
	Getera	14.17	2,692.30	470.83	2,221.48	33.23	471.8
	Arabat	13.60	2,584.00	469.83	2,114.18	34.55	450.0
	Average	**12.99**	**2,468.42**	**470.02**	**1,998.40**	**36.28**	**425.2**
LSD_{05}	A	0.840					
LSD_{05}	B	0.545					

Note: The cost of 1 ton of grain–190 €/t.
Source: Own results.

The lowest productivity was shown by the Stepovyy hybrid in the version with sprinkler irrigation - 8.6 t/ha. The use of subsoil drip irrigation showed an increase in productivity by 3.77 t/ha compared to sprinkling.

This growth of the Yield is caused by the fact that drip irrigation allows you to carry out many waterings with small rates and maintain a more uniform level of moisture in the root layer of the soil.

Also, subsoil drip irrigation systems showed greater adaptability to the climatic conditions of the region. Meteorological conditions during the years of the study were quite typical for Southern Ukraine. The amount of precipitation during the corn growing season in 2019 was 180.0 mm, and in 2020 – 213.5 mm. The main part of precipitation fell in the form of heavy downpours, between which there were long periods without rain. Thus, irrigation was stopped for some time after rains for 5–6 days, and then resumed. However, due to the peculiarities of the sprinkling technology, some areas of the field received moisture several days later than it was necessary. With drip irrigation, thanks to the flexible schedule of moisture supply to the fields, this problem was avoided.

Therefore, the use of subsoil drip irrigation allows to simultaneously increase the yield of corn and reduce the cost of the obtained products. By reducing the irrigation rate, it was possible to reduce production costs by €48.66 per hectare. Profit from one hectare increased by €764.96. Thus, on subsoil drip irrigation, the profitability of corn grain production increased by 78.8%.

For late-ripening hybrids, production costs were approximately the same as for early-ripening ones, and the net profit increased due to increased productivity. Thus, the difference between the cultivation of the steppe hybrid - FAO 190 and the hybrid Arabat - FAO 430 on sprinkler irrigation was 8.2%, and on subsoil drip irrigation - 10.4%.

CONCLUSIONS

The use of subsoil drip irrigation when growing corn for grain in the Southern Steppe of Ukraine made it possible to reduce the irrigation rate by an average of 24%, which led to a decrease in production costs by 9.4%. On the contrary, productivity increased by an average of 40.9%. Subsoil drip irrigation yielded a net profit of 62% higher than sprinkler irrigation. Production costs decreased by 9.4%, and profitability accordingly increased by 78.8%.

REFERENCES

[1]Arbat, G., Cufí, S., Duran-Ros, M., Pinsach, J., Puig-Bargués, J., Pujol, J., Ramírez de Cartagena, F., 2020, Modeling approaches for determining dripline depth and irrigation frequency of subsurface drip irrigated rice on different soil textures. Water, 12(6), 1724. https://doi.org/10.3390/w12061724

[2]Bilgen, G.K., Kodal, S., Yildirim, Y.E., 2019, Effects of deficit irrigation application with subsurface drip irrigation on corn. Indian National Committee on Surface Water (INCSW)-CWC Ambassador Ajanta, Aurangabad, India 16 Jan-18 Jan 2019 Publishers: Ivy League Systems. com, 115.

[3]Lamm, F.R., 2022, High Yielding Corn Production with Subsurface Drip Irrigation. Kansas Agricultural Experiment Station Research Reports, 8(8), 7. https://doi.org/10.4148/2378-5977.8335

[4]Lavrynenko, Yu.O., Ruban, V.B., 2013, Substantiation of technology of corn cultivation by drip irrigation. Taurian Scientific Bulletin, 86, 53–56.

[5]Muslimah, Y., Lizmah, S.F., Harahap, E.J., Jasmi, Alfatah, M., 2022, The effect of drip irrigation on the growth of two varieties of sweet corn (*Zea mays* L.). IOP Conf. Ser.: Earth Environ. Sci.977 012040. https://doi.org/10.1088/1755-1315/977/1/012040

[6]Rank, P.H., Satasiya, R.M., 2022, Sweet corn crop (*Zea mays* L.) performance under various irrigation water management strategies. The Pharma Innovation Journal, 11(6), 1525-1531.

[7]Tari, A.F., 2022, The impact of different irrigation intervals and levels on yield and quality of drip-irrigated corn silage (*Zea mays* L.) Under arid climate. Applied ecology and environmental research, 20(5), 4173-4191. http://dx.doi.org/10.15666/aeer/2005_41734191

[8]Tyshchenko, O., Tyshchenko, A., Piliarska, O., Biliaeva, I., Kuts, H., Lykhovyd, P., Halchenko, N., 2020, Seed productivity of alfalfa varieties depending on the conditions of humidification and growth regulators in the Southern Steppe of Ukraine. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development. 20(4), 551-562.

[9]Tyshchenko, O., Tyshchenko, A., Piliarska, O., Kuts, H., Lykhovyd, P., 2020, Evaluation of drought tolerance in alfalfa *(Medicago sativa)* genotypes in the conditions of osmotic stress. AgroLife Scientific Journal. 9(2), 353-358.

[10]Umair, M., Hussain, T., Jiang, H., Ahmad, A., Yao, J., Qi, Y., Zhang, Y., Min, L., Shen, Y., 2019, Water-saving potential of subsurface drip irrigation for winter wheat. Sustainability, 11(10), 2978. https://doi.org/10.3390/su11102978

[11]Vozhehova, R., Tyshchenko, A., Tyshchenko, O., Piliarska, O., Konovalova, V., Sharii, V., Fundirat, K., 2022, Economic feasibility of application of bacterial and fungal drugs on seed-used alfalfa. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development. 22(4), 827-834.

[12]Vozhehova, R., Lavrynenko, Y., Marchenko, T., Piliarska, O., Sharii, V., Tyshchenko, A., Drobit, O., Mishchenko, S., Grabovskyi, M., 2022, Water consumption and efficiency of irrigation of maize hybrids of different FAO groups in the Southern Steppe of Ukraine. Scientific Papers. Series A. Agronomy, LXV(1), 603–612.

[13]Vozhehova, R., Marchenko, T., Lavrynenko, Y., Piliarska, O., Zabara, P., Zaiets, S., Tyshchenko, A., Mishchenko, S., Kormosh, S., 2022, Productivityoflines – parental components of maize hybrids depending on plant density and application of biopreparations under drip irrigation. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development. 22(1), 695–704.

[14]Vozhehova, R., Tyshchenko, A., Tyshchenko, O., Dymov, O., Piliarska, O., Lykhovyd, P., 2021, Evaluation of breeding indices for drought tolerance in alfalfa (*Medicago*) genotypes. Scientific Papers. Series A. Agronomy, LXIV(2), 435-444.

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STUDY OF THE FREQUENCY OF COMPOSITE BETA- AND KAPPA-CASEIN GENOTYPES OF CATTLE POPULATIONS AS A FACTOR IMPROVING THE MILK QUALITY

Volodymyr LADYKA[1], Yuriy SKLIARENKO[2], Yuliia PAVLENKO[1], Viktoriia VECHORKA[1], Alona MALIKOVA[1]

[1]Sumy National Agrarian University, 160, H. Kondratiiev St., Sumy, Ukraine, E-mail: v.i.ladyka@ukr.net, jasjulia@ukr.net, vvvechorka@gmail.com, lelikunique2@gmail.com
[2]Institute of Agriculture in the North East of the National Academy of Agrarian Sciences of Ukraine, Ukraine, Sumy region, Sumy district, Sad village, Zelena Street 1 E-mail: Sklyrenko9753@ukr.net

Corresponding author: Sklyrenko9753@ukr.net

Abstract

The study of polymorphism of beta-casein genes CSN2 and kappa-casein CSN3 in cows of Brown cattle, Simmental breed, Black and White cattle has been carried out with the use of polymerase chain reaction in real time. It is shown that the frequency distribution of CSN2 / CSN3 composite genotypes differs significantly in different breeds: Brown cattle – 22.0 A1A2/AB, 22.7% A2A2/AB and 22.0% A2A2/BB; Simmental – 26.8% A1A2/AB; A2A2/AF, 22.0%, A2A2/AB 19.5%; Black and White cattle – 26.9% A1A2/AA; A1A1/AB, 23.1%, A2A2/AA 23.1%. The obtained results indicate the prospects of breeding work concerning the formation of herds (micropopulations) by the A2A2/BB composite genotype, which is only possible among Brown breeds. This makes it possible to increase the effectiveness of measures to preserve the population of Brown cattle by improving the quality of their milk.

Key words: *genetic polymorphism, beta-casein, kappa- casein, genotype frequency, cattle breeds*

INTRODUCTION

Genetic studies of farm animals mainly focus on identifying genes that determine economically important traits and may be used in breeding programs. In dairy cattle breeding, genes that can determine differences in milk yield and composition are mainly studied. The use of genetic markers makes it possible to predict breeding value based on traits that are difficult to measure by phenotypic manifestation, and therefore, that are not part of the selection criterion. The main goal of our work was to show what happened to the frequencies of alleles of some important QTL, which directly affected the level of manifestation of economically useful traits, but did not have a pronounced phenotypic manifestation (for their determination by phenotype), and therefore were not taken into account by traditional methods of breeding [5].

Identification of genes and their mutations that determine the direction and degree of development of a quantitative trait (for example, the amount of milk yield, the average daily weight gain of fattening animals, the content of fat and protein in milk, etc.) in countries with developed animal husbandry provides significant profits due to the rapid achievement of genetic progress, the main components of which are the intensity of breeding, its accuracy and reduction of the generation interval [11, 9].

Therefore, today molecular genetic research methods are a promising area of fundamental and applied genetics, in particular, the breeding of farm animals. The use of marker-associated breeding makes it possible to increase the effectiveness of traditional methods of breeding work by direct assessment of animals by genotype.

In dairy cattle breeding, the most economically significant genes are those whose products are associated with the nutritional value and technological properties of milk.

According to their properties, all milk proteins can be divided into two groups:

82% are caseins (αS1-, αS2-, β-, k-casein) and 18% are whey proteins (α- and βlactoglobulins). Alleles that determine milk protein synthesis are inherited by co-dominance and clearly diagnosed using molecular genetic methods. The vast majority of studies relate to the two most economically important genes – beta-lactoglobulin (β-LG) and kappa-casein (k-casein, CSN3, k-CN), whose polymorphism is associated with milk producing ability.

Unlike the other three casein proteins, kappa-casein is similar in its amino acid composition to fibrin and has the property of forming clots based on the results of proteolysis. This property has long been used in cheese making. The DNA analysis of exon regions of the CSN3 gene has resulted in the identification of several nucleotide substitutions and polymorphic restriction sites and description of 9 allelic variants (A, B, C, E, F, G, H, I, and A1), among which A and B variants are the most common [8]. Much attention in the United States of America, New Zealand, China, and some European countries is paid to the research of the milk protein fraction - β-casein (CSN2) [13]. Scientists and practitioners pay special attention to two allelic variants - A1 and A2. These beta-casein proteins differ in one amino acid, which causes the formation of beta-casomorphin in the human digestive tract (in the case of the A1 beta-casein), which causes a number of pathological effects [1]. In turn, the use of A2 milk significantly reduces the acute symptoms of undigested cow's milk [14, 4]. Products based on A2 milk are gradually spreading in the markets of such countries as New Zealand (2000), Australia (2004), the United States (2003), the United Kingdom (2011), and China (2013). In recent years, where some interest began to appear among our domestic farms regarding the typing of cows by β-casein alleles, it should be noted that the four casein genes (αS1-CN, αS2-CN, β-CN, k-CN) are closely related to and organized on chromosome 6 B. taurus (200-250 kb) in the following order: αS1, β, αS2 і k. This makes this construction interesting from the point of view of studying the nonequilibrium coupling of allelic variants of these genes [5, 11, 12]. In this case, interest arises not only in the polymorphism of individual genes (for example, kappa-casein), but also in the need to analyze complex genotypes and haplotypes of both promising loci – beta- and kappa casein [6, 3].

Different breeds differ significantly in complex genotypes according to beta- and kappa-casein. Thus, the A2A2/AB (22.9%) and A2A2/BB (15.6%) genotypes are more common in Jersey animals. The A1A1/AA та A1A2/AA genotypes are not found. On the contrary, in animals of the Red Danish breed, the A1A2/AA (17.0%) and A2A2/AA (13.1%) genotypes have a higher proportion. The A1A2/BB and A2A2/BB genotypes do not occur [2].

The aim of our research is to study the frequency of composite beta- and kappa-casein genotypes in dairy cattle populations in Ukraine in order to establish the possibility of obtaining milk with the desired qualitative characteristics.

MATERIALS AND METHODS

The genotyping of 193 heads of the following cattle breeds was carried out during the research: Brown cattle (n=145), Simmental (n=41), Black and White cattle (n=26). Experimental animals are bred on the leading breeding farms of Ukraine and purebred. Experimental cows of Lebedyn breed are kept at Mykhailivka Breeding Plant LLC (Lebedyn district of Sumy region) and Komyshanske CAL (Okhtyrka district of Sumy region), Ukrainian Brown dairy breed and Ukrainian Black-and-White dairy breed - at the State Enterprise Research Farm of the Institute of Agriculture of Northern East of the National Academy of Agrarian Sciences (Sumy district of Sumy region), Simmental breed - at Urozhai LLC (Romny district of Sumy region).

The genotyping of 23 bullocks of Brown cattle grown in Mykhailivka Breeding Plant LLC (Lebedyn district of Sumy region) and Komyshanske CAL (Okhtyrka district of Sumy region) and the State Enterprise Research Farm of the Institute of Agriculture of Northern East of the National Academy of

Agrarian Sciences (Sumy district of Sumy region) and 12 breeders of Brown cattle (Sumy State Breeding Center).

Blood samples were taken under sterile conditions into 2.7 mL monovettes containing EDTA potassium salt as an anticoagulant (Sarstedt, Germany) with the following freezing of samples and their storage at -20ºC.

DNA for genotyping was extracted from the samples using Monarch® Genomic DNA Purification Kit New England BioLab kits (USA) according to manufacturer's protocol.

TaqMan®Custom was used to perform allelic discrimination. The TaqMan® SNP Genotyping Assays use TaqMan® 5′-nuclease chemistry for amplifying and detecting specific polymorphisms in purified genomic DNA samples. All assays are developed using Life Technologies robust bioinformatics assay design process relying on a pipeline using heuristic rules deduced from both manufacturing and assay performance data. These assays use TaqMan® minor groove-binding (MGB) probes for superior allelic discrimination, improved signal-to-noise ratios, and design flexibility. TaqMan real-time PCR Two primers were designed to amplify the 101 bp product involving SNP rs43703011 (genomic DNA: X14711 (http://www.ncbi.nih.gov); forward primer, 5′- AAG CAG TAG AGA GCA CTG TAG CTA -3′; reverse primer, 5′- TGA TCT CAG GTG GGC TCT CAA TAA -3′). Two fluorogenic TaqMan probes were designed with different fluorescent dye reporters to allow single-tube genotyping. The first probe was targeted at the wild type allele A (5′-VIC-CTTCTGGAGAAGCTTCTA-3′) and the second one at the mutated allele B (5′-FAM- CTTCTGGAGAATCTTCTA -FAM-3′) of the CSN3 gene. The NFQ quencher was linked to the 3′ end of both probes. Primers and probes were designed using Primer Express software, version 3.0 (Applied Biosystems, CA, USA) and were obtained from Applied Biosystems. The accuracy of the used sequence source was verified by comparison with sequences from the GenBank database using BLAST (http://www.ncbi.nlm.nih. gov/BLAST/). Real-time PCR was performed in 20 µl reactions with 10 µl of TaqMan universal PCR master mix containing AmpliTaq Gold DNA Polymerase (Applied Biosystems, CA, USA), 200 nM concentration of forward and reverse primer, 100 nM of each probe and 2 µl (50–100 ng) of sample DNA. The PCR reaction was obtained using the FAST 7500 Real Time PCR System (Applied Biosystems). The time and temperature profile of the PCR reaction consisted of the following steps: 2 min at 50°C for UNG activation, 10 min at 95°C for starting AmpliTaq Gold activity, 40 cycles of 95°C for 15 s and 60°C for 1 min. As a negative control, we used a sample without a template. An allelic discrimination experiment consisted of three steps: a pre-read run, an amplification run and a post-read run.

The obtained samples were tested by analyzing the obtained PCR curves. SDS software version 4.2. was used by us to analyze the amplification products.

Statistical analysis was performed in the R (www.R-project.org, V.4.0).

The allele frequency was calculated taking into account the number of homozygotes and heterozygotes found in the respective allele using the following formula:

$$P(A)=\frac{2N_1+N_2}{n} \qquad (1)$$

where:

N1 and N2 – number of homozygotes and heterozygotes for the studied allele, respectively;

n – sample number.

RESULTS AND DISCUSSIONS

The studies to determine the proportion of composite genotypes for beta- and kappa-casein showed that Brown cattle were characterized by the all possible genotypes. In most cases, the Simmental breed was characterized by the availability of three composite genotypes: A2A2/AA (22.0%), A1A2/AB (26.8%), A2A2/AB (19.5%). Cows of the Black and White cattle were characterized by the following three composite genotypes: A1A2/AA (26.9%),

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A2A2/AA (23.1%) and A1A1/AB (23.1%) (Table 1).

Table 1. Frequency distribution of the studied combinations of CSN2 and CSN3 milk protein genotypes

Populations	CSN3	Frequency of composite genotypes, %		
		CSN2		
		A1A1	A1A2	A2A2
Brown cattle	AA	4.7	9.6	8.2
Simmental		7.3	14.6	22.0
Black and White cattle		7.7	26.9	23.1
Brown cattle	AB	3.4	22.0	22.7
Simmental		0.0	26.8	19.5
Black and White cattle		23.1	0.0	3.8
Brown cattle	BB	2.6	4.8	22.0
Simmental		0.0	9.8	0.0
Black and White cattle		7.7	7.7	0.0

Source: Own research.

Research results indicate the absence of complex genotypes A1A1/AB, A1A1/BB and A2A2/BB in animals of Simmental breed, and A1A2/AB and A2A2/BB in animals of Black and White breed. The combination of the two desired A2A2 beta-casein genotypes and BB kappa-casein is only found only in cattle of the Brown cattle.

The formation of cattle genotype is equally influenced by the genotypes of the male and female parents. Based on the results of our previous studies, it is found that among the breeding bulls of the Holstein breed, which are widely used in the breeding stock of Black and White cattle, only 43% were evaluated by the polymorphism of the beta- and kappa-casein genes. 9 combinations of such genotypes were identified. Most stud bulls had the combined A2/AB genotype. The share of stud bulls of the desired A2A2/BB composite genotype was only 12.4%. Breeding bulls of the Brown Swiss breed have only two variants of the complex genotype. The desired complex genotype A2A2/BB was found in them with a frequency of 75%. This determines their further use in Brown cattle in Ukraine.

No cattle with the desired A2A2/BB composite genotype have been found among the Simmental stud bulls [10].

In the period from 2017 to 2019, the scientists of Sumy National Agrarian University implemented the scientific project "Justification of the Methodology for Improving and Conserving the Brown Cattle Population in the conditions of the North-Eastern Region of Ukraine". The project resulted in the development and practical implementation of a fundamentally new scheme for reproducing the genealogical structure of local (native) brown breed herds, namely, work with the application of the population reciprocal crossing method. The original breeds involved in creating the Brown cattle were the Gray Ukrainian and various offspring of the Swiss breed. Therefore, the use of stud bulls of these breeds will expand the genealogical structure of the Brown cattle to avoid undesirable inbreeding in further work with stud bulls, whose semen is stored. At the initiative of the Rector of Sumy NAU in 2019, the semen of three stud bulls of the original German Brown breed (Julex DE 814660509, Urano SN 110027139002, Nimrod DE 814720783) was imported to the farms of the region. The expected result of using these stud bulls was: the conservation of the Brown cattle in micropopulations; the formation of dairy herds with the A2A2 beta-casein genotype and BB kappa-casein [9]. We performed a genetic assessment of the obtained stud bulls and stud bulls whose semen is stored in a deep frozen state, according to the complex genotypes of beta-and kappa casein (Table 2).

Among the obtained bulls, the majority was animals with such composite genotypes as A1A2/AA, A1A2/AB, A2A2/AB, A2A2/BB.

The small proportion of homozygotes in the A1A12/AA composite genotype indicates prospects for creating micropopulations with the desired A2A2/BB composite genotype.

This is also evidenced by the presence of stud bulls with the A2A2/BB composite genotype, and a significant proportion of heterozygous animals. Although it should be noted that it is essential to increase the proportion of cattle with the A2A2/BB genotype.

Table 2. Characteristics of the frequency of composite genotypes for the conservation of Brown cattle

CSN3	Frequency of composite genotypes, %		
	CSN2		
	A1A1	A1A2	A2A2
AA	2.9	22.9	11.4
AB	5.7	20.0	17.1
BB	0.0	5.7	14.3

Source: The authors' own research.

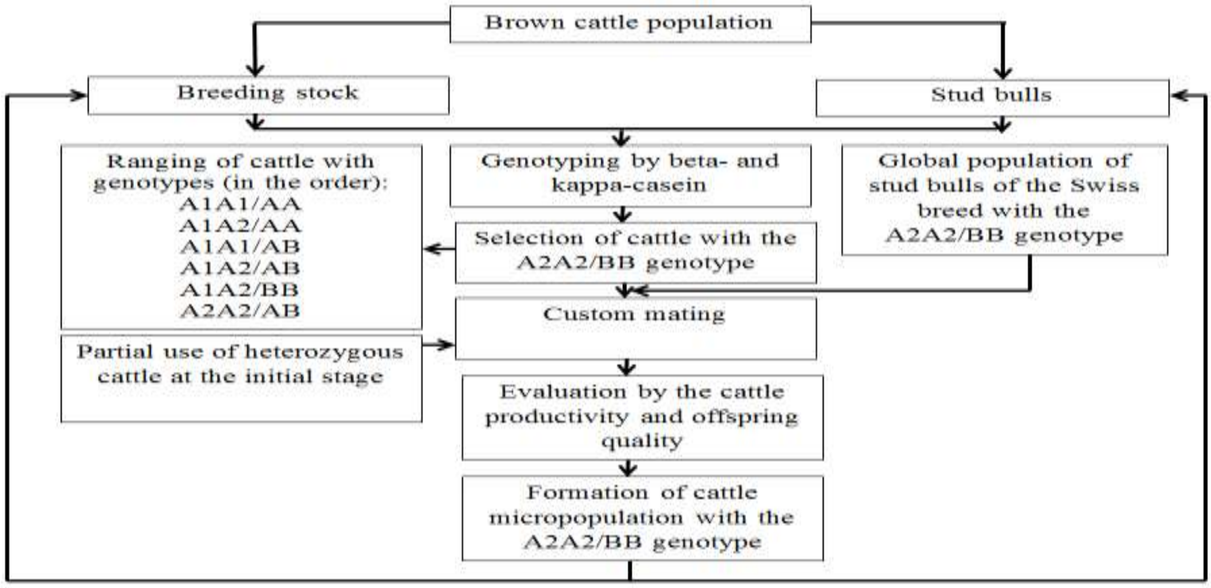

Fig. 1. Scheme of population formation with the desired A2A2/BB composite genotype
Source: The authors' own research.

In order to preserve the population of Brown cattle and form micropopulations with the desired genotype by beta-and kappa-casein, we propose an appropriate scheme (Fig. 1).

Comparing our results with those of other researchers, we note that the frequency distribution of complex genotypes in Black and White cattle had similar results to the studies of Vallas M. et al [15]. The proportion of A2A2/AA and A1A2/AA composite genotypes almost coincided (27.4% and 23.1%, respectively; 23.1 and 26.9%). The proportion of the desired A2A2/BB genotype was equally low (0.0 and 0.1%, respectively).

Comparing the research results of Kyselová, J. et al [7] on Simmental cattle, we note a similarity in the frequency distribution by the A1A2/AB (26.8 and 17.8%, respectively), A2A2/AA (22.0 and 18.1%, respectively), and A1A2/AA (14.6% and 16.65%, respectively) genotypes. The desired A2A2/BB genotype had a low frequency (0.0 and 1.3%, respectively).

CONCLUSIONS

The conducted work has resulted in determining the frequency of alleles and genotypes by the beta- and kappa-casein loci, composite genotype. It is established that the breeds of dairy cattle bred in the North-East of Ukraine differ significantly in these traits.

At this stage of breeding, the formation of herds (micropopulations) with the A2A2/BB composite genotype is only possible among the Brown cattle.

In the future, exclusively by order of processing enterprises (the market), it is possible to breed herds of the Simmental breed with the specified genetic parameters quite quickly.

Among Black and White populations, the above genetic combinations may only appear as a result of implementing special breeding programs, where the primary task will be to breed bulls of the A2A2/BB genotype that requires much more time to increase the occurrence frequency of among breeding stock.

The results obtained make it possible to increase the effectiveness of measures to preserve the population of Brown cattle in Ukraine. In addition, the formation of a population of Brown cattle with the A2A2/BB genotype enables to provide the population with safe and high-quality dairy raw materials, which will inevitably improve people's health. Increased cheese suitability of milk content will increase the economic efficiency of milk production.

REFERENCES

[1]Cie´sli´nska, A., Fiedorowicz, E., Rozmus, D., Sienkiewicz-Szłapka, E., Jarmołowska, B., Kami´ nski, S., 2022, Does a Little Difference Make a Big Difference? Bovine _-Casein A1 and A2 Variants and Human Health—An Update. Int. J. Mol. Sci., 23:15637.

[2]Gustavsson, F., Buitenhuis, A. J., Johansson, M., Bertelsen, H. P., Glantz, M., Poulsen, N. A., 2013, Effects of Breed and Casein Genetic Variants on Protein Profile in Milk from Swedish Red, Danish Holstein, and Danish Jersey Cows. J. Dairy Sci., 97, 3866–3877.

[3]Heck, J., Schennink, A., van Valenberg, H., Bovenhuis, H., Visker, M. van Arendonk, J., van Hooijdonk, A., 2009, Effects of milk protein variants on the protein composition of bovine milk. Journal of Dairy Science, 92 (3): 1192–1202.

[4]Kamiński, S, Zabolewicz, T, Oleński, K, Babuchowski, A., 2023, Long-term changes in the frequency of beta-casein, kappa-casein and beta-lactoglobulin alleles in Polish Holstein-Friesian dairy cattle. Journal of Animal and Feed Sciences, 32(2):205-210.

[5]Kulibaba, R., Liashenko, Yu., Sakhatskyi, M., 2023, Using the results of genetic and population studies to evaluate breeding work in populations of dairy cows. Scientific and Technical Bulletin of Institute of Animal Husbandry of NAAS, 129: 103-114.

[6]Kulibaba, R., Sakhatskyi, M., Liashenko, Yu., 2022, Analysis of the distribution of haplotype frequencies by csn2 and csn3 loci in the population of cows of the Ukrainian Black and White dairy breed. Scientific and Technical Bulletin of Institute of Animal Husbandry of NAAS. 128: 94-104.

[7]Kyselová, J., Ječmínková, K., Matějíčková, J., Hanuš, O., Kott, T., Štípková, M., Krejčová, M., 2019, Physiochemical characteristics and fermentation ability of milk from Czech Fleckvieh cows are related to genetic polymorphisms of β-casein, κ-casein, and β-lactoglobulin. Asian-Australas J Anim Sci, 32 (1): 14-22.

[8]Ladyka V., Skliarenko Y., Pavlenko Y., Vechorka V., Malikova A., 2023, Evaluation of stud bulls by the kappa-casein genotype in the context of conservation of local brown cattle breeds in Ukraine. Scientific Papers Series. Management, Economic Engineering in Agriculture and Rural Development. 23 (1): 355-362.

[9]Ladyka, V., Metlitska, O., Skliarenko, Y., Pavlenko, Y., 2019, Genetic analysis of sires of Lebedyn cattle and related populations, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.19(4), 149-158.

[10]Ladyka, V.I., Skliarenko, Yu. I, Pavlenko, Yu. M., 2020, Analysis of stud bulls of dairy breeds by composite genotypes of beta– and kappa-casein. Animal Breeding and Genetics. Kyiv, 2020. Issue 60. pp. 99-109.

[11]Metlytska, O., Kopylov, K., Berezovskyi, O., 2016, Modern molecular genetic approaches for improving the efficiency of the breeding process in animal husbandry in Ukraine, Breeding and Animal Genetics, 51: 193-200.

[12]Poulsen, N., Glantz, M. Anette, K., Paulsson, M., Lotte, B., 2017, Comparison of milk protein composition and rennet coagulation properties in native Swedish dairy cow breeds and high-yielding Swedish Red cows. J. Dairy Sci., 100: 8722–8734.

[13]Ramakrishnan, M., Zhou, X., Dydak, U., Savaiano, D.A., 2023, Gastric Emptying of New-World Milk Containing A1 and A2 B-Casein Is More Rapid as Compared to Milk Containing Only A2 B-Casein in Lactose Maldigesters: A Randomized, Cross-Over Trial Using Magnetic Resonance Imaging. Nutrients, 15(4): 801.

[14]Sebastiani, C., Arcangeli. C.,, Torricelli, M., Ciullo, M., D'avino, N., Cinti, G., Fisichella, S., Biagetti, M., 2022, Marker-assisted selection of dairy cows for β-casein gene A2 variant, Italian Journal of Food Science, 34 (2): 21–27.

[15]Vallas, M., Kaart, T., Värv, I. Jõudu, I., Viinalass, H., Pärna, E., 2012, Composite β-κ-casein genotypes and their effect on composition and coagulation of milk from Estonian Holstein cows. J. Dairy Sci., 95: 6760–6769.

SOME ENVIRONMENTAL PARAMETERS VERSUS VEGETATIVE AND FRESH PODS' YIELDS OF OKRA (A*belmoschus esculentus* L. *Moench*)

Wasiu Agunbiade LAMIDI[1], Michael Segun AFOLABI[2], Mosobalaje Abdulsalam MURTADHA[2], Kabiru Alani SHITTU[2], Elizabeth Abiola OJELEYE[2]

[1]Osun State University, Faculty of Engineering, Department of Agricultural Engineering, Osogbo, Nigeria, Phone: +2348135860977; E-mail: wasiu.agunbiade@uniosun.edu.ng
[2]Osun State University, College of Agriculture, Department of Agronomy, Ejigbo, Osogbo, Phone: +2348060351474; E-mails: michael.afolabi@uniosun.edu.ng, mosobalaje.murtadha@uniosun.edu.ng, kabiru.shittu@uniosun.edu.ng, abiola.ojeleye@uniosun.edu.ng

Corresponding author: wasiu.agunbiade@uniosun.edu.ng

Abstract

The research work evaluated the yields of fresh pods and vegetativeness of okra (Abelmoschus esculentus L.) leaves when they were naturally subjected to different environmental parameters at two different years. The okra crops were planted two times, in the rainy season of 2019 and in 2020 between May and August. Temperature and humidity values were taken at 10.00 h and 14.00 h daily from School meteorological unit. Temperature-Humidity-Index (THI) values were computed. Yield parameters namely plants' heights, Leaf Area Index (LAI), number of leaves, stem girth, cumulative yields of leaves and okra fresh pods were measured. Results show that okra planted in 2019 gave the highest vegetative yield via LAI (398.50 m^2) and number of leaves (16.50) in 2019, the values in 2019 have increase of 9.57% and 8.91% respectively over their corresponding values in year 2020. Also, the THI directly affects the growth rates, yield components and average cumulative yields of fresh okra pods at the significant difference ($P \leq 0.05$).Years of planting and season of planting, temperature and humidity of the environment affect the yield and yield components of okra and the project is feasible in economic sense.

Key words: *leaf area index, plants' heights, seasons of the year, THI-temperature and humidity index*

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is a crop that can be planted as leafy vegetable as well as fruit vegetable, because its leaves and fruits are eaten raw or cooked. It has high nutritious fresh leaves and fresh fruits which can help to normalize sucrose and assist to control the rate at which sucrose is stored in both animals' and human bodies [15]. Okra is planted in different parts of the world, Africa, America, Asia and Europe and they are affected by different factors like soil types, breeds, environmental factors among others [15, 7, 9]. Okra's leaves and fresh fruits are used among south western people of Nigeria to make soup- a delicacy of nutritive values. Okra soup is prepared after size reduction have been done to the leaves or the green fresh pods that are usually harvested when they are just about to be matured. The reason why harvesting is very timely is because when they are fully matured, they become more fibrous and non-delicate and non-delicious either raw or when cooked. Otherwise, the pods are left to dry for the seeds to be planted in the next season. Okra is a good source of vitamins, minerals, fibres and antioxidants. It contains sticky, slippery, 'slimy', highly viscous juice that people make use of to thicken sauce [3, 1, 4]. The fresh fruit pods while eaten raw or cooked drops, and is slippery or 'slimy' mouth feel.

In the face of current global climate change, there is a need for improving on better production techniques toward increment in the yield of the okra; to further improve its overall yields in vegetativeness and fresh pods, especially now that the world is facing global warming, some other improvements in growing of crops are needed. These may be in the form of climatic modifications/integration at the crop surfaces. Or it may be strategical

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planting of different kinds of crops according to seasons because seasons have been found to affect some yields of certain crops [16].

Although okra have been researched into by some previous works [15, 3, 6], the study of temperature and humidity on the plant still have to be researched into [6, 17, 8]. Because of the importance of okra to man and its multi-purpose uses, it has therefore become necessary to study okra production under different planting conditions with the intension to boost food supply.

The goal of this research was to evaluate the vegetativeness of leafy okra and the fresh pods' yield when they are exposed naturally to different temperatures and humidities at two different years.

MATERIALS AND METHODS

The field experiment was conducted at the Teaching and Research Farms of the College of Agricultural Production Management and Renewable Natural Resources, Osun State University, (7.8717; 4.3067) Ejigbo campus in 2019 and 2020. The vegetation and weather, just like in south west Nigeria where Osun State is situated, is rain forest type with two peaks of rain which is between 1,158 mm-1,250 mm per annum. The temperature is high all the year round with range between 28°C-33°C, range of relative humidity is 65-85%.The okra seeds were planted two times, in each of the rainy season between May and August -a period of about 120 days each in 2019 and in 2020 years. The variety of okra used was *finger nail okra* as it is popularly known in South Western Nigerian States. The conventional rate of 10 tons/ha of poultry manure was supplied to the plots4 weeks before the seeds were planted. The number of the weeks allowed all the soil to have mixed up thoroughly with the poultry manure to be able to be absorbed as nutrients for the crops. Temperature and humidity values were taken at 10.00h and 14.00h daily from School meteorological unit. Temperature-Humidity-Index (THI) values were evaluated using the following expression:

$$THI = t_{db}-[0.31(1-\frac{RH}{100})(t_{db}-14.4)] \text{ in } ^oC \ [10]$$

where:

THI = Temperature-Humidity Index

t_{db}= dry bulb temperature, ^oC

RH = relative humidity, %

The computed THI values were the results from combination of temperature and humidity as a degree of measure of comfort/discomfort experience by animals and by extension, by crops when computed from temperature and humidity values using THI equation [10]. Also, measured were plant height, number of leaves, number of branches, stem girth. Other parameters measured were plant heights using metre rule, number of leaves, and number of branches by direct counting of their number. Stem girth was also measured using vernier callipers. Besides, measured also were vein lengths using metre rule and leaf area index using portable leaf area metre, LI-COR LI-3000C, made in USA. The okra fresh fruits were harvested at 4 full days intervals (96 hrs) in compliance with the tradition in the area of the experiment. The leafy and fruit yields of okra were measured using standardized weighing scale(digital balance (Camry 50 kg weighing scale, model CA277HL, made in Nigeria).

The leaves' weights were measured only when they were about just to drop off from the plant. This period was closely monitored per leaf per plant to remove them for weighing before they turned into yellowish colour on the plant.

Mean cumulative weights of okra fruits and leaves were found at the end of the experiment for each of the years. There was a plot of land cultivated near the research plot which was planted normally with okra to serve as a control experiment.

It also has rate of 10 tons/ha of poultry manure supplied to it 4 weeks before the seeds were planted.

The farm plots used for both years were not on the same plot of land, adjacent lands were used to reduce interference. All the characters were subjected to descriptive statistics and one-way ANOVA.

RESULTS AND DISCUSSIONS

There were increments in number of leaves of okra during the first three weeks of growth especially in 2020. The increase in the number of leaves of okra during these earliest weeks could be as a result of foliage development, Figures 1 and 2, it could also be from some other factors, like the THI, a product from combined evaluation of temperature and humidity values. Because increase in vegetativeness of leafy okra will start from the development of foliage, and since these foliage's development happened as at when due (first two weeks after planting), it could be surmised that their ease of formation could be as a result of many factors. Some of these factors could be from the soil; changes in environmental parameters; breed of okra in use and the availability of nutrients in the soil just like it affects other green crops [5, 11]. More leaves were formed in the third week through to eighth week and especially in 2019 during which the number of leaves were continuously on the increase per plant, Figure 1.

For both years, there were statistical differences ($P \leq 0.05$)in the mean values, implying significant differences among some yield components of okra namely plants' heights, leaf area index and stem girth. However, it was not statistically/significantly different for the number of leaves as revealed in Table 1. This can be surmised to mean that the performances of okra were different for both years. This could be as a result of differences in the environmental parameters with temperatures and humidity values that were different in both periods, even though both seasons were rainy season.

There were variations in the temperature and humidity values collected from the experimental field spot in both years. Even though there were variations, but there were no statistical differences ($P \leq 0.05$) among the THI values in both years. But variations were enough to have the computed temperature-humidity index, THI values as shown in Table 2 to reveal non-uniformity at different stages of the growth in the weeks. The THI values were between the range 29.70 and 34.40°C in 2019, this range was higher than what was obtained in 2020, notwithstanding all these are within the comfort zone for both animals and crops in the tropics and therefore suitable for the okra [11].

Also, each of the corresponding weekly THI mean values were more in 2020 than in 2019 except in week 2. This implies that 2020 was warmer than 2019, this may explain why all the growth and yield parameters in 2020 were less than their corresponding values in 2019. Implication could be that okra will not grow vegetatively well in higher temperature and low humidity climatic conditions.

Although the okra planted were not induced environmentally, yet THI directly affects their growth rates and hence leafy yields and therefore could have resulted into statistical differences ($P \leq 0.05$) among the yield components of okra and average cumulative yield of fresh okra pods, Table 1.

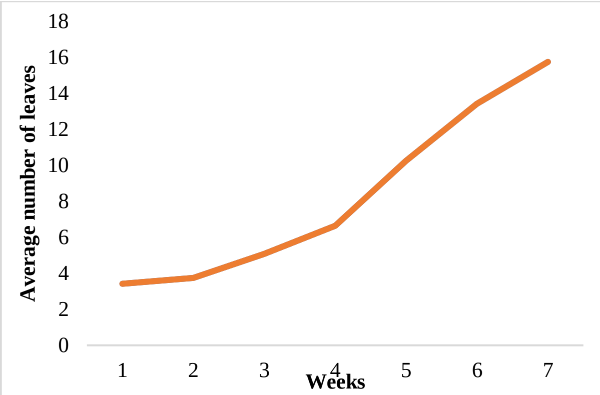

Fig. 1. Average number of leaves of okra at different weeks in 2019 rainy season
Source: Field work 2019.

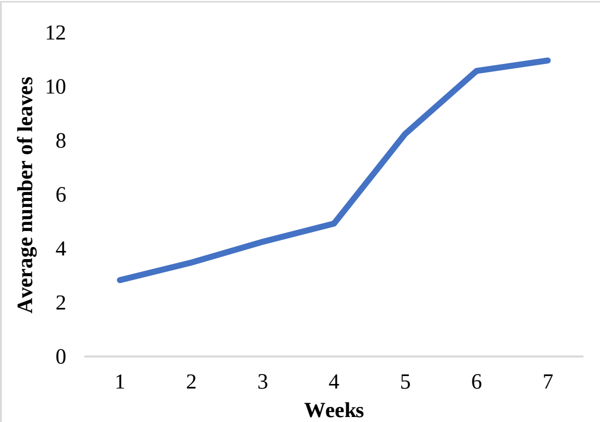

Fig. 2. Average number of leaves of okra at different weeks in 2020 rainy season
Source: Field work 2020.

Table 1. Mean characteristic performances of okra in 2019 and 2020

Years of planting	Plant Height, cm	Leaf Area Index, cm^2	Number of Leaves	Stem Girth, cm	Average Cumulative yield, ton/ha
2019	27.55a ± 7.13	398.50 a± 13.12	16.50 a± 2.11	1.75b ± 6.34	13.285a± 2.34
2020	21.00b ± 2.12	363.69b ± 12.12	15.15 a± 2.00	2.04a± 12.10	12.980b± 2.22
Control	19.00 ± 2.12	313.52 ± 12.12	14.75 ± 2.00	2.00 ± 12.10	11.882 ± 4.12

ab= means on the same column with different letters are significantly different. (P≤ 0.05).
Source: Field work 2019-2020.

Table 2. THI mean values at different weeks in 2019 and 2020

Weeks	THI	
	2019	2020
1	34.40a± 2.11	35.28a± 0.62
2	33.52a± 1.10	33.15a± 2.12
3	32.17a± 2.02	32.85a± 1.11
4	29.70ab± 1.12	30.92ab± 1.20
5	31.30ab ± 2.23	31.75ab± 2.10
6	30.90ab± 0.42	31.79ab± 2.01
7	31.12ab± 2.22	31.33ab± 1.10

ab= means on the same column with different letters are significantly different. (P≤ 0.05).
Source: Field work 2019-2020.

As a result of the variations in the temperatures and humidities and the THI values, as shown in Table 2 which were moderate and were within the ranges that will allow okra to perform well, okra planted in 2019 gave the highest vegetative stance, Table 1. Also, the Leaf Area Index = 398.50, and number of leaves = 16.50 in 2019, the values in 2019 are respectively 9.57% and 8.91% increase over the 2020 year.

These high vegetative stances could have evidenced in the yields during the days of harvesting which were increasing like sigmoid curves up to the maximum (1,980 kg and 1,800 kg for 2019 and 2020 years respectively), Figure 3.

There were periods of increment from one harvesting to the next for the initial 37 days and thereafter, the diminishing returns set in for the harvesting for the next 40 days after the peak harvest in the 37th day. This was a normal feature of okra farm like other agricultural produce as it shows that an optimum level of output has been attained between the 37 and 41 days when the harvesting have started. The lower R square values depicted in both years could only mean that the dependent variable x (days of harvesting) is favourably explained by independent variable y (yield in tons/ha) in a regression model, that is 70 or 71% of the observed variations in the yield components and cumulative yield of the fresh pods of okra can be explained by the model inputs.

This high vegetativeness recorded could also have resulted into the high cumulative yield of 13.285 and 12.980 tons/ha for 2019 and 2020 years respectively Table 1.

These yields of okra fresh pods got were higher than the highest okra fresh pod yields of 7.36 and 7.43 tons/ha obtained in the earlier experiment by [2] in the south eastern part of the same country and were higher than 4.9 tons/ha okra fresh pod harvested yield recorded by [6] in the Northern part of the country.

These differences could be as a result of soil differences, management and handling (the poultry manure used for the soil could have increased the yield).

The lesser development of vegetative characters in 2020 could have happened because other factor like wind effects could also have affected the yield [12, 13]. This could be so because the precipitations within each of the three months in both years were almost the same and the soil where the crops were experimented upon were almost the same from earlier experiment [14].

Again, due to the low values of the THI in 2019, the crops could be adjudged to be comfortable at those temperatures, humidities and there were no evidence of lodging of okra plant nor torn leaves [17]. Therefore, the okra could be adjudged to have been better in 2019 than in 2020 as evident in the LAI and number of leaves, both parameters signify the increased vegetative yield and fruit yields of the okra.

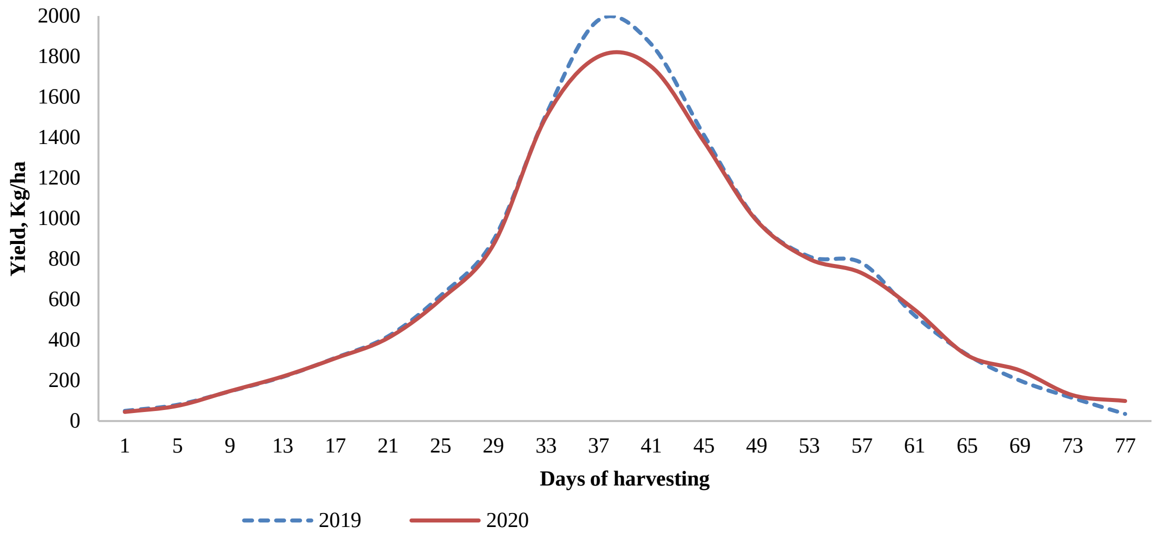

Fig. 3. Average yield of fresh okra pods at 4-days of harvesting interval showing the peak yields at 2019 and 2020
where: the yield in tons/ha is y and the days of harvesting is x, then,
$y= -0.0052x^3 - 0.431x^2 + 63.957x - 316.22$, $R^2 = 70\%$ for year 2019; and,
$y= -0.0045x^3 - 0.4507x^2 + 62.02x – 302$, $R^2 = 71\%$ for year 2020
Source: Fieldwork 2019-2020.

Economic feasibility of the fresh okra pods

The costs were estimated to be ₦862,000 ($1,149.33; Assuming 1$ = ₦750.00) needed for okra farming in the area. This was for both years, as inflation was not set in because of the stability in the supply of premium fuel in the country during the periods (fuel crisis always induce inflation in Nigeria).

The cost of harvesting is always minimal since the market women will always come to the farm to harvest fresh okra pods themselves and weigh themin the farm for monetary cost to be paid to the farmers (Table 3).

Table 3. Table of analysis of cost(₦) incurred, sales made and feasibility

S/N	Items	Cost incurred (₦)	Sales (₦) in 2019	Sales (₦) in 2020	Profit (₦) in 2019	Profit (₦) in 2020
1	Costs of renting a hectare of land for 4 months	15,000				
2	Land clearing	20,000				
3	Procurement of seeds and chemicals and spraying	50,000				
4	Cost of ploughing twice	25,000				
5	Transporting poultry manure and spreading	520,000				
6	Seed planting	32,000				
7	Weeding	110,000				
8	Transportation during Harvesting	32,000				
9	Cost of marketing	18,000				
10	Miscellaneous	40,000				
	Total	862,000 ($1,149.33)				
	Sales in the years	Not Applicable	1,328,500 ($1,771)	1,298,000 ($1,731)		
	Profit for each year				466,500 ($622)	436,000 ($581.33)

Source: Farm works 2020.

The cost price per okra fluctuates, but at the time of the experiment, the cost per 1 kg was ₦100 ($0.13). this translated to ₦1,328,500 ($1,771) in 2019 and ₦1,298,000 ($1,731) in 2020.

Profits after were ₦466,500 ($622) in 2019 and ₦436,000 ($581.33) in 2020, Table 3.

The experiment was feasible because, there were profits of 54.12% and 50.58% of the total cost incurred on the project in 2019 and 2020 respectively.

Besides, there are no any other costs that would be necessary during the cultivation, harvesting and sales by the farmers or the middle women (some of them are women-in-agriculture).

CONCLUSIONS

THI directly affects growth rates of okra and hence their leafy and fresh pods yields. The years of planting and season also resulted into statistical differences among the yield components of okra showing that seasons affect the yield parameters of okra and therefore its vegetativeness and cumulative yield of fresh okra pods. The project is feasible economically in the area.

REFERENCES

[1]Adelakun, O.E., Ade Omowaye, B.I.O., Adeyemi, I.A., Van de Venter, M, 2012, Mineral Composition and the functional attributes of Nigerian okra seed (*Abelmoschus esculentus L*) flour. Food Research International. 47(2):348-352.

[2] Agba, O.A., Mbah, B. N., Asiegbu, J.E., Adinya, I. B., 2011, Effects of spacing on the growth and yield of okra (*Abelmochus esculentus*) L. Moench in Obubra, Cross River State. Global Journal of Agricultural Sciences, 10(1): 57-61, https://www.ajol.info/index.php/gjass/article/view/79078 , Accessed on 02/07/2023

[3]Akintoye, H. A., Adebayo, A. G., Aina, O. O., 2011, Growth and yield response of okra intercropped with live mulches. Asian Journal of Agricultural Research, 5: 146 – 153.

[4]Bemiller, J.N., Whistler, R.L., Barkalow, D.G., Chen, C.C., 1993, Industrial Gums (Third Edition). In: Chapter 9 - Aloe, chia, flaxseed, okra, psyllium seed, quince seed, and tamarindgums, pp. 227-256, https://doi.org/10.1016/B978-0-08-092654-4.50013-9.

[5]Ilupeju, E. A. O., Akanbi, W. B., Olaniyi, J. O., Lawal, B. A., Ojo, M. A., Akintokun, P. O., 2015, Impact of organic and inorganic fertilizers on growth, fruit yield, nutritional and lycopene contents of three varieties of tomato (*Lycopersicon esculentum* (l.) Mill) in Ogbomoso, Nigeria. African Journal of Biotechnology, 14(31):2424-2433.

[6] Jamala, G. Y., Boni, P. G., Abraham, P., Musa, A. M., 2012,Soil status and yield response of different varieties of okra (*Abelmoschus esculentus* (L.) Moench) grown at Mubi floodplain, North Eastern, Nigeria. Journal of Agricultural Biotechnology and Sustainable Development 3(7): 120 -125, September 2012.

[7]Johari, N.S., Asilah, A. M., Zalina, I., Fazhana, I., Ab Latif, Z., Shaibatul' Islamiah, C. M., Tang, J. R., 2020, Effects of Fish Amino Acid (FAA) Application on Growth and Development of Okra (*Abelmoschus Esculentus*) at Different Sampling Times. Journal of Vocational Education Studies. 3(2): 35-42. 10.12928/joves.v3i2.2932.

[8]Katung, M. D., 2017, Productivity of Okra varieties as influenced by seasonal changes in Northern Nigeria. NotulaeBotanicae Horti Agrobotanici Cluj-Napoca, 35(1): 65–71, DOI: https://doi.org/10.15835/nbha351256

[9]Lamidi, W.A., Shittu, K.A., Akinrinade, E.O., 2022, Effect of organic amendments on the vegetative development of okra (*Abelmoschus esculentus L. Moench*) at different wind's directions. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(4):359-366.https://managementjournal.usamv.ro/pdf/vol.22_4/Art38.pdf. Accessed on 22/07/2023

[10]Lamidi, W. A., Ola, S. I., 2021, Modelling of the Temperature-Humidity Index (THI) and Ventilation patterns in the rabbits' pens. Ethiopian Journal of Environmental Studies and Management, 14 (4): 487-499. doi:http://doi: https://ejesm.org/doi/v14i4.8

[11]Lamidi W. A., Afolabi M. S., 2016, Influence of Some Environmental Factors on Maize Productivity in Osun State, Nigeria**.** Ethiopian Journal of Environmental Studies and Management, 9 (2), Supplementary 2: 1009-1021.http://www.ajol.info/index.php/ejesm/article/view/150117/139683.Accessed on 02/07/2023

[12]Lamidi, W. A., Afolabi, M. S., Murtadha, M. A., 2020, Performances of cucumber (*Cucumis sativus*) at different heights of the prevailing wind'sspeeds. Journal of Agricultural Engineering and Technology, 25(1):123-134, http://jaet.com.ng/index.php/Jaet/article/view/155/129. Accessed on 18/07/2023

[13]Lamidi, W.A., Akinrinade, E.O., Murtadha, M.A., 2019, Growth and yield of pumpkin (*Telfairiaoccidentalis*L) as affected by different prevailing wind speeds', heights and directions under different organic media. UniosunJournal of Agriculture and Renewable Resources, 3: 25-29, http://www.journals.uniosun.edu.ng/index.php/UJARR/article/view/518/360.Accessed on 02/05/2022

[14]Lamidi, W. A., Nwoke, O.C., Shittu, K.A., 2018, Assessment of soil characteristics under four cropping and land management systems in south west Nigeria.

African Journal of Agricultural Research,13(27): 1400-1406, DOI: 10.5897/AJAR2017.12227

[15]Maduwanthi, A.K.M.R.B., Karunarathna, B., 2019, Growth and Dry Matter Accumulation of Okra (*Abelmoschus esculentus L*.) as Influenced by Different Plating Pattern Under Okra -Cowpea (*Vigna unguiculata* L.) Intercropping. Journal of Horticulture and Plant Research, 7: 81-96. 10.18052/www.scipress.com/JHPR.7.81. Accessed on 03/07/2023.

[16]Murtadha, M.A., Adebooye, O.C., Sanni, T.A., Lamidi, W.A., Afolabi, M.S., 2018, Seasons and Farming Practice Effects on Yield and Growthaattributes of Cucumber (*Cucumis sativus* L.) Varieties. UNIOSUN Journal of Sciences, 3(2): 150-156.

[17]Tiamiyu, R.A., Ahmed, H.G., Muhammad, A.S., 2012, Effect of Sources of Organic Manure on Growth and Yields of Okra (*Abelmoschus esculentus* L.) in Sokoto, Nigeria. Nigerian Journal of Basic and Applied Science, 20(3): 213-216.

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USING NDVI CONVERTER APPLICATION FOR ASSESSMENT OF THE VEGETATION INDEX IN WINTER CEREALS AND OILSEED RAPE

Pavlo LYKHOVYD[1], Sergiy LAVRENKO[2], Nataliia LAVRENKO[2]

[1]Institute of Climate-Smart Agriculture, 9 Mykhaila Omelianovycha-Pavlenka Str, 01010, Kyiv, Ukraine; E-mail: pavel.likhovid@gmail.com
[2]Kherson State Agrarian and Economic University, 23 Stritenska Str, 73006, Kherson, Ukraine; Email: lavrenko.sr@gmail.com

Corresponding author: pavel.likhovid@gmail.com

Abstract

The purpose of the article was to describe the outcomes of an in-field evaluation of the NDVI Converter application, which was created to assess the normalized difference vegetation index (NDVI) using estimates of the percentage of green canopy cover. The study was carried out in 2023 on fields of winter wheat, winter barley, and winter oilseed rape in the phenological stages BBCH 21–32 and BBCH 18–39, respectively. The fraction of green canopy cover was estimated using the application Canopeo. By comparing the mean absolute percentage error and Pearson's correlation coefficient to the actual values of the spatial vegetation index, as determined by the platform OneSoil, the quality of the vegetation index evaluation was assessed. Thus, it has been established that NDVI Converter offers accurate vegetation index assessment for cereal crops, with mean absolute percentage error 16.23% and Pearson's correlation coefficient within 0.99, and reasonable quality for oilseed rape (statistical indicators of 46.61% and 0.99, respectively). After the adjustment, the accuracy score of the NDVI Converter increased up to 27.62% for oilseed rape, and 8.71% for winter cereals. Therefore, NDVI Converter could be recommended for practical use in case the spatial vegetation index is not provided by satellite imagery services.

Key words: *fraction of green canopy cover, NDVI, phenology, winter barley, winter oilseed rape, winter wheat*

INTRODUCTION

One of the major producers and exporters of grains worldwide is Ukraine [5]. Because of this, cereal crops benefit from significant attention paid to boosting output and lowering monitoring costs.
Current agricultural science and practice applies Normalized difference vegetation index (NDVI) to solve the tasks of remote crops conditions monitoring, crops mapping, crops productivity forecasting, phytosanitary monitoring, etc. [9, 12, 14, 15]. Therefore, the importance of this vegetation index for successful crop production is hardly to be overestimated.
However, not all crop producers have access to the platforms, which provide ready-to-use solutions for NDVI. Some of the products are expensive, and most free of charge services have strict limitations, e. g., limited areas or number of fields, limited time series of satellite imagery, and limited areas covered. That is why in some cases farmers cannot implement the latest scientific approaches for crop monitoring and yield simulation, where NDVI is utilized.
To solve this problem, NDVI Converter mobile application has been developed. Its main purpose is to provide crop producers with a simple tool for getting NDVI values for their fields using the fraction of green canopy cover (FGCC).
FGCC could be easily evaluated using Canopeo mobile application through photographing field plots on a smartphone's camera [16]. Then, a farmer can use the obtained FGCC value in NDVI Converter, and in several clicks, one gets the value of the vegetation index on a screen of a smartphone.
NDVI Converter mobile application is built up based on scientific research on the interaction and relationship between FGCC and NDVI, conducted for major crops, cultivated in the South of Ukraine [10, 11].
Therefore, the application seems to be robust and reliable tool. Although there is good

scientific evidence for the principles, laid up into the basis of the application, it is important to test its performance in real in-field conditions using the exterior data.
This study's primary objective was to assess the accuracy of the NDVI assessments made by the NDVI Converter on the winter cereals (namely barley and wheat) and winter oilseed rape crops grown in the southern Ukraine.
The evaluation was performed in the initial stages of the crops' growth and development, as on these stages the foundation for further productivity of the crops is laid, thus they require careful monitoring, which could be performed through the vegetation indices, in our case, NDVI [2, 18].

MATERIALS AND METHODS

The in-field fixation of the FGCC was carried out in 2023 on the fields of winter wheat, winter barley and winter oilseed rape, located in Odesa region, in the neighbourhood of Stavrove village. The fixation was performed using a smartphone's camera, with strict accordance to Canopeo mobile application guidelines [8]. The examples of the taken images of the crops are presented in Photos 1 and 2. All the photographs made were linked to geographical network and further allocated on the OneSoil platform to corresponding spatial NDVI values of moderate resolution (250 m), collected from the combined imagery of the satellites' sensors Sentinel-1 and Sentinel-2.

Photo 1. The image of winter cereals, processed in Canopeo application
Source: The authors' own study.

Photo 2. The example of the image for winter oilseed rape crops, used for processing in Canopeo
Source: The authors' own in-field research work.

The study was performed in the stages BBCH 21-32 (tillering – beginning of stem elongation) for winter cereals [21], and BBCH 18-39 (stem elongation) for winter oilseed rape [4].
To determine the values of the vegetation index, the FGCC values were entered into the corresponding cells of the NDVI Converter mobile application. In total, 72 pairs of input data (FGCC – NDVI) were analyzed.
Further, the modelled in the application and true values of NDVI, obtained at the OneSoil platform, were compared through the calculation of Pearson's correlation coefficient (R) and mean absolute percentage error (MAPE). Statistical computations, as well as graphical work, were performed in Microsoft Excel 365 through the standard algorithms [1, 13].

RESULTS AND DISCUSSIONS

As a result, the Table 1 was formed to present the outcomes of statistical comparison of the true and assessed in NDVI Converter values of the normalized difference vegetation index.
The fitting quality is quite high and that the simulated and genuine NDVI values coincide very well, with the correlation coefficient varying between 0.98 and 1.00. [17].
The accuracy of NDVI Converter mobile application differs by the studied crops, with the best accuracy provided for the cereals (MAPE is 16.23%), and the worse precision for the oilseed rape (MAPE is 46.61%). Generally, the values of MAPE for winter wheat and barley falls within the interval 10-

20%, so that it could be considered as a marker of good prediction [3]; while the MAPE 46.61% tells that the accuracy of NDVI modelling for oilseed rape is reasonable and should be used cautiously. The main reason of such an outcome could be in the difference of the crops' conditions at the moment of in-field screening: winter cereals had better winter resistance, therefore, their early-spring conditions were sufficiently better than of oilseed rape, which was partially damaged by frosts and diseases.

Table 1. Evaluation of NDVI Converter for assessment of the spatial vegetation index values

Crop name	R	R^2	MAPE (%)
Winter cereals	0.9949	0.9897	16.23
Winter oilseed rape	0.9853	0.9707	46.61

Source: The authors' own calculations.

Visualization of the comparison between the modelled and actual values of the NDVI revealed that the modelled index values tend to be less than the true ones (Figures 1 and 2).

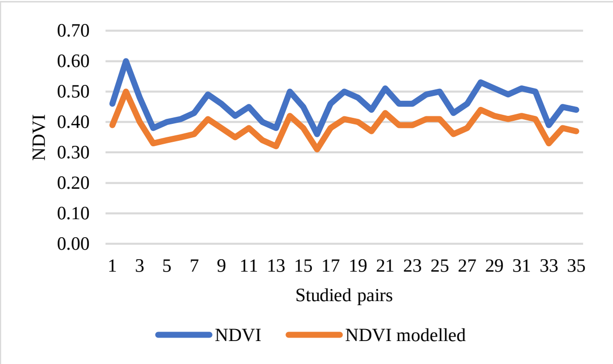

Fig. 1. Visual Evaluation of the NDVI Modelling Quality for Winter Cereals at the Stage BBCH 21-32
Source: The authors' own graphical work.

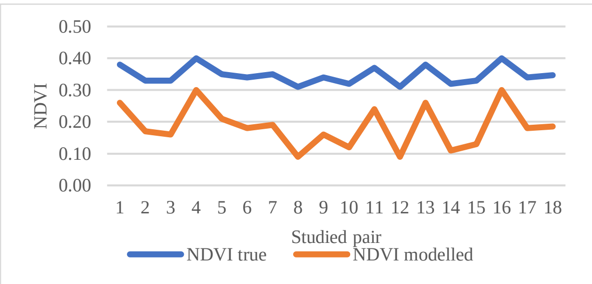

Fig. 2. Visual Evaluation of the NDVI Modelling Quality for Winter Oilseed Rape at the Stage BBCH 18-39
Source: The authors' own graphical work.

The greater discrepancy is observed for winter oilseed rape (the amplitude of the absolute error is 0.12), while the latter for winter cereals is slight (the amplitude is 0.05). The highest value of the absolute error for the oilseed rape crops was 0.22, and for the cereals – 0.10.

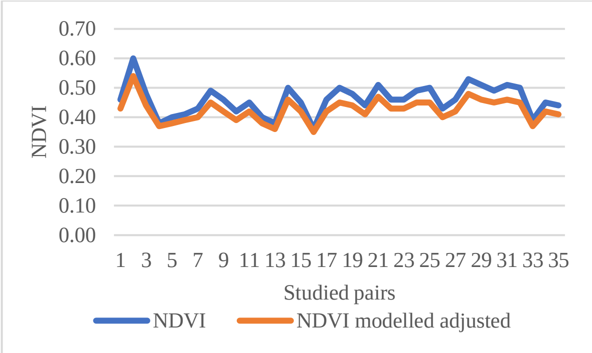

Fig. 3. Visual Evaluation of the NDVI Adjusted Modelling Quality for Winter Cereals at the Stage BBCH 21-3
Source: The authors' own graphical work.

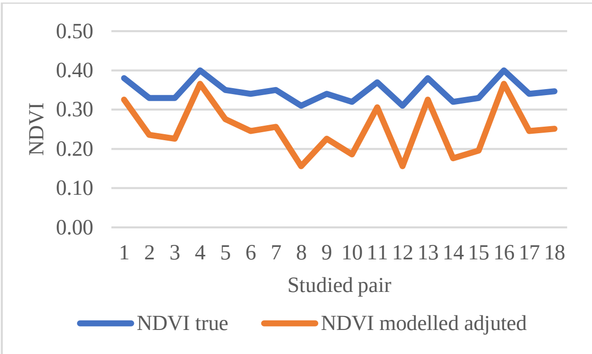

Fig. 4. Visual Evaluation of the NDVI Adjusted Modelling Quality for Winter Oilseed Rape at the Stage BBCH 18-39
Source: The authors' own graphical work.

Therefore, it should be noted that NDVI Converter's values of assessed vegetation index underestimate the real conditions of the crops' growth and development, and the adjustment for the estimation should be applied. In the intercourse of statistical estimation, it was established that the adjustment is to be performed by 0.07 NDVI score for oilseed rape, and by 0.04 – for winter cereals. After the adjustment, the precision of the modelled NDVI increased, and the MAPE changed to 27.62% for oilseed rape, and to 8.71% for winter cereals. The results of the visual evaluation of the adjusted models are provided in the Figures 3 and 4.

To sum up, the performance of NDVI Converter application seems to be good enough to provide reliable assessment of NDVI for the cropping areas, where for any reasons it is impossible to obtain direct ready-to-use spatial images.

The findings of the evaluation of the mobile NDVI Converter application are presented in our study for the first time. However, given the close relationship between the normalized difference vegetation index (NDVI) and crop yields, there are several studies in which writers endorse the idea of utilizing the fraction of green canopy cover (FGCC) as an input [7, 20]. It is interesting that some studies are devoted to the subject of reverse conversion between the green canopy cover percentage and NDVI, proving strong direct interconnection (determination index ≥75%) between the two indices [19]. However, some scientists claim that there is lack of evidence for using spatial index for canopy assessment and mapping, because of extremely low interconnection between them [6]. We believe that such a difference in the statements and scientific results could be put upon different methodological and technical approaches used, as well as different kind of vegetation, which has been put to evaluation in different studies.

To sum up, the NDVI Converter mobile application is an innovative and simple tool to assist current agricultural science and practice in reaping the benefits of crop modelling and monitoring through the mobile devices in geoinformation systems. It is free to use, as well as Canopeo mobile application, and requires no specific qualification or knowledge to be successfully implemented. Therefore, this mobile application may save costs and time of farmers, who are keen to try novel approaches in crop production with no economic risks and extra expenditures.

CONCLUSIONS

The results of the in-field testing of NDVI Converter mobile application revealed that the latter is a simple and reliable tool for the assessment of NDVI values at the fields, where this index cannot be obtained at spatial monitoring platforms and hubs. The fitting quality is very high, and the accuracy of the index estimation is good for winter cereals and reasonable for oilseed rape, so that to use it in the crop monitoring.

REFERENCES

[1]Akoglu, H., 2018, User's guide to correlation coefficients. Turkish Journal of Emergency Medicine, 18(3): 91-93.
[2]Anonymous, 2020, Oilseed Rape Growth Guide. AHDB Cereals & Oilseeds.
[3]Blasco, B.C., Moreno, J.J.M., Pol, A.P., Abad, A.S., 2013, Using the R-MAPE index as a resistant measure of forecast accuracy. Psicothema, 25(4): 500-506.
[4]Böttcher, U., Rampin, E., Hartmann, K., Zanetti, F., Flenet, F., Morison, M., Kage, H., 2016, A phenological model of winter oilseed rape according to the BBCH scale. Crop and Pasture Science, 67(4): 345-358.
[5]Fesenko, H., Averchev, O., Lavrenko, S., Avercheva, N., Lavrenko, N., 2022, Monitoring, assessment and development prospect of the cereal crop market in Ukraine, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.22(2), 317-323.
[6]Ghorbani, A., Mossivand, A.M., Ouri, A.E., 2012, Utility of the Normalized Difference Vegetation Index (NDVI) for land/canopy cover mapping in Khalkhal County (Iran). Annals of Biological Research, 3(12): 5494-5503.
[7]Goodwin, A.W., Lindsey, L.E., Harrison, S.K., Paul, P.A., 2018, Estimating wheat yield with normalized difference vegetation index and fractional green canopy cover. Crop, Forage & Turfgrass Management, 4(1), 1-6.
[8]Jáuregui, J.M., Delbino, F.G., Bonvini, M.I.B., Berhongaray, G., 2019, Determining yield of forage crops using the Canopeo mobile phone app. Journal of New Zealand Grasslands, 81: 41-46.
[9]Lykhovyd, P.V., 2021, Forecasting oil crops yields on the regional scale using normalized difference vegetation index. Journal of Ecological Engineering, 22(3): 53-57.
[10]Lykhovyd, P.V., Vozhehova, R.A., Lavrenko, S.O., Lavrenko, N.M., 2022, The study on the relationship between normalized difference vegetation index and fractional green canopy cover in five selected crops. The Scientific World Journal, 2022, 8479424.
[11]Lykhovyd, P., Vozhehova, R., Lavrenko, S., 2022, Annual NDVI dynamics observed in industrial tomato grown in the South of Ukraine. Modern Phytomorphology, 16: 160-164.
[12]Mazzetto, F., Calcante, A., Mena, A., Vercesi, A., 2010, Integration of optical and analogue sensors for monitoring canopy health and vigour in precision viticulture. Precision Agriculture, 11: 636-649.

[13]Millar, N., 2001, Biology statistics made simple using Excel. School Science Review, 83: 23-34.
[14]Osinnii, O., Averchev, O., Lavrenko, S., Lykhovyd, P., 2022, Cost-effective and time saving method of phenological monitoring using satellite imagery in drip-irrigated rice. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(4): 511-515.
[15]Pan, Z., Huang, J., Zhou, Q., Wang, L., Cheng, Y., Zhang, H., Blackburn, G.A., Yan, J., Liu, J., 2015, Mapping crop phenology using NDVI time-series derived from HJ-1 A/B data. International Journal of Applied Earth Observation and Geoinformation, 34: 188-197.
[16]Patrignani, A., Ochsner, T.E., 2015, Canopeo: A powerful new tool for measuring fractional green canopy cover. Agronomy Journal, 107(6): 2312-2320.
[17]Saigal, S., Mehrotra, D., 2012, Performance comparison of time series data using predictive data mining techniques. Advances in Information Mining, 4(1): 57-66.
[18]Satorre, E.H., Slafer, G.A., 1999, Wheat: Ecology and Physiology of Yield Determination. CRC Press.
[19]Tenreiro, T.R., García-Vila, M., Gómez, J.A., Jiménez-Berni, J.A., Fereres, E., 2021, Using NDVI for the assessment of canopy cover in agricultural crops within modelling research. Computers and Electronics in Agriculture, 182: 106038.
[20]Trout, T.J., Johnson, L.F., Gartung, J., 2008, Remote sensing of canopy cover in horticultural crops. HortScience, 43(2): 333-337.
[21]Ventura, F., Marletto, V., Traini, S., Tomei, F., Botarelli, L., Rossi, P., 2009, Validation of development models for winter cereals and maize with independent agrophenological observations in the BBCH scale. Rivista Italiana Di Agrometeorologia, 14: 17-26.

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TECHNOLOGY ADAPTATION AND ECONOMIC EFICIENCY FOR WINTER WHEAT CROP IN THE CONDITIONS OF CLIMATE CHANGES – SOUTH-EAST ROMANIA, DOBROGEA AREA

Dumitru MANOLE[1,2], Ana Maria GIUMBA[2], Agatha POPESCU[1, 3, 4]

[1]Academy of the Romanian Scientists, 3, Ilfov Street, Bucharest, Romania, E-mails: dumitrumanole38@yahoo.ro, agatha_popescu@yahoo.com
[2]Commercial Company Sport Agra Ltd., 4, Zorelelor Alley, Amzacea Village, Constanta County, Romania, Mobile Phone: 0722698668, E-mails: dumitrumanole38@yahoo.ro, anamaria.giumba@yahoo.com
[3]University of Agronomic Sciences and Veterinary Medicine Bucharest, 59 Marasti Blvd, District 1, 011464, Bucharest Romania, Phone: +40213182564, Fax: +40213182888, Emails: agatha_popescu@yahoo.com
[4]Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu-Sisesti", 61 Marasti Blvd, District 1, 011464, Bucharest Romania, Email: agatha_popescu@yahoo.com

Corresponding author: dumitrumanole38@yahoo.ro

Abstract

The paper presents the behaviour of some wheat varieties under the years 2014, 2016, 2018, 2019, 2020, 2023 conditions in Dobrogea area in demonstrative plots carried out at S.C. SPORT AGRA S.R.L. Amzacea, Constanta County. The main aspects emphasized in this research area have been: climatic conditions, obtained yield, and economical efficiency. Looking to the pathogens, for wheat Septoria tritici showed an AR between 17-27% and Pyrenophora graminea showed a low atack (AR = 4.5-17.5%). The pathogen Puccinia striiformis was present in low precentage (AR = 0-13.5%) in the 2018 April observations. For crop protection against pathogens, 2 foliar tratments with fungicides were applied, Artea 330 EC(ciproconazol 80 g/l + propiconazol 250 g/l) 0,4 l/ha, in March and Priaxor EC (fluxapiroxad 150 g/l + piraclostrobin 75 g/l) 1l/ha and in April respectively. Fungal treatments have stopped the development of foliar and ear diseases.The beneficial effects were found in the good yields obtained in 2014, 2016, 2018, 2019, except the years 2020 and 2023. In 2020 Otilia reached 2,370 kg/ha, Miranda 2,260 kg/ha and Solindo variety 4,297 kg/ha and Ursita 4,165 kg/ha in 2023. All these special yields have been obtained under non-irrigated conditions.

Key words: *climate change, winter wheat, technology adaptation, pathogens, yields, Dobrogea, Romania*

INTRODUCTION

Wheat is "the king of cereals" because it is a staple cereal supplying high value grains producing "our bread of everyday" and not only. Wheat is the most cultivated crop worldwide, in the year 2021, being cultivated on 220.7 million ha from which there were harvested 778 million metric tons grains (850 million short tons) [44].

In the year 2021/2022, the most important wheat producers in the world were the European Union, China, and India which together produced 384.7 million metric tons, accounting for 49.38% of the global output. In 2022/2023, China, the EU and India achieved 375.4 million metric tons [45].

In the European Union, in 2022, France was the top producer (34.8 million tons), followed by Germany (22.7 million tons) and Poland (13.2 million tons). Romania being ranked fourth for 9.18 million tons harvested from 2.1 million ha [1].

Romania plays an important role in the EU being among the top producers, exporters and importers of wheat [34, 36]. In this country, wheat production occupies the top position, representing 45.43% of cereals production (18.84 million tons), being followed by maize [30].

In 2022, the highest average yield in the world was obtained by France (7.7 tons/ha), Germany (7.6 tons/ha), Poland (5.2 tons/ha) and Romania (4.2 tons/ha) [1].

Despite that the cultivated area with wheat is increasing from a year to another at the global level, production goes down because of many factors, varying from a country to another, but also due to the negative impact of the climate change [7].

During the last decade, the EU countries were facing extreme meteorological phenomena (huge rainfalls, high temperatures, heat waves, droughts etc) which affected wheat and other agricultural crops, resulting in poorer yields, higher production costs, price volatility, and a lower grains quality [6].

In the last 35 years, Romania was affected by the increase of the annual average temperature and decline in the annual average precipitations and a higher and higher deficit in soil water.

The year 2015 was one of the warmest years with an increase of +1.96^{0}C compared to the average temperature during 1961-1990. During the last seven year 2016-2023 more longer droughts have emerged, Dobrogea area being among the high risk of drought regions in the country, as the annual average temperature is over 11^{0}C and the rainfalls range only between an average of 351 and 450 mm/year [37].

Romania's agriculture was among the most affected domains by climate change [42].

Wheat, maize, sunflower and other crops registered lower yields in the last decade with large variation in total production and market price both in Romania and in the EU [38, 39, 40].

Dobrogea is an important region of Romania where wheat, maize, barley, sorghum and sunflower are cultivated [15].However, it is recognized as an area with specific climatologic conditions concerning low rainfalls and high temperatures, whose level has deeply changed during the last decade. More and more weak precipitations, mild winters lacked or with a low snow layer, a low water reserve into the soil, higher and higher temperatures, long and strong droughts, pedological droughts have a higher frequency in Dobrogea region and mainly in its South, which are considered arid areas [2, 28].

All these climate factors have influenced the size of the cultivated area, production performance in terms of yield and economic efficiency of crop farming.

In 2022,inConstanta County, situated in the South Dobrogea, there were cultivated 443,347 ha, by 6.34% less than in 2018.

Wheat had the largest area, accounting for 162,688 ha, but by 9.27% smaller than in 2018, which led to a lower share of wheat, from 37.8% in 2018 to 36.6% in 2022, in the county cultivated surface [4, 29].

In 2022, the average wheat production per ha was 4,989 kg, being by 12.12% smaller than in 2018.

Along this period, its level went up and down depending in the variation of the climate factors. The lowest yield was 983 kg/ha in the year 2020 [49].

The lower productions are explained by climate change which favored the attack of pests and diseases appearance, which involved plant protection measures [3, 26, 41].

Under these conditions of climate change in Dobrogea, the scientific research tried to help the farmers looking for and providing solutions to mitigate the negative effects.

Important studies were destined to test different wheat varieties [8, 31, 32, 47], barley and wheat varieties [10, 12, 19, 24], and sunflower hybrids [23] in Dobrogea in order to identify the most resistant cultivars to low precipitations, high temperatures and drought.

Other studies were focused on plant protection measures for winter cereals: barley and wheat [9, 12, 24] .

Other research works were carried out to improve the production technologies regarding the change of the sowing period in relation to water resource into the soil, to avoid the high temperatures during the period of vegetation. Important results were achieved in adapted technologies for wheat growing [14], sunflower [11, 21], and sunflower and sorghum technology [18].

Other research works analyzed the impact of climate change on crop productivity and efficiency (yields, production, price etc). It is about the studies focused on winter wheat productivity [48], barley and wheat yields [12, 19, 24], wheat, maize and sunflower yields [40], sunflower hybrids yield [21, 23], wheat and maize production [46], sorghum yield [13, 22], sunflower and sorghum yields [18], cereal production [38], cereal production and price [39], gross margin in vegetal production [33] and yield in agricultural crops [35, 37].

Other researchers approached the use of Sorghum as a complementary crop with maize in Dobrogea, taking into account that sorghum is more resistant to drought, high temperatures and even heavy rains and hail [13, 17, 20, 22].

In this context, the paper aimed to analyze the behavior, productivity and economic efficiency in winter wheat growing under climate change conditions in Amzacea Village, South Dobrogea, the most arid and droughty part of the region where Sport Agra Ltd is operating and its manager has found and applied solutions to maintain and increase wheat production performance and profitability in the period 2013-2023.

MATERIALS AND METHODS

Study area

This research work was run in Amzacea Village, Constanta County, South East Dobrogea, Romania, where the agricultural holding Sport Agra Ltd, top 1 in agribusiness in the field of Agriculture, hunting and annex services, is operating.

Data collection

This study is based on multitude of scientific publications which have represented the literature background on the topic regarding the main results in Dobrogea's agriculture.

A part of the data regarding the cultivated area and yields for the main crops grown in Constanta County were provided by the National Institute of Statistics and Agricultural Division of the county.

The meteorological data regarding the monthly and year average temperatures and monthly and year precipitations regimes were provided by National Administration of Meteorology, Amzacea Meteorological Station, Mangalia Meteorological Station and Medgidia Meteorological Station.

The data resulting from the own scientific research works were provided by Sport Agra Ltd for the period 2013- 2023.

Soil type

The experiments were situated on a land belonging to the South Dobrogea Plateau, represented by cambic cernoziom with a profile deeper than other cernozioms, a blackish-brown soil of 40-50 cm thickness, medium texture [5]. The content of nutrients was: mobile P index – 72; N index – 4; K index – 200; humus – 3.11%; neutral pH – 7.2. The climate is deeply temperate continental, with an average annual temperature of 10.7 – 11.7 °C. with a high temperature in the period 20th June to 15th August. This area is the most arid in the country, with 69-year multi-annual average rainfall of 401 litres. In the last 3 years, we didn't reach more than 315 mm./sqm.

Climate conditions

Precipitations regime

Dobrogea is recognized as a region with a low precipitations level in Romania. A comparison regarding the precipitations in different periods across the time is suggestive in this respect.

In the period 1961-2010, Dobrogea registered 451.2 l/m^{2}precipitations, by 131.8 l/m^{2}less than at the level of Romania. Also, in the period, 1971-2000, in Dobrogea there were recorded 451.4l/m^2 precipitations, being by 118.4 l/m^2 lower than in the country.

Table 1. Precipitations regime in Dobrogea versus Romania in the interval 1961-2010 (Agricultural years-September -August)

	MU	1961-1990	1971-2000	1981-2010	1981-2010/ 1961-1990 (%)
Dobrogea	l/ m^2	451.2	451.4	459.6	101.86
Romania	l/ m^2	583	569.8	571.1	97.95
DB- RO	l/ m^2	-131.8	-118.4	-111.5	84.59

Source: National Administration of Meteorology [27].

In the interval 1981-2010, it was also noticed a negative difference of 111.5 l/m^2 between Romania and Dobrogea (Table 1).
The difference of precipitations between Dobrogea and Romania reflects an important deficit and the fact that Romania has a predominantly moderate droughty and droughty pluviometric regime, while Dobrogea has a predominantly droughty regime in South, South East and East areas.
The precipitations regime connected to winter wheat growing at Amzacea, South East Dobrogea, during the interval 2013-2023 is presented in Table 2, from which it is easy to notice the variation of precipitations by month of each agricultural year taken into consideration in this study.

Table 1. Monthly and Annual Precipitations regime related to wheat growing at Amzacea, 2013-2023 (mm)

Crt. no.	Agric. year	IX	X	XI	XII	I	II	III	IV	V	VI
1	2013/14	65	76.5	13	20	113	2	40.5	42	61.5	228.5
2	2014/15	43	151	40	106	83	40	74.5	48	0	25.5
3	2015/16	17	93	40	3	110	30.5	55	20	97	23.5
4	2016/17	23	72	47	3	70	20	40	41	27	29
5	2017/18	5	55.5	65	50	63	120	68	2	92	76
6	2018/19	3	3	57.5	47	36	8	16	35.5	18	14
7	2019/20	37	44	9.5	27.5	2	50	16	15	42	24
8	2020/21	31	18.5	21	100	122.5	34	61.5	35	22	270
9	2021/22	40	115	49	92.5	19	40	42	46.5	14	45.5
10	2022/23	69.5	0	26	21	47	24	21.5	75	18	30.4

Source: Amazacea Meteorological Station [26].

The general trend regarding the annual precipitations is a decreasing one from 661.1 mm in 2013/2014 to 332.4 mm in 2022/2023, which reflects a reduction by about 50%. However, in 2013/2014, 2017/2018 and 2020/2021, it was registered a peak of annual precipitations but their distribution along the agricultural year did not favor yield performance (Fig. 1).

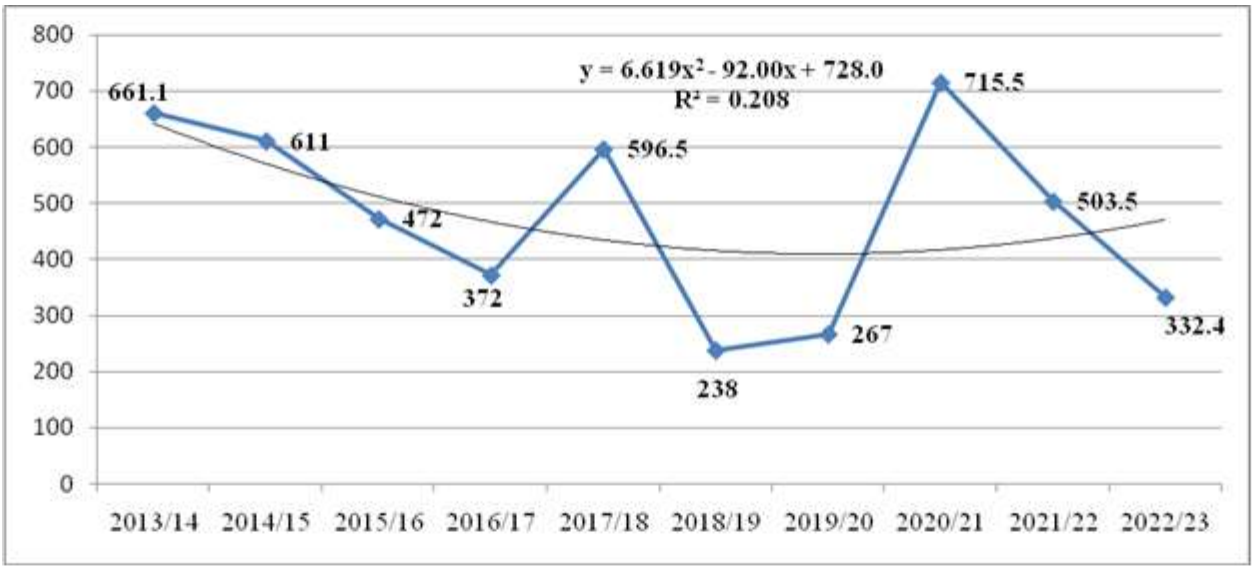

Fig. 1. Dynamics of annual precipitations level connected to winter wheat growing at Amzacea, along the ten agricultural years in the interval 2013-2023 (mm)
Source: Own design based on the data from Amazacea Meteorological Station, 2023 [26].

The descriptive statistics for annual precipitations at Amzacea, in the interval 2013-2023, reflects an average precipitation level of 476.9 mm/year, a 53.42 mm/year standard error of the mean, and a high variation coefficient equal to 35.42 %, as shown in Fig.1.

Temperature regime

In Dobrogea, the average annual temperatures are completely different than in other regions of the country, during the last decade being higher and higher since May till late in the Fall season, being intensified by hot waves which caused the drought and compromised many crops which could not reach their maturity and led to important production losses.

The comparison between the distribution of average air temperatures by month of the agricultural year 2022-2023 related to wheat crop, registered in the South of Dobrogea at Mangalia and Medgidia Meteorological Stations is a suggestive example which shows large variations even though these stations are situated very close to each other.

The differences reflect that in Mangalia area the average monthly air temperatures were superior to the temperature level in Medgidia areaby a surplus ranging between +2.1 ^{0}C in December and +0.1 ^{0}C in April. The months of March and May were exceptions, as in these months it was registered the same temperature and June, when in Medgidia was recorded + 0.3 ^{0}C more than in Mangalia. The variation of the monthly temperatures were very high, as confirmed by the high level of the variation coefficient which accounted of 48.18% at Mangalia and for 56.04% at Medgidia (Table 2).

Table 2. The monthly air temperature in the agricultural year September 2022-June 2023, connected to wheat growing in the South of Dobrogea

Month	**Average air temperature (^{0}C)**		
	Mangalia Meteorological Station	Medgidia Meteorological Station	Differences between Mangalia and Medgidia Meteorological Stations
September	19.4	19.1	+0.3
October	14.7	14.1	+0.6
November	11.2	9.5	+1.7
December	6.5	4.4.	+2.1
January	6.7	5.7	+1.0
February	4.6	3.2	+1.4
March	7.7	7.7.	0
April	10.3	10.2	+0.1
May	15.7	15.7	0
June	20.9	21.2	- 0.3
Average temp.	11.7	11.08	+0.62
Standard Deviation	±1.79	±1.96	-
Coefficient of variation (%)	48.18	56.04	-

Source: Mangalia and Medgidia Meteorological Stations, 2023 [16, 25].

Because Amzacea Sport Agra Ltd is closer to Mangalia than to Medgidia Meteorological Station, we could easily understand why wheat crop was really affected during its period of vegetation till harvest.

Therefore, during the period 2013-2023, climate has deeply changed at Amzacea reflecting a critical decreasing trend in the precipitations regime (low rainfalls and lack of snow layer) and an increasing trend in high temperatures, heat waves and long and severe droughts, with a strong impact on wheat production, which determined the manager of the company to identify the proper solutions to sustain wheat crop.

Experiments organization

In the fall of the year 2019, like in every year, it was organized a field of applied research with 10 wheat varieties, as shown in Table 3.

Table 3. Technological sheet for demonstrative plots for winter wheat at Sport Agra Ltd., Plot A211/A209, Amzacea 2019-2020

Variety	Predecessor crop	Area sq.m.	Seed norm Kg/ha	Sowing date	Emergence date	No. of plants at 13 January 2020	No. of ears at 8 June 2020	No. of grains by ear	Plant height cm	Yield Kg/ha
Glosa	Wheat	400	240	16 Oct.	25 Oct.	680	308	16	35	1,870
Miranda	Wheat	400	215	16 Oct.	25 Oct.	610	372	16	38	2,260
Otilia	Grau	400	215	16 Oct.	25 Oct.	660	416	15	32	2,370
Apilco	Grau	400	220	16 Oct.	25 Oct.	690	160	9	19	550
Avenue	Grau	400	220	16 Oct.	25 Oct.	700	0	0	17	0
Katarina	Grau	400	240	16 Oct.	25 Oct.	620	0	0	15	0
Kraljica	Grau	400	240	16 Oct.	25 Oct.	700	0	0	20	0
Mobile	Grau	400	200	16 Oct.	25 Oct.	610	28	10	20	110
Combin	Grau	400	250	16 Oct.	25 Oct.	640	212	10	25	805
Rubisko	Grau	400	240	16 Oct.	25 Oct.	680	52	14	27	276

Source: Original.

Photo 1, 2, 3. Plant vegetation phase on June 8, 2020.
Source: Original.

Table 4. Technological sheet for autumn crops in 2018

Variety	Seed norm (kg /ha)	Plant density in the autumn 14.11.2017	Plant density in the spring 11.01.2018	Inflorescence emergence date	Flowering date	Plant height (cm)	Yield (kg/ ha)	Quality index	
								M Hl (kg/hl)	Protein (%)
Two-rowed Autumn Barley + Autumn Barley									
Bingo	220	520	888	April 20	April 28	73	7,375	70.5	-
Panonic	220	522	868	April 26	May 3	101	8,500	70.6	-
Predator	220	534	848	April 23	May 2	86	7,875	70.6	-
Wheat									
Avenue	250	440	772	April 27	May 4	71	8,026	74.6	11.9
Katarina	250	422	828	April 30	May 7	70	7,475	76.9	12.0
Miranda	250	468	660	May 3	May 8	94	7,425	75.6	12.3
Litera	250	495	684	May 4	May 8	95	7,125	74.2	12.4
Kraljica	250	484	812	May 1	May 5	68	8,300	74.5	12.3
Spranjka	250	534	784	May 1	May 9	65	8,106	75.2	11.9
Fifi	250	472	732	May 3	May 9	76	6,666	77.0	14.5
Silvja	250	445	672	May 2	May 7	80	7,675	77.2	12.7
Bubimir	250	432	764	May 2	May 7	71	6,575	77.5	12.6
El Nino	250	476	796	April 30	May 5	75	8,125	76.5	12.5
Tata Mata	250	502	772	May 4	May 9	87	7,475	70.4	12.5
Pepeljura	250	464	784	May 4	May 9	91	7,920	73.1	11.9

Source: Original.

Table 5. Autumn cereals phytosanitary status -May 8, 2018

Two-rowed Autumn Barley + Autumn Barley									
Variety	*Rhynchosporiumsecalis*			*Pyrenophora teres*			*Pyrenophoragraminea*		
	F (%)	I (%)	AR (%)	F (%)	I (%)	AR (%)	F (%)	I (%)	AR (%)
Bingo	6	2	0.1	3	1	0.01	10	5	0.5
Panonic	0	0	0	0	0	0	0	0	0
Predator	0	0	0	2	1	0.01	8	5	0.4
Wheat									
Variety	*Septoria tritici*			*Pyrenophora graminea*			*Puccinia striiformis*		
	F (%)	I (%)	AR (%)	F (%)	I (%)	AR (%)	F (%)	I (%)	AR (%)
Avenue	5	2	0.1	0	0	0	5	1	0.05
Katarina	0	0	0	5	2	0.1	0	0	0
Miranda	0	0	0	0	0	0	0	0	0
Litera	0	0	0	10	5	0.5	0	0	0
Kraljca	8	2	0.1	0	0	0	2	1	0.02
Spranjca	5	2	0.1	0	0	0	5	2	0.1
Fiji	0	0	0	10	5	0.5	7	1	0.07
Wheat									
Variety	*Septoria tritici*			*Pyrenophora graminea*			*Puccinia striiformis*		
	F (%)	I (%)	AR (%)	F (%)	I (%)	AR (%)	F (%)	I (%)	AR (%)
Silvja	5	3	0.1	0	0	0	0	0	0
Bubimir	8	2	0.1	0	0	0	2	1	0.02
El Nino	5	2	0.1	10	4	0.4	5	1	0.05
Tata Mata	10	3	0.3	0	0	0	0	0	0
Pepeljura	5	2	0.1	0	0	0	0	0	0

Source: Original.

Table 6. Technological sheet for autumn crops, 2019

Variety	**Seed norm (kg /ha)**	**Plant density in the spring 01.02.2019**	**Inflorescence emergence date**	**Flowering date**	**Yield (kg/ ha)**	**Quality index**	
						M Hl (kg/hl)	Protein (%)
Two-rowed Autumn Barley + Autumn Barley							
Pleter	220	440	May 7	May 12	6,200	67.9	-
Preator	220	424	May 7	May 12	6,275	68.6	-
OSK6.2/3-13	220	484	May 7	May 12	7,012	69.1	-
OSK	220	436	May 9	May 12	6,812	69.8	-
OSK	220	424	May 9	May 12	6,450	65.9	-
Panonic	220	420	May 9	May 12	6,587	66.1	-
Wheat							
Glosa	255	468	May 15	May 17	6,187	80.7	11.6
Avenue	260	512	May 12	May 15	6,000	78.9	10.8
Renata	260	488	May 14	May 17	5,750	81	12.1
OSK 51.117	260	480	May 15	May 19	6,375	79.3	10.8
OSK 110/17	260	440	May 15	May 19	5,750	78.9	11.7
OSK 159/17	260	504	May 15	May 19	6,125	80.2	12.1
OSK 84/116	260	516	May 16	May 19	6,187	80.2	12.4
Borealis	260	496	May 13	May 17	5,562	61.9	12.9
Icona 2S	260	524	May 14	May 17	5,287	79	13.6

Source: Original.

In the agricultural year 2020, an amount of only 267 mm was registered, and this was the cause for which large surfaces cultivated with wheat were calamity in Constanta County and Sport Agra Ltd.

In the experimental field, the Romanian varieties looked to be better adapted to the soil and climate conditions so that the Otilia

variety achieved 2,370 kg/ha, Miranda 2,260 kg/ha and Glosa 1,870 kg/ha. The foreign varieties Avenue, Katarina, Kraljica could not be harvested as shown in Table 3.
The plant height of the foreign varieties was affected compared to 68-70 cm recorded in case of the Romanian varieties.
This happened to: Miranda 38 cm, Otilia 35 cm, and to the foreign varieties Katarina 15 cm, and Avenue 17 cm.
The low temperatures recorded in the period 5 – 12 April of - 6 and -8 C° affected the number of grains on the ear and plant density. As a result, the average yield carried out in Constanta county was only 983 kg/ha.

Table 7. Autumn cereals phytosanitary status – April 18, 2019

Two-rowed Autumn Barley + Autumn Barley									
Variety	*Rhyncosporiumsecalis*			*Pyrenophora teres*			*Pyrenophoragraminea*		
	F (%)	I (%)	AR (%)	F (%)	I (%)	AR (%)	F (%)	I (%)	AR (%)
Pleter	40	20	8	30	10	3	70	15	10.5
Predator	40	10	4	90	20	18	40	5	2.0
OSK 6.2/3-13	20	10	2	80	25	20	80	30	2.4
OSK	20	15	3	10	30	3	50	20	10
OSK	30	10	3	20	40	8	30	30	9
Panonic	30	20	6	10	20	2	40	20	8
Wheat									
Variety	*Septoria tritici*			*Pyrenophora graminea*			*Puccinia striiformis*		
	F (%)	I (%)	AR (%)	F (%)	I (%)	AR (%)	F (%)	I (%)	AR (%)
Glosa	80	20	16	70	20	14	25	5	1.25
Avenue	90	25	23.7	25	20	5	20	10	2
Renata	70	20	14	70	25	17.5	0	0	0
OSK 51.117	70	30	21	45	20	9	0	0	0
OSK 110/17	80	25	20	35	15	5.3	20	5	1.0
OSK 159/17	75	25	18.7	45	10	4.5	30	5	1.5
OSK 84/116	80	25	20	80	15	12	90	15	13.5
Borealis	90	30	27	70	25	17.5	0	0	0
ICONA 2S	80	25	20	40	30	12	20	7	1.4

Source: Original.

Therefore, we can firmly assert that the heavy rainfall from March 2018 and 2019, favored the rise of pathogens. Both in April 2018 and in May 2019, after the application of the product PRIAXOR EC, it could be observed that the degree of attack was significantly reduced.

Photo 4. Autumn grain crops - field trial
Source: Original photo.

Photo 5. Phytosanitary status
Source: Original photo.

To prevent and control the pathogens that cause diseases in autumn cereal crops, two treatments with fungicides were necessary under climatic conditions of 2018 and 2019.The beneficial effects were found in the good yields obtained. For barley crop, the pathogen *Pyrenophora gramminis* showed reduced attack rates compared to *Pyrenophora teres* or *Rhyncosporium secalis* in both years of experience. For wheat crop, pathogens *Septoria* sp. and *Pyrenophora* sp. showed a reduced attack rates, compared to *Puccinia* sp., in both years of experience. The productions obtained these years were very good, considering that they were obtained using a non-irrigation technology. Thereby, under 2018 conditions, the yields obtained ranged between 7,375 and 8,500 kg/ha and good quality index (hectolitre weight = 70.6 kg/hl) for barley and for wheat yields recorded were between 6,575 (Bubimir) and 8,300 (Kraljica) kg/ha Osijek Institute Croatia. In 2019, the yields obtained varied between 6,200 and 7,012 kg/ha for barley, and between 5,287 kg/ha (Icona 2S) and 6,375 (OSK 51.117) kg/ha for wheat.

Photo 6. Autumn grain crops – experimental field – 2016
Source: Original photo.

Table 8. Autumn cereals phytosanitary status - 2016

Variety	***Rhincosporium secalis***			***Pyrenophora teres***			***Pyrenophora graminis***		
	F (%)	I (%)	RA (%)	F (%)	I (%)	RA (%)	F (%)	I (%)	RA (%)
Two-rowed Autumn Barley									
Metaxa	50	3	1.5	60	3	1.8	-	-	-
Wendy	30	2	0.6	70	3	2.1	-	-	-
Henriette	20	4	0.8	40	3	1.2	30	3	0.9
Wheat									
Variety	*Septoria* sp.			*Pyrenophora graminis*			*Puccinia striiforme*		
	F (%)	I (%)	RA (%)	F (%)	I (%)	RA (%)	F (%)	I (%)	RA (%)
Katarina	20	5	1.0	30	5	1.5	-	-	-
Petur	50	8	4.0	60	9	5.4	-	-	-
Genius	60	3	1.8	50	7	3.5	-	-	-
Joker	30	5	1.5	40	5	2	-	-	-
Mulan	30	2	0.6	20	5	1	30	2	0.6
Felix	40	10	4.0	25	10	2.5	30	5	1.5
Hyty	30	3	0.9	20	5	1	-	-	-
Hybiza	50	3	1.5	60	8	4.8	-	-	-
Hylux	80	8	6.4	70	10	7	-	-	-
Avenue	50	2	1.0	60	3	1.8	50	5	2.5
Soobel	50	10	5.0	40	5	2	-	-	-
Sofru	70	10	7.0	80	3	2.4	-	-	-
Solveg	60	5	3.0	70	10	7	-	-	-
Winter Gold	90	9	8.1	70	8	5.6	-	-	-
Pescador	50	3	1.5	60	10	6	30	5	1.5

Source: Original.

Table 9. Experimental fields with wheat varieties in 2016

Variety	**Seed norm (kg /ha)**	**Date of sowing**	**Emergence date**	**Number of plants in the emergence**	**Number of plants in the spring**	**Yield (kg / ha)**	**Quality index**	
							U %	M Hl
Two-rowed Barley								
Metaxa	180	19-Oct	28 Oct	284	584	8,612	13.1	64.0
Wendy	180	19-Oct	28 Oct	288	620	8,450	12.6	64.2
Henriette	180	19-Oct	28 Oct	292	640	8,800	12.3	65.0
Wheat								
Katarina	220	19-Oct	29 Oct	372	736	8,400	14.8	79.1
Petur	220	19-Oct	29 Oct	356	704	8,000	14.4	76.4
Genius	220	19-Oct	29 Oct	344	680	8,300	14.3	80.6
Joker	220	19-Oct	29 Oct	372	712	8,040	14.7	79.9
Mulan	220	19-Oct	29 0ct	352	700	7,340	14.1	79.1
Felix	220	19-Oct	29 Oct	368	720	6,800	14.4	77.0
Hyfi	80	19-Oct	29 Oct	152	692	7,140	14.5	81.0
Hybiza	80	19-Oct	29 Oct	232	670	4,740	14.2	76.7
Hylux	80	19-Oct	29 Oct	212	682	5,465	14.7	74.6
Avenue	180	19-Oct	29 Oct	348	696	4,860	14.1	75.4
Soobel	180	19-Oct	29 Oct	336	672	6,702	14.4	80.1
Sofru	180	19-Oct	29 Oct	368	700	7,544	14.6	77.5
Solveig	180	19-Oct	29 Oct	352	684	7,122	14.5	77.0
WinterGold	180	19-Oct	29 Oct	356	700	6,500	14.4	81.0
Pescador	180	19-Oct	29 Oct	348	690	6,245	14.6	80.0

Source: Original.

After the 3 fungicide treatments, foliar diseases were stopped at basal leaves (you can look the Photo 5 pg.9) The last 3 leaves and the ear were protected due to phytosanitary treatments, which contributed to the achievement of high productions of about 8 tons in the two-rowed barley and 4 wheat varieties.

The yields obtained in experimental plots are shown in Table 9.

For two-rowed barley crop, the lowest yield was 8,450 kg/ha for Wendy variety and the best yields were 8,800 kg/ha for Henriette variety.

Table 10. Autumn cereals phytosanitary status - 2014

Variety	***Rhincosporium secaris***			***Pyrenophora teres***			***Pyrenophora graminis***		
	F (%)	I (%)	DA (%)	F (%)	I (%)	DA (%)	F (%)	I (%)	DA (%)
Wheat									
Variety	*Septoria* sp.			*Pyrenophora graminis*			*Puccinia striiforme*		
	F (%)	I (%)	GA (%)	F (%)	I (%)	GA (%)	F (%)	I (%)	GA (%)
Katarina	30	7	2.1	50	3	1.5	-	-	-
Ilinca	70	4	2.8	50	5	2.5	60	5	3.0
Andelka	50	5	2.5	60	5	3.0	50	10	5.0
Renata	20	5	1.0	30	5	1.5	-	-	-
Genius	60	3	1.8	50	7	3.5	40	5	2.0
Joker	30	5	1.5	40	5	2.0	-	-	-
Florian	30	2	0.6	20	5	1.0	30	8	2.4
Akratos	40	10	4.0	25	10	2.5	30	5	1.5
Hystar	30	3	0.9	20	5	1.0	-	-	-
Apache	50	3	1.5	60	8	4.8	-	-	-
Renan	60	8	4.8	70	10	7.0	-	-	-
Altigo	50	2	1.0	60	3	1.8	-	-	-
Jindra	50	10	5.0	40	5	2.0	-	-	-
Epos	70	10	7.0	80	3	2.4	-	-	-
Einstein	60	5	3.0	70	10	7.0	-	-	-
Ewina	50	9	4.5	70	8	5.6	-	-	-
Arkeos	50	3	1.5	60	10	6.0	50	5	2.5
Ingenio	50	8	4.0	60	9	5.4	-	-	-
Illico	70	5	3.5	60	7	4.2	-	-	-

Source: Original.

The highest yields in wheat were obtained with Genius (8,300 kg/ha) and Petur varieties (8,000 kg/ha). Quality indices of wheat grains were between 74.6 for Hylux variety and 81.0% hectoliter mass for Winter Gold variety. To prevent and control the pathogens that cause diseases in autumn cereal crops, in the climatic conditions of the 2016 year, there were needed 3 treatments with fungicides. *Rhyncosporium* and *Pyrenophora* pathogens showed a low degree attack to two-rowed barley. In wheat crop, pathogens *Septoria* and *Pyrenophora* showed reduced attack degrees, as the pathogen *Puccinia striiforme*. The yields obtained in conditions of 2016 ranged from between 8,000-8,800kg /ha for two-rowed barley, and between 4,740 kg/ha (Hybiza variety) to 8,400 kg/ha (Katarina variety) for wheat. For all varieties analyzed, the hectoliter weight was influenced by rainfall, showing values between 74.6 to 81.0 (Table 9).

Table 11. Experimental fields with wheat varieties in 2014

Variety	Seed norm (kg /ha)	Date of sowing	Emergence date	Number of plants in the emergence	Number of plants in spring	Yield (kg / ha)	Quality index	
							U %	M Hl
Wheat								
Katarina	200	16-Oct	28-29 Oct	520	928	7,930	13	78
Ilinca	200	16-Oct	28-29 Oct	422	828	7,100	14.1	78
Genius	200	16-Oct	28-29 Oct	504	1,160	6,313	13.8	78.5
Joker	200	16-Oct	28-29 Oct	620	788	7,000	14.2	78.7
Florian	200	16-Oct	28-29 Oct	412	868	6,600	13	77.7
Akratos	200	16-Oct	28-29 Oct	448	812	4,700	13.2	77.2
Hystar	80	16-Oct	28-29 Oct	168	692	7,100	13.2	73.6
Apache	180	16-Oct	28-29 Oct	552	1,172	5,100	12.4	74.6
Renan	180	16-Oct	28-29 Oct	460	1,112	4,300	13.4	76.6
Altigo	180	16-Oct	28-29 Oct	320	1,192	7,200	13.4	74
Jindra	180	16-Oct	28-29 Oct	480	800	5,900	12.7	76.8
Epos	180	16-Oct	28-29 Oct	560	852	4,600	13	75.2
Einstein	180	16-Oct	28-29 Oct	460	1,132	5,600	13.6	74.3
Evena	180	16-Oct	28-29 Oct	480	816	5,000	14.1	77.6
Arkeos	180	16-Oct	28-29 Oct	540	732	4,250	13.8	70.9
Ingenio	180	16-Oct	28-29 Oct	400	828	7,600	12.9	72.5
Illico	180	16-Oct	28-29 Oct	520	660	7,500	14.1	76.2

Source: Original.

Photo 7. Autumn grain crops - 2014
Source: Original.

The data on yields obtained in experimental plots in the year 2014 are shown in Table 11. In autumn two-rowed barley crops were obtained yields of 5,600-6,200 kg/ha. In barley crops, productions ranged between 5,858 - 8,000 kg/ha. The wheat productions varied from 4,250 to 7,930 kg /ha. The production quality indexes in most wheat crops were over 76.6 hectoliter mass.

Table 12. Technological sheet for experimental field - 2023

Crt. No.	Variety	Predecessor plant	Area m^2	Seed norm kg /ha	Sowing date	Plant emergence date	Plant density 25.02. 2023	Plant density 23.05 .2023	Earing date	Flowering date	Remarks 9.06. 2023	Yield kg / ha 11.07. 2023
1	**Ursita**	Sunflower	400	230	12.10. 2023	23.12. 2023	640	412	11.05. 2023	16.05. 2023	With hairs	4,165
2	**Brko**	Sunflower	400	230	12.10. 2023	23.12. 2023	600	400	7.05. 2023	14.05. 2023	With hairs	3,875
3	**Indira**	Sunflower	400	230	12.10 .2023	23.12. 2023	534	444	11.05. 2023	16.05. 2023	Without hairs?	3875
4	**Garavusa**	Sunflower	400	230	12.10. 2023	23.12. 2023	656	388	16.05. 2023	22.05. 2023	Without hairs	4,050
5	**OSK 5219**	Sunflower	400	230	12.10. 2023	23.12. 2023	642	348	16.05. 2023	21.05. 2023	Without hairs Late/Low resistant	4,000
6	**OSK 4172**	Sunflower	400	230	12.10. 2023	23.12. 2023	664	316	16.05. 2023	21.05. 2023	With hairs Diseases tolerant	4,125
7	**OSK 5317**	Sunflower	400	230	12.10. 2023	23.12. 2023	560	364	11.05. 2023	16.05. 2023	With hairs	4,150
8	**Montecristo**	Sunflower	400	230	12.10. 2023	23.12. 2023	624	400	16.05. 2023	20.05. 2023	With hairs Diseases and drought tolerant	4,125
9	**Somtuoso**	Sunflower	400	230	12.10.20 23	23.12.202 3	540	388	16.05. 2023	21.05. 2023	With hairs Late/ Diseases and drought tolerant	4,125
10	**Flavor**	Sunflower	400	230	12.10. 2023	23.12. 2023	648	388	16.05. 2023	22.05. 2023	With hairs	4,100
11	**Solindo**	Sunflower	400	230	12.10. 2023	23.12. 2023	610	384	16.05. 2023	22.05. 2023	With hairs Semi-late/ Diseases and drought tolerant	4,297
12	**Sofru**	Sunflower	400	230	12.10. 2023	23.12. 2023	652	420	14.05. 2023	21.05. 2023	With hairs / Mid-early/ Diseases and drought tolerant	4,125
13	**Rubisko**	Sunflower	400	230	12.10. 2023	23.12. 2023	548	344	14.05. 2023	19.05. 2023	With hairs / Diseases and drought tolerant	4,000
14	**PG102**	Sunflower	400	230	12.10. 2023	23.12. 2023	538	364	16.05. 2023	19.05. 2023	With hairs / Diseases and drought tolerant	4,000
15	**Pitar**	Sunflower	400	230	12.10. 2023	23.12. 2023	596	416	16.05. 2023	19.05. 2023	With hairs	4,000

Source: Original.

According to the Dobrogea Regional Meteorological Center, the agricultural year 2023 together with the year 2020 are the driest years and with the highest temperatures since the meteorological evidence is registered.

In the fall of 2022, it was established an experiment with 15 wheat varieties, of which

3 varieties were produced in Romania: Ursita, PG102, Pitar, but the other varieties belong to Research Institute in Osijek – Croatia: Brko, Indira, Garavusa, OSK5219, OSK4172, OSK5317, and the remaining 6 varieties belong to RAGT, Lidea. Due to the lack of precipitations in the fall 2022, as seen from Table 12, the emergence phenophase was registered very late in the month of December, despite that the sowing was made in the month of October. This means that the twinning phenophase took place later in Spring of the year 2023. The limiting factor-water, determined that harvesting to be late on July 11, 2023 at a moisture percentage of over 14%. The data from Table 12 highlighted that Solindo variety carried out the highest yield 4,297 kg/ha, followed by Ursita 4,165 kg/ha, Flavor 4,100 kg/ha, OSK5317 4,150 kg/ha.

The following varieties were tolerant to drought and diseases: Solindo, Sofru, Rubisko, PG102. Due to the lack of precipitations and negative temperatures registered in April, as can be seen from Table 12: Ursita variety had a density of 640 plants/m^2 on 25 February 2023, but on 23 May 2023, it had 412 plants/m^2, while Brko variety recorded 600 plants/m^2 on 25 February 2023 and on 23 May 2023 it had only 400 plants/m^2.

Photo 8. Experimental plot with wheat (Left- Sowing on October 20, 2022 and Right- plant phenophase in March 2023)
Source: Original.

Photo 9. Experimental plot 2023 – emergence phenophase, Left- Brko variety 600 plants/m^2, and Right- Ursita variety 640 plants/m^2
Source: Original.

Data processing

The main economic indicators studied in this research on wheat growing have been: cultivated area, wheat yield, wheat production, production costs, income from wheat grains delivery, gross profit, profit rate, cost/ha, cost/ton, income/ha, income/ton, profit per ha, and profit per ton.

The results were tabled and graphically illustrated, pointing out the main trends based on regression equations and R^2, suitable to the dispersion of the data in the chart.

The descriptive statistics analysis showed the mean, standard deviation and the coefficient of variations levels.

Also, the coefficient of correlation was determined between wheat yield and annual precipitation regime in order to identify how strong or weak was the influence of this climate factor on production performance per ha.

RESULTS AND DISCUSSIONS

Description of the technology applied

In all the years of research and observations, the predecessors plants were especially sunflower, followed by maize and soybean.

The soil was prepared for sowing in the years 2013-2017, using equipments for shredding plant residues and then the soil was plowed to a depth of 20-22 cm.

Starting since 2017, the land was processed through a deep refinement at 20 cm. Till the sowing date, the land was maintained clear of weeds using equipments able to make a shallow tillage of the soil at the depth of 8-10 cm.

For sowing it was used a treated seed which was introduced into the soil at a distance of 12.5 cm and a depth of 4-6 cm depending on the soil moisture.

At the same time with sowing, it was made fertilization using complex fertilizer, assuring an average along all the years of observations of 45-50 kg/ha N, 65-80 kg/ha P_2O_5, 20 kg/ha K_2O. During the vegetation period, there were made two fertilizations assuring a supplement of 80 kg/ha NO_2 active substance.

To combat weeding, it was used the herbicide Tritosulhuron 714 g/kg + Florasulam 54 g/kg applied in a dose of 0.07 kg/ha.

In all the years of observations and research, before sowing, the seeds were treated for protecting the plants till the twinning phenophase using a series of active substances like: Clotianidin (166.7 g/l) + Imidacloprid (166.7 g/l) + Proticonazol (33.3 g/l) + Tebuconazol (6.7 g/l) in a dose of 1.6 l/to in the years 2016-2018-2019, in 2014 - Thiamethoxam + Fludioxnil + Difenoconazole in a dose of 1.5 l/to, and in 2020- 2023 – Teflutrin + Fludioxonil 5 l/to.

The researches demonstarted that the lack of seed treatment with suitable active substances (Thiamethoxam, Imidacloprid) led to compromise large surfaces cultivated with wheat due to the pathogens: Zabrus Tenebrioides, specific to the geographical area of Dobrogea, as well as to the attack of the grains flies due to the high temperatures in autumn seasons.

The attack of cycads in teh absence of seed treatments favors the development of diseases.

the sowing was carried out according to the climatic data, no later than October 25, knowing that from sunrise to the phenophase of twinning, wheat needs 450^0C thermal degrees, so that the tillers to have approximately the same number of grains on the mother plant.

Photo 10. Fields with wheat attacked by pests
Source: Original.

Annualy, there were applied two treatments against foliar diseases and Eurygaster sp. as follows: the first treatment in the period 15-20 March using the following active substances: Cyproconazole 80g/l + Propiconazol 250 g/l in a dose of 0.4 l/ha; the second treatment, at the end of April: Piraclostrobin 150g/l + Fluxapiroxad 75 g/l in a dose of 1 l/ha, Lambda-cihalotrin 50 g/l in a dose of 0.75 l/ha till the year 2017, and in the other years Lambda-cihalotrin in a dose of 0.3 kg/ha.

In the years 2018-2019, it was applied the second treatment cu Lambda-cihalotrin due to the invasion of the grain bugs – *Eurygaster* Sp., in a dose of 0.3 kg/ha.

Photo 11. In 2021, the attack of *Zabrus Tenebrioydes* (cereal ground beetle), the wheat is affected and it was sown together with another crop due to the lack of seed treatment with suitable substances
Source: Original.

Dynamics of wheat cultivated area

Despite that in Constanta County, the area cultivated with wheat is decreasing, at Amzacea Sport Agra agricultural holding, winter wheat was sown on larger surfaces which increased by 24.68% from 370.95 ha in the year 2013/2014 to 462.51 ha in the year 2022/2023. This tendency is confirmed by the coefficient of determination R square whose value reflects that 76.4% of the variation was timely determined, according to farmer's decision in close relation to the assurance of the crop rotation (Fig. 2).

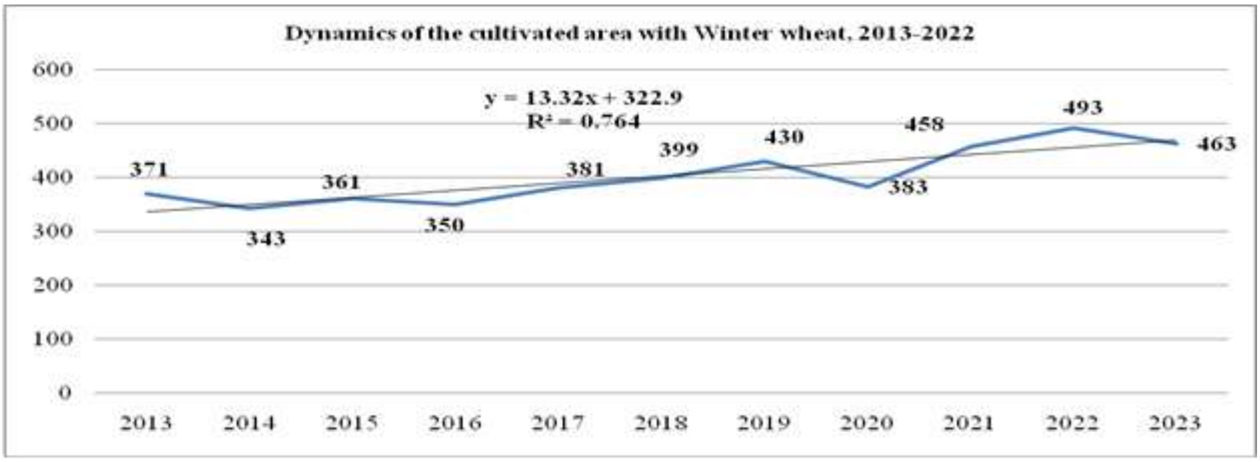

Fig. 2. Dynamics of the cultivated area with winter wheat at Amazacea Sport Agra Ltd. 2012-2022 (ha)
Source: Own design based on the data supplied by Amazacea Sport Agra Ltd. [43].

Dynamics of wheat production

Wheat production varied depending on the technology applied regarding the used varieties, fertilization and plant protection, the timing application of the agricultural works, precipitation and temperatures regime in the interval from sowing to harvesting. Its level ranged between the peak level of 3,818,440 kg in the year 2022 and 87,720 kg in the year 2020, the lowest level registered in the studied interval, practically showing a real calamity in this crop culture (Fig. 3).

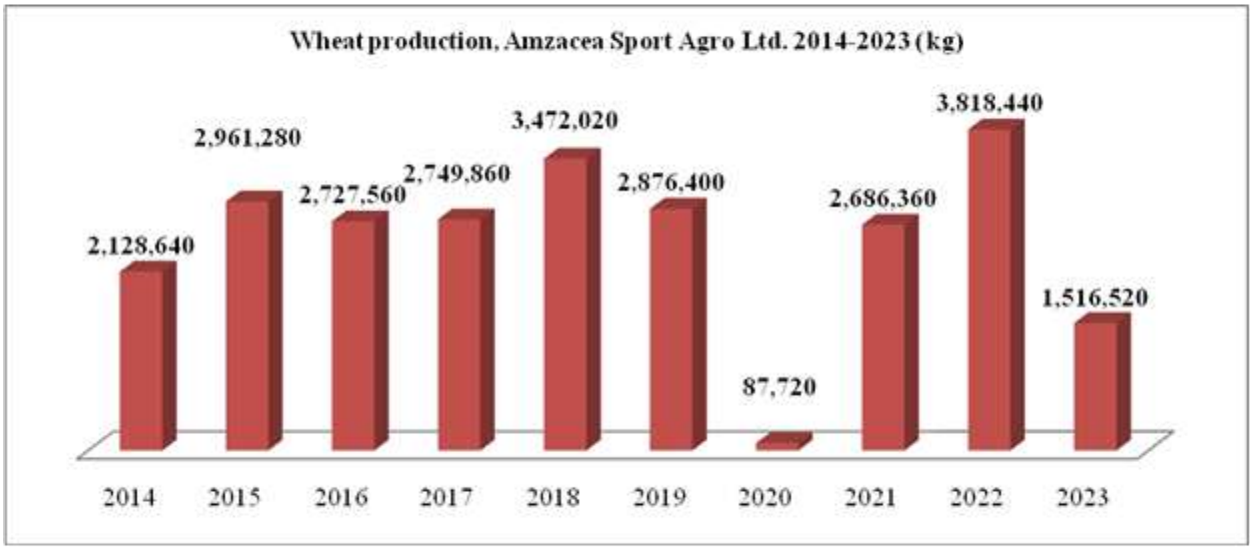

Fig. 3. Dynamics of the winter wheat production at Amazacea Sport Agra Ltd. 2014-2023 (kg)
Source: Own design based on the data supplied by Amazacea Sport Agra Ltd.[43].

Dynamics of wheat yield

In the analyzed interval, wheat yield varied from a year to another, the top level being 8,700 kg/ha recorded in the year 2018 and the lowest level was registered in the year 2020, only 228.28 kg/ha (Fig. 4).

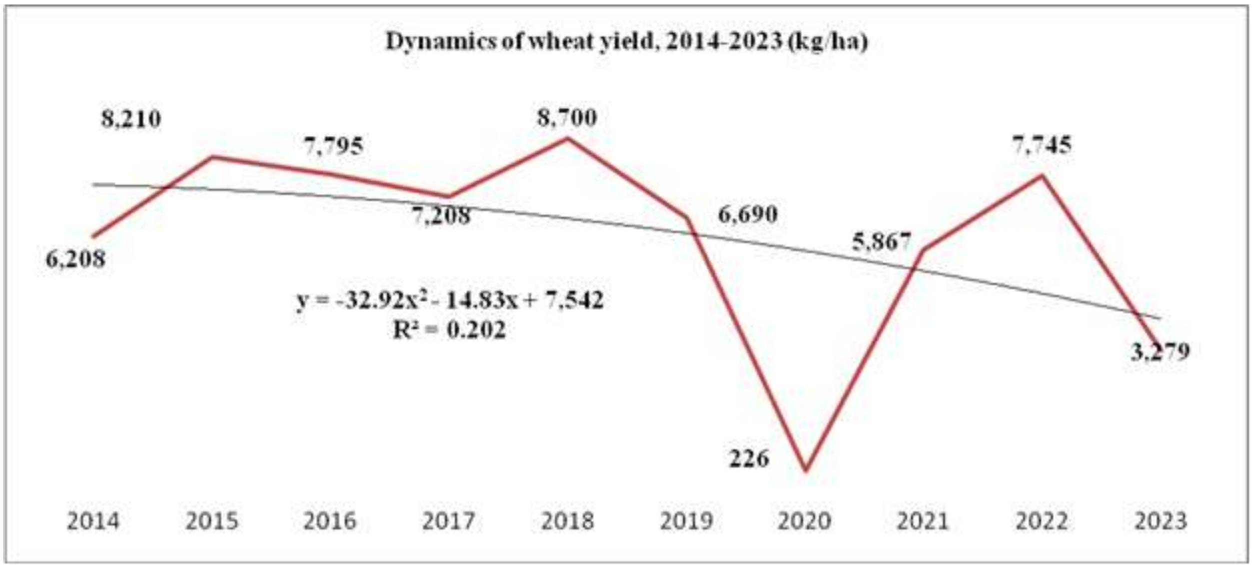

Fig. 4. Dynamics of the winter wheat yield at Amazacea Sport Agra Ltd. 2014-2023 (kg/ha)
Source: Own design based on the data supplied by Amazacea Sport Agra Ltd.[43].

Correlation between yield and annual precipitation level during the wheat growing period

Using the Excel facilities, a positive and strong correlation coefficient, r_{xy} = 0.50, was found between wheat yield and annual precipitations. R square value was 0.2502, meaning that 25.02% of the yield variation is given by the changes in the quantity of precipitations, and the remaining of 74.98% represent the influence of the variation of other factors on wheat yield.

F had the value 2.6696 and Significance F = 0.1409.

Taking into account that in the regression equation, Y = bx + a, "Y" is the dependent variable, that is wheat yield and "x" is the amount of precipitations, the calculated equation, Y = 7.69 x + 2,523.66, reflects that an increase of precipitations by one unit could lead to an important additional yield. The existence of a significant connection between yield and annual precipitations was confirmed by t Test of the correlation coefficient.

The intercept value 2,523,66 had a standard error of 2,369.18, t stat was equal to 1.065, p-value = 0.3178. And the intercept value was situated in the confidence interval ranging between -2,939.68 the lower 95% and 7,987.01 the upper 95%. X variable 1= 7.6941 had a standard error of 4.709, t stat = 1.633, p-value = 0.1409. The value of X variable 1 was situated in the confidence interval - 3.1648 for lower 95% and 18.553 for upper 95%.

Correlation between wheat production and annual precipitation level during the wheat growing period

In this case, the coefficient of correlation was r_{xy}= 0.447, reflecting a positive and moderate link between the two variables taken into consideration. R^2 value equal to 0.1198 reflects that only 11.98% of the variation of production is caused by the variation in the amount of precipitations during the agricultural year. Therefore, other factors are responsible of the difference of production variation. F was 1.9979 and Significant F = 0.195. The determined regression equation is Y = 2,804.45 x + 1,165,036.81.

The intercept value 1,165,036.81 had a standard error of 998,215.795, t stat was equal to 1.1671, p-value = 0.2767. The intercept value was situated in the confidence interval varying between -1,136,852.9 the lower 95% and 3,466,927 the upper 95%. X variable 1= 2,804.45 had a standard error of 1,984.07, t stat = 1.4134, p-value = 0.2767. The value of X variable 1 was situated in the confidence interval - 1,170.83 for the lower 95% and 7,379.74 for the upper 95%.

Dynamics of production costs

Production costs reflect the financial efforts made by farm manager to sustain production, by assuring farm inputs in terms of certified seeds from various wheat varieties with high production potential, fertilizers and other chemicals for plant protection, fuel for machinery and other materials, salary for work force involved in carrying out the agricultural works.

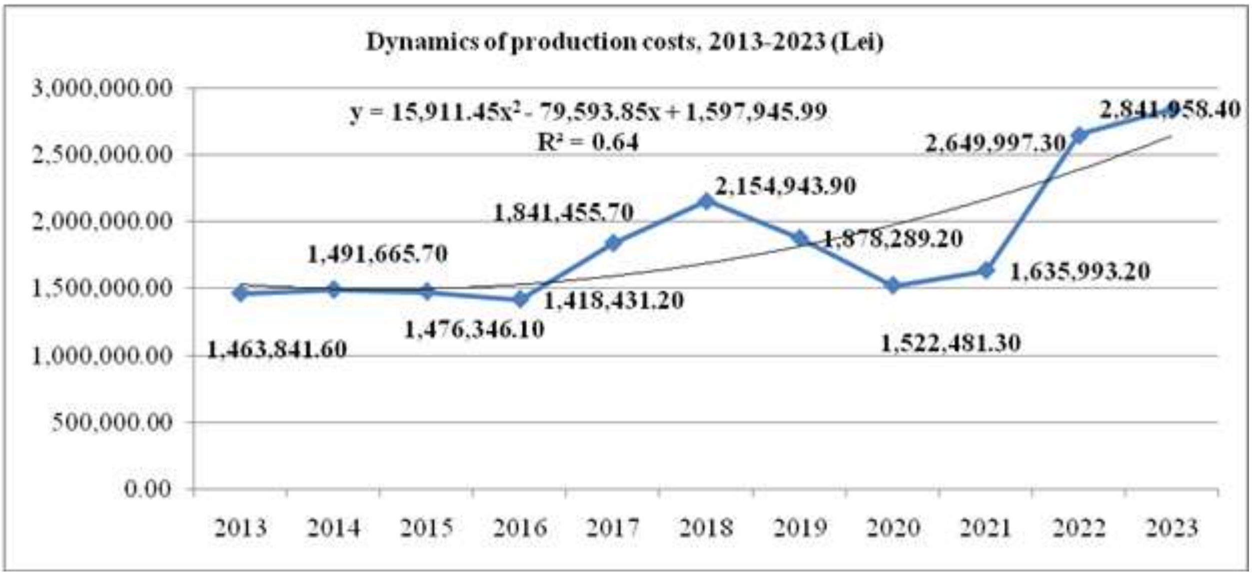

Fig. 5. Dynamics of production costs related to the winter wheat growing at Amazacea Sport Agra Ltd., 2013-2023 (Lei)
Source: Own design based on the data supplied by Amazacea Sport Agra Ltd.[43].

The level of production costs increased from a year to another in the studied period 2013-2023. In the 2023, they reached Lei 2,841,958, being by 94.14% higher than in 2013 and this happened due to the higher and higher price for farm inputs (Fig. 5).

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Dynamics of income coming from wheat grains delivery

Income achieved from wheat marketed grains depended on the amount of grains sold in the market and also on the average market price.

In the analyzed period, wheat market price varied between Lei 849.67 per ton in 2013 and Lei 894.66 per ton in 2023. In the analyzed interval, it reached a peak of Lei 1,720 per ton in the year 2022, and the lowest level was Lei 663 per ton in the year 2016 (Fig. 6).

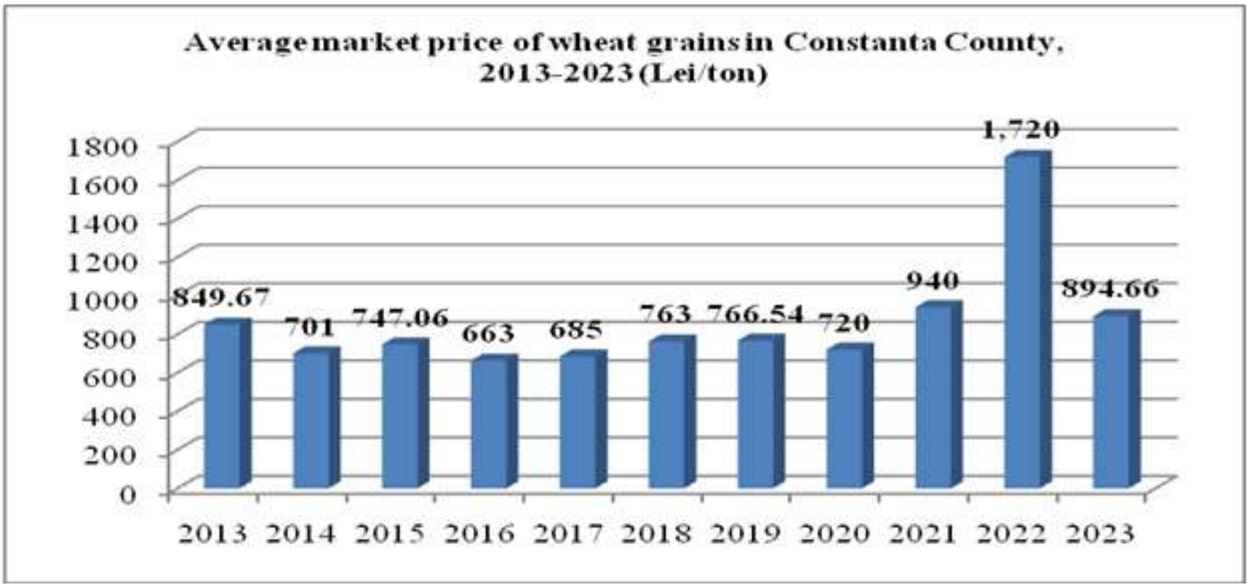

Fig. 6. Dynamics of average wheat grains market price, in Constanta county, 2013-2023 (Lei/ton)
Source: Own design based on the data provided by Amzacea Sport Agra Ltd.[43].

The wheat grains volatility is influenced by the demand/offer ratio, knowing that in the years with a high harvest performance, the market price is small, while in the years with low offer, the high demand increases the delivery price.

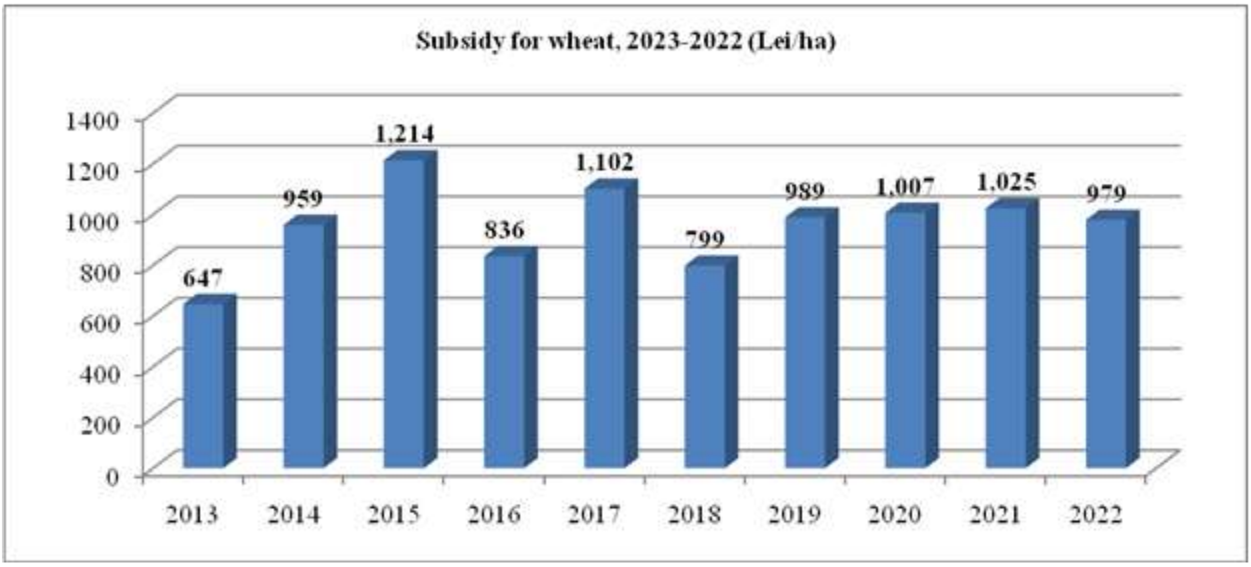

Fig. 7. The unique payment per surface unit cultivated with wheat, 2013-2022 (Lei/ha)
Source: Own design based on the data provided by Amzacea Sport Agra Ltd. [43].

It worth to mention that in the years 2022 and 2023, the wheat market price was influenced by the cereals coming from Ukraine which have upset the market decreasing wheat price which caused a real disappointment to the Romanian producers.

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Income got by farmer was also influenced by the unique payment per surface unit cultivated with wheat, as provided by Payments and Intervention Agency for Agriculture- APIA in the period 2013-2022. As it is known, the value of subsidy varied from a year to another as reflected in Figure 7.

According to Emergency Ordinance 3/2015, the role of this unique payment per surface unit is destined to the farmers who have eligible surfaces where agricultural practices with beneficial effects for climate and environment are implemented, like in case of Amzacea Sport Agra Ltd.

Without taking into consideration, the dynamics of income obtained by farmer from wheat growing in the period 2013-2023 varied between Lei 1,613,825.2 in 2013 and Lei 1,356,768.7 in the year 2023, which reflects a decline by Lei 256,855.5, because the income level in the last year of the analysis represented 84.08% of the 2013 level.

Of course, the variation of income from a year to another was caused by the amount of wheat sold in the market and market price. In the years when production performance was affected by climate change, especially by the low precipitations and drought, the income went down.

In this studied interval, the income peak was registered in the year 2022, which could be considered the best agricultural year for wheat at Amzacea Sport Agra Ltd., as the farmer obtained Lei 6,567,716.8. The lowest income level, accounting for Lei 630,864 was achieved in the year 2020, the worst year for wheat crop which was a calamity, a real disaster.

Taking into consideration the subsidy per hectare, the income level ranged between Lei 1,853,628.8 in 2013 and Lei 7,050,363.8 in the year 2022, which was 3.8 times higher than in 2013.

The dynamics of income coming from wheat crop without and with subsidy included at Amzacea Sport Agra Ltd. in the period 2013-2023 is shown in Fig. 8.

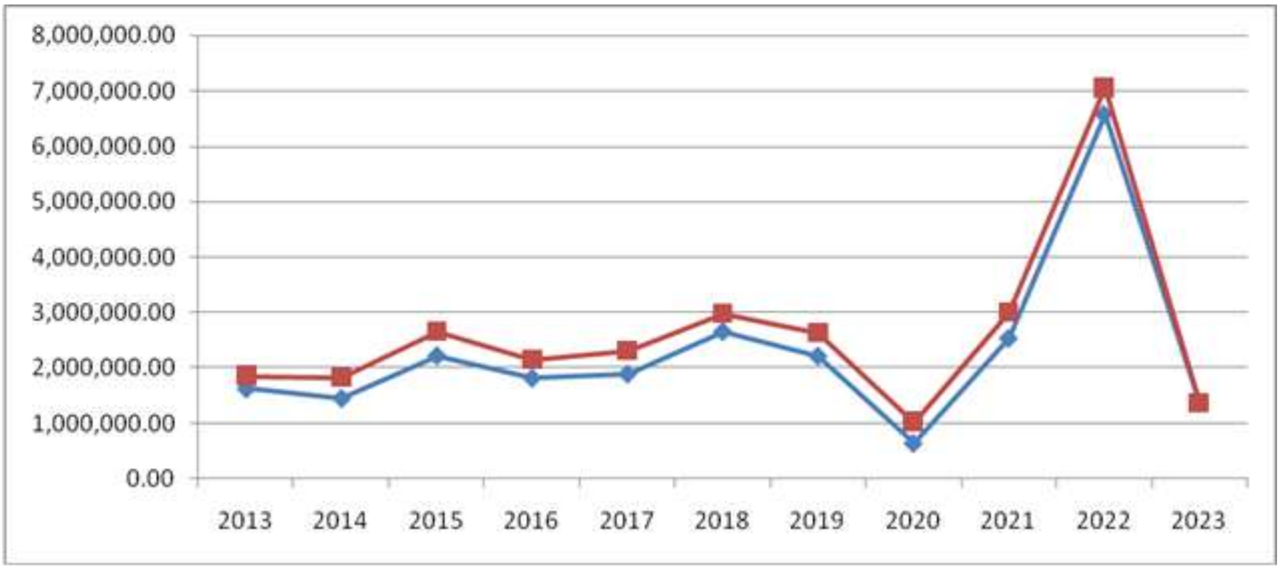

Fig. 8. Dynamics of income without and with subsidy included related to wheat culture in the period 2013-2023 (Lei)
Source: Own design based on the data provided by Amzacea Sport Agra Ltd.[43].
Note: Red line= Income with subsidy; Blue line= Income without subsidy

Dynamics of income only with subsidy included is shown in Fig. 9.

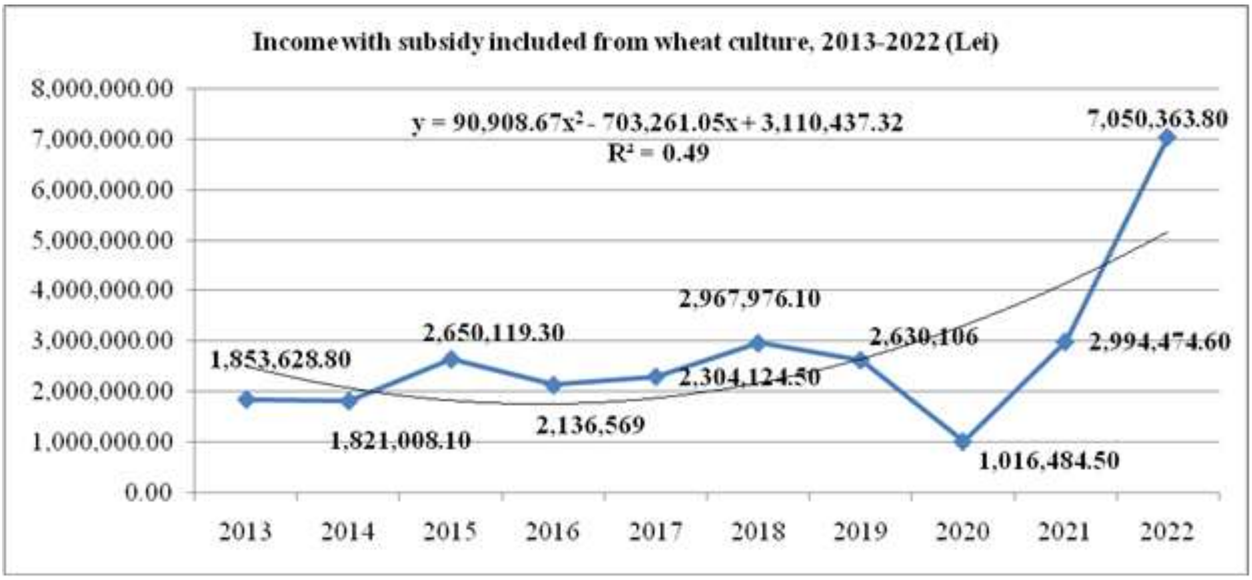

Fig. 9. Dynamics of income with subsidy included related to wheat culture in the period 2013-2022 (Lei)
Source: Own design based on the data provided by Amzacea Sport Agra Ltd.[43].

Dynamics of profit and profit rate coming from wheat culture

In the most years in the studied period, the company registered positive financial results in terms of profit, except the years 2020 and 2023, when it recorded losses.

The best financial year, with the highest profit was 2022, when the company carried out Lei 3,917,719.5 profit, which was 26.15 times higher than the profit achieved in the year 2013. The lowest profit level in this interval was Lei 510.9, achieved in the year 2014.

In 2020, the loss accounted for Lei -891,617.3, while in 2023, it is Lei -1,485,188.7, by 66.57% higher than in the year 2020 (Fig. 10).

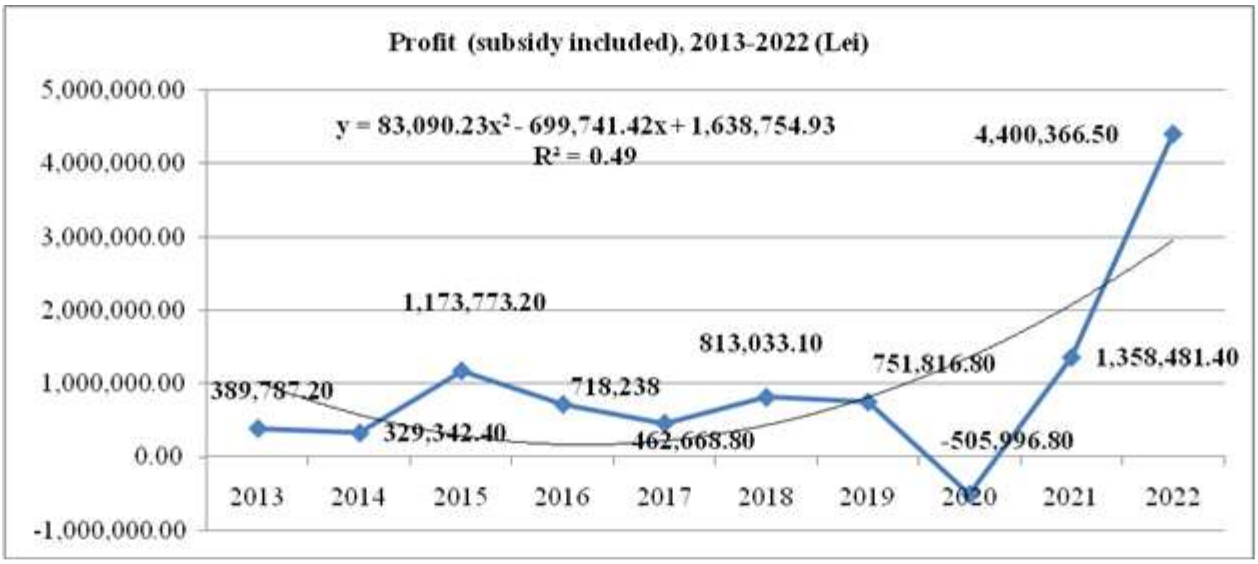

Fig.10. Dynamics of profit (subsidy included) related to wheat culture in the period 2013-2022 (Lei)
Source: Own design based on the data provided by Amzacea Sport Agra Ltd.[43].

Therefore, the worst agricultural years for wheat growing at Amazacea Sport Agra Ltd. were 2020 and 2023, and this happened due to the low production performance caused by the low precipitations and long and severe droughts.

Profit rate in wheat culture

Profit rate shows the efficiency of the spent expenses for wheat growing at Amzacea Sport Agra Ltd. in the majority of the agricultural years, except the years 2020 and 2023, when we identified discuss about loss rates.

In the analyzed interval, profit rate varied between 166.05%, the highest level, recorded in the year 2022 and 22.07% in the year 2014. Also, in other years, the company achieved good profit rates like: 83.03% in the year 2021, 79.5% in the year 2015, and 50.76% in the year 2016. In 2020, the loss rate accounted for -33.22% (Fig. 11).

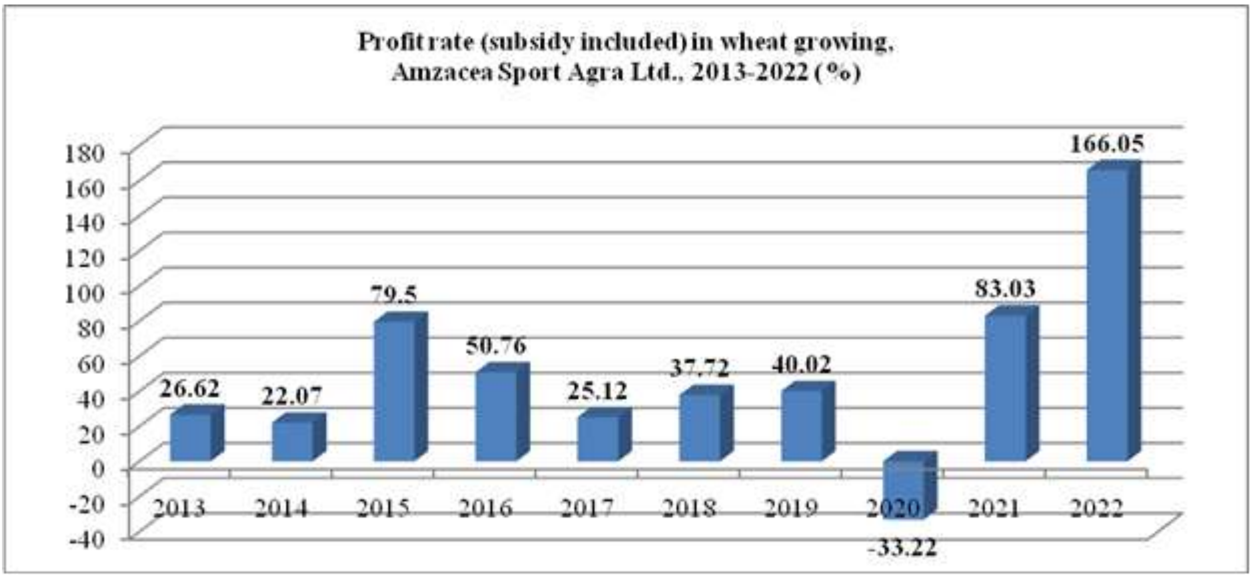

Fig.11. Dynamics of profit/loss rate (subsidy included) related to wheat culture in the period 2013-2022 (Lei)
Source: Own design based on the data provided by Amzacea Sport Agra Ltd.[43].

In 2023, the loss rate accounts for - 52.25% at present, when the subsidy is not year received. But, if the company will get, for example, Lei 1,000 per ha subsidy, the loss rate could be diminished to - 35.98%.

Cost per ha and ton grains wheat

Another studied indicator reflecting economic efficiency in wheat growing is the cost per surface unit and per ton of grains.

To cultivate a hectare with wheat, the farmer spent Lei 3,946.49 in the year 2013 and Lei 6,144.84 in the year 2023, and if we look at the evolution of this indicator in the analyzed years we may easily identify the increasing trend, and this is explained only by the higher and higher price for farm inputs (Fig.12).

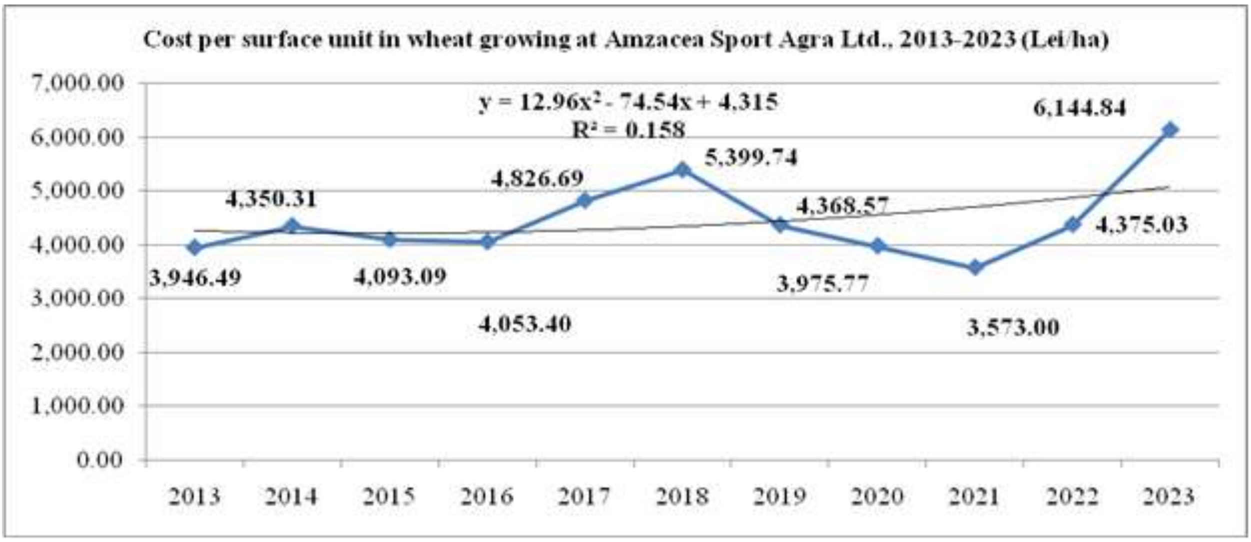

Fig. 12. Dynamics of costs per ha in wheat growing at Amzacea Sport Agra Ltd., 2013-2023 (Lei/ha)
Source: Own design based on the data provided by Amzacea Sport Agra Ltd. [43].

To produce a ton of wheat grains, the farmer spent between Lei 770.80 in the year 2013 and Lei 1,874.00 in the year 2023. Of course, there are variations from a year to another depending on cultivated area, production, and total expenses in close relationship with the factors which influenced wheat growing at Amzacea Sport Agra Ltd.

We have to mention that the worst year for wheat growing was 2020, when the production was almost entirely compromised due to the terrible bad climate conditions in terms of very low precipitations, high temperatures and long and severe drought and pedological drought in the agricultural year 2019-2020. In 2020, wheat production was only 228.80 kg/ha, meaning 87,620 kg harvested from the whole cultivated surface of 382.94 ha. Taking into account, that the total production costs were Lei 1,522,481.3, this means a cost per ton of Lei 17,370.

A high cost per ton is also obtained in the year 2023, when due to the unfavorable climate conditions, wheat seeds production is 1,516,520 kg and the production costs accounted for Lei 2,841,958.4, the highest level in the analyzed interval, In this case, the unitary cost per ton of wheat is Lei 1,874 (Fig. 13).

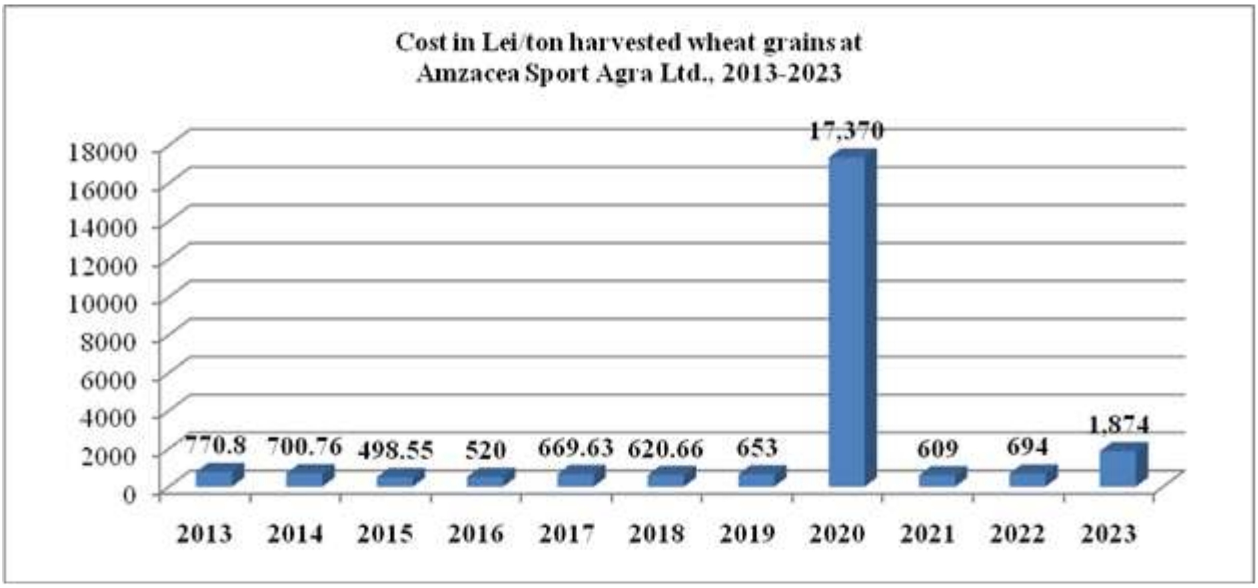

Fig. 13. Dynamics of cost per ton of harvested wheat seeds at Amzacea Sport Agra Ltd., 2013-2023 (Lei/ton)
Source: Own design based on the data provided by Amzacea Sport Agra Ltd. [43].

Profit per cultivated ha with wheat and per ton of harvested production

This indicators also reflect the economic efficiency in a crop cultivation, that is why we analyzed it in this study case at Amzacea Sport Agra Ltd.

Profit per cultivated hectare with winter wheat varied between Lei 1,050.78 in the year 2013 and Lei -3,211.14 in 2023, which in fact it is a loss per surface unit, not a profit.

Along the years included in the interval of analysis, it was also registered a loss per ha of -1,321.30 in the year 2020, when wheat production was almost entirely compromised.

However, the farmer was able to produce the highest profit per ha accounting for Lei 8,925.69 in the year 2022, the best year for wheat crop at Amzacea Sport Agra Ltd.

The lowest profit per ha was Lei 960.48 recorded in the year 2014.

Also, good profits per ha over Lei 3,000 in 2015 (Lei +3,255.23), and over Lei 2,000 per ha were registered in the year 2021 (Lei+2,967.08), in 2016 ((Lei + 2,052) and in 2018 (Lei + 2,037.52)
(Fig. 14).

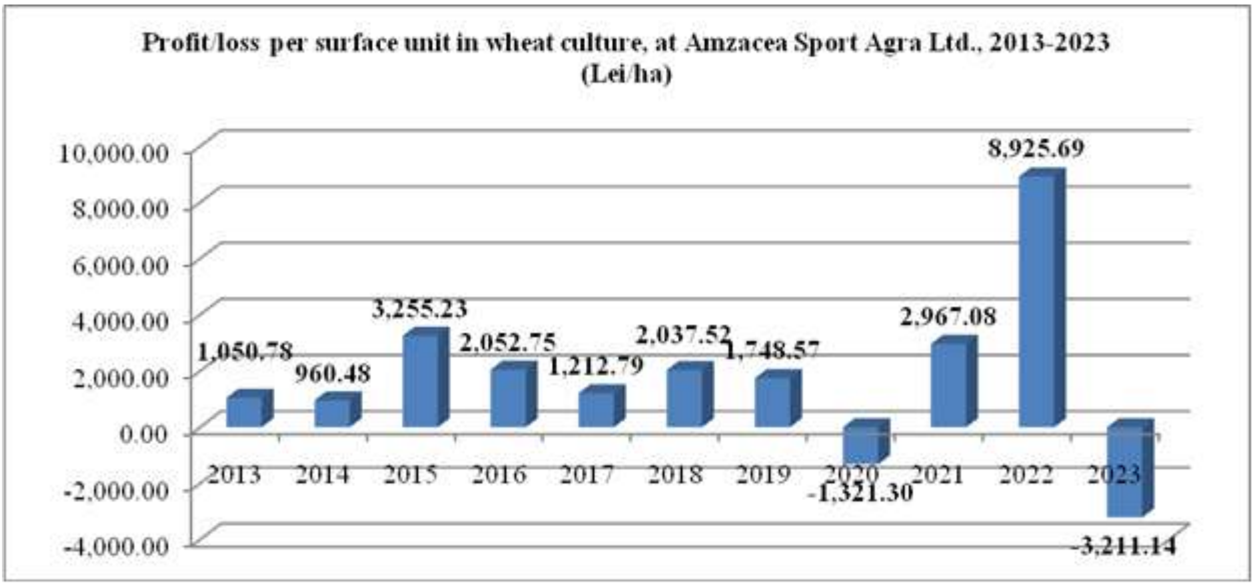

Fig. 14. Dynamics of profit per ha cultivated with wheat at Amzacea Sport Agra Ltd., 2013-2023 (Lei/ha)
Source: Own design based on the data provided by Amzacea Sport Agra Ltd. [43].

Regarding the profit obtained per ton of obtained wheat grains, we found that the level of this indicator varied between Lei +205.24 per ton in 2013 and a loss of Lei -979.33 per ton in 2023.

The best result was registered in the year 2022, when the farmer recorded a profit of Lei 1,152.39 per ton of wheat, and the lowest profit per ton was Lei +154.71 carried out in the year 2014.

Across the interval, the farmers was facing with losses per harvested ton of wheat, it is the case of the year 2020, when the loss accounted for Lei -5,774.90 per ton and the year 2023, as mentioned above, when it was registered a loss of Lei -979.33 per ton (Fig. 15).

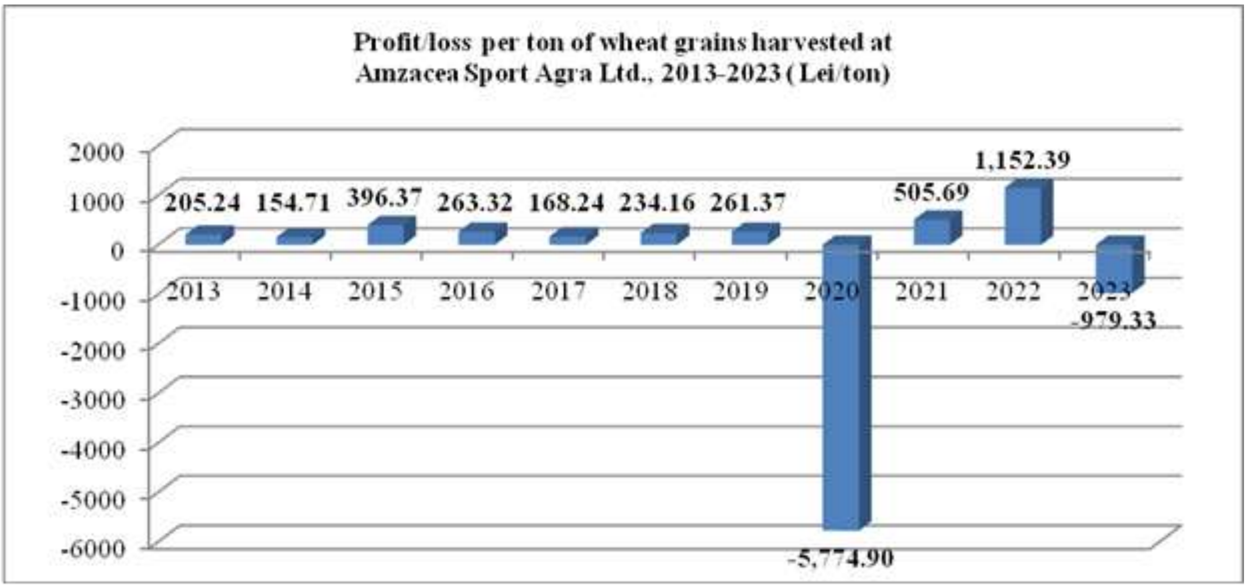

Fig. 15. Dynamics of profit per ton of harvested wheat seeds at Amzacea Sport Agra Ltd., 2013-2023 (Lei/ton)
Source: Own design based on the data provided by Amzacea Sport Agra Ltd.[43].

CONCLUSIONS

Given the pedoclimatic conditions of the geographical area of Dobrogea and especially of the coastal area in this area (Agigea, Topraisar, Amzacea, Comana, Negru-Voda, Albesti, Mangalia, 23 August, Tuzla, Eforie) mainly the temperatures that are increasingly high in the last 10 years as well as the lack of precipitations, the observations and research results have shown that choosing the sowing period between October 15-20 gave the best results given the extension of the autumn period with high temperatures 20-22 C° even in the months of November - December and the precipitations that fell favored the processes of germination, emergence and twinning. The 450 thermal degrees required for the twinning process were achieved due to the high temperatures. the seed treatment with appropriate substances (thiamethoxam, imidacloprid) for this geographical area is mandatory. Depending on the mass of 1,000 grains when sowing, a minimum of 600 germinating grains/m^2 must be ensured.

Although the seed supply companies recommend 400-450 germinating grains/m^2, in case of the varieties with high twinning capacity (Avenue, Rubisko), the brothers from the spring do not have the same number of grains in the ear as the mother plant.

In the 10 years of observations testing a large range of varieties produced in Romania and in other countries, the early and semi-early varieties: Katarina in 2014 – 7,930 kg/ha, El-Nino 8,125 kg/ha, Avenue 8,026 kg/ha, Kraljica 8,300 kg/ha in 2018 gave the best results, also in 2016 Katarina 8,400 kg/ha, Genius 8,300 kg/ha, Petur 8,000 kg/ha.

Due to the high temperatures that are established in the last decade of May and the first decade of June, 32-34 C°, the early varieties exceed the hot period, which aggravates the ripening and produces the phenomenon of stalling, so that for these varieties, the harvest starts on June 20 compared to July 1-5 in case of the other varieties. The early varieties also show the waist, the height of the plants, between 68 cm. Kraljica, 71 cm. Avenue, 75 cm. El Nino which had this height in the year 2018 when 596 mm were accumulated.

In 2016, the autumn wheat hybrids Hyfi, Hybiza and Hylux were tested for the first time, which achieved average productions between 7,140 kg/ha Hyfi and 4,740 kg/ha Hylux, while the rest of the varieties had productions of over 8,000 kg/ha.

The research results have shown that under non-irrigated conditions, even though in the agricultural year 2015-2016, in the fall of 2015, it had 611 mm./m^2 in the whole year and in 2016, 472 mm./m^2.

The climatic changes have also determined the attack of foliar diseases (Septoria tritici, Puccinia sp.) so that it is necessary to apply at least two treatments in the vegetation period with approved fungicides.

Because in the recent years, in the last decade of April, negative temperatures have been recorded, especially during the nights (-4, -5 C°), the application of treatments during that period will be avoided.

The years 2020 - 2023 recorded the lowest precipitations, 2020 - 267 mm., 2023 - 332.4 mm.

In 2020, thousands of hectares of wheat in Dobrogea were a calamity, the production at the level of Constanta County being 226 kg/ha. This year, the Romanian wheat varieties were better adapted to the climatic conditions, so that the Otilia variety achieved 2,370 kg/ha, Miranda 2,260 kg/ha, Glosa 1,870 kg/ha, while the Avenue variety could not be harvested, the Combin variety achieved 850 kg/ha, Apilco 550 kg/ha, Rubisko 276 kg/ha. The Miranda variety recorded 38 cm. height and Avenue 15 cm.

In the year 2023 with a total of 332.4 mm precipitations, the best results were recorded by the Solindo variety - 4,297 kg/ha and Ursita 4,165 kg/ha.

Due to the low temperatures -4,-5 C° in the first decade of April in 2023, although on February 25 the Ursita variety had a number of 640 plants/m^2 and on May 23rd it presented only 412 plants/sq.m., so that the research we carried out showed that it is absolutely necessary to ensure at least 600 germinating grains/sq.m. at sowing for this geographic area.

In all the years of observation and research, regardless of the varieties used, the level of production/ha was in close correlation with the water reserve from the fall of the previous year, as well as with the cumulative precipitations during the wheat growing season, so that in 2015, 8,216 kg were achieved /ha, in 2018 – 8,700 kg/ha, in 2022 – 7,745 kg/ha. In 2015, 611 mm./sq.m. were accumulated, in 2018 – 596.5 mm./sq.m. and in 2022 – 503.5 mm./sq.m. while in 2023 only 3,297 kg/ha and accumulated 332.4 mm./sq.m.

Regarding the financial results obtained from the whole cultivated area with winter wheat, we may affirm that this crop was profitable in almost the whole period 2013-2023, except the years 2020 and 2023.

The best agricultural year was 2022, when the profit from wheat cropping reached Lei 3,917,719.5 being 26.15 times higher than in 2013.

In the years 2020 and 2023, the company registered losses accounting for Lei-891,617.3 and, respectively, Lei -1,485,188.7.

Analyzing the financial result per cultivated area, the company carried out Lei 960.48 profit in 2014, the lowest level, a loss of Lei 1,321.30 in 2020 and Lei -3,211.14 in 2023, and the highest profit Lei 8,925.69 in 2022.

Per ton of wheat grains, the company profit ranged between Lei 154.71, the smallest level in 2014, and Lei 1,152.39 in 2022, the highest level. In the worst years, the loss per ton accounted for Lei -5,774.90 in 2020 and for -979.33 in 2023.

REFERENCES

[1]Agroberichten Biutenland, 2023, Eurostat: Romania ranks fourth in the EU by wheat crop in 2022, https://www.agroberichtenbuitenland.nl/actueel/nieuws/2023/01/18/romania-is-on-4th-place-in-the-eu-by-wheat-crop-in-2022#:~:text=France%20is%20EU's%20biggest%20wheat,tons%2C%20the%20same%20source%20shows., Accessed on Oct.14, 2023.

[2]Bandoc, G., Pravalie, R., 2015, Climatic water balance dynamics over the last five decades in Romania's most arid region, Dobrogea, Journal of Geographical Sciences, 25, 1307-1327.

[3]Chireceanu, C., Margarit, G., Jinga, V., Pascu, G., Manole, D., 2009, The invertebrate fauna associated of the wheat agricenosis in Amzacea, Romanian Journal of Plant Protection, Vol.2, 66-71.

[4]Constanta County Agricultural Division, 2023, http://www.dadr-ct.ro/, Accessed on Oct.14, 2023.

[5]Demeter, T., 2009, General Soil Science (Pedologie generala), Credis Publishing House, Bucharest, 174.

[6]Devot, A., Royer, L., Carron-Giauffret, E., Ayral, V., Deryng, D., Arvis, B., Giraud, L., Rouillard, J., 2023, The impact of extreme climate events on agriculture production in the EU, European Parliament, https://www.europarl.europa.eu/RegData/etudes/STUD/2023/733115/IPOL_STU(2023)733115_EN.pdf, Accessed on Oct.14, 2023.

[7]Elahi, I., Saeed, U., Wadood, A., Abbas, A, Nawaz, H, Jabbar, S., 2022, Effect of Climate Change on Wheat Productivity, Intechopen, DOI: 10.5772/intechopen.103780

[8]Ivanov, A., Tsenov, N., Stoeva, I., 2013. Grain quality of common wheat according to variety and growing conditions in the region of Dobrudzha. Bulg. J. Agric. Sci., 19: 523-529.

[9]Jinga, V., Manole, T., Gradila, M., Dudoiu, R., Giumba, A.M., Manole, D., 2014, Phyto-sanitary status of winter cereals in Dobrogea. Rom J.P lant Protection, http://www.rjpp.ro/index.php/archive/2014, Accessed on 14 Oct. 2023.

[10]Jinga, V., Lupu, C., Giumba, A.M., Manole, D., 2015, Behavior of new winter grain varieties in South Dobrogea, Scientific Papers. Series A. Agronomy, Vol. LVIII, 2015, 228-231. https://agronomyjournal.usamv.ro/pdf/2015/vol.LVIII/art41.pdf, Accessed on 14 Oct. 2023.

[11]Jinga, V., Dudoiu, R., Lupu, C., Manole, D., Giumba, A.M., 2016, Research regarding the improvement of sunflower crop technology in South-Eastern Dobrogea in the context of the current climate changes, Romanian Journal for Plant Protection, Vol. IX, 2016, 16-21.

[12]Jinga, V., Lupu, C., Giumba, A.M., Manole, D., 2017, Yields and pathogens of new varieties of barley and wheat during 2016 in Dobrogea region of Romania. Book of Proceedings, VIII International Scientific Agriculture Symposium, 'Agrosym 2017', 1290-1294.

[13]Jinga, V., Vlăduț, V., Marin, E., Manole, D., 2018, Sorghum culture - a solution for Dobrogea agriculture. Proceedings of International Symposium, ISB-INMA TEH'2018, Agricultural and mechanical engineering, Bucharest, Romania, 1-3 November 2018, pp.951-954.

[14]Luković, K., Zečević, V., Prodanović, S., Milivojević, J., Đekić, V., 2017, Effect of growing season and genotype on winter wheat quality. Proceedings of the VIII International Agricultural Symposium „AGROSYM 2017", 536–542.

[15]Lup, A., Chirila, C., 2012, Agriculture of Dobrogea from Ion Ionescu de la Brad until the European integration. Historical highlights, Scientific Papers – Vol. 55, Supplement /2012, Series Agronomy, 209-2013.

[16]Mangalia Meteorological Stations, 2023, Climatological data for the years 2022 and 2023

[17]Manole, D., 2018, Sorghum Crop an Alternative for Dobrogea Farmers, 4th International Congress of Sorghum, Millan, Italy, Nov.8, 2018.

[18]Manole, D., Jinga, V., Giumba, A.M., Dudoiu, R., Cristea, S., 2018, Researches regarding new and improved technologies for sunflower and sorghum crops in the context of climate changes in Dobrogea

region, Agriculture for Life, Life for Agriculture" Conference Proceedings, Vol.1, 79-86.

[19]Manole, D., Giumba, A.M., Jinga, V., Radu, I., 2018, The behavior of new barley and wheat varieties at S.C. Sport Agra-Amzacea, under 2018 conditions. Romanian Journal for Plant Protection, Vol. 11, pp. 39-43.

[20]Manole, D., Jinga, V., Giumba, A.M., Dudoiu, R., 2018, Sorghum crop, an alternative for Dobrogea farmers in the context of climate changes, Proceeding Book AGROBIOL, Edirne, Turkey, pp. 415 – 419.

[21]Manole, D., Jinga, V., Gradila, M., Radu, I., Iordache, S., Soare, S., 2019, New edition on sunflower crop-Romanian technology under climate change conditions in Dobrogea, Scientific Papers. Series A. Agronomy, Vol. LXII, No. 1, 2019, 348-354.

[22]Manole, D., Giumba, A.M., Ganea, L., 2020, Researches and Contributions to Plant Sorghum Crop in the conditions of Climate Change, Annals of the Academy of Romanian Scientists Series Agriculture, Silviculture and Veterinary Medicine Sciences Vol.9, No.1, 2020.

[23]Manole, D., Ganea, L., 2020, 2020, Sunflower hybrids in the climatic conditions of the year 2020 in Constanta County - South East of Dobrogea, Romania, Annals of the Academy of Romanian Scientists Series Agriculture, Silviculture and Veterinary Medicine Sciences Vol.9, No.2, 2020.

[24]Manole, D., Jinga, V., Gurau, L.-R., Radu, I., 2020, Diseases and yield of new varieties of barley and wheat in Dobrogea region, Scientific Papers. Series A. Agronomy, Vol. LXIII, No. 1, 2020, 380-386.

[25]Medgidia Meteorological Stations, 2023, Climatological data for the years 2022 and 2023

[26]Meteorological Station Amzacea, Constanta County, 2023.

[27]Musat, M., 2023, Ferma, 14 iunie 2023, În Dobrogea, culturile suferă din cauza uscăciunii!https://revista-ferma.ro/in-dobrogea-culturile-sufera-din-cauza-uscaciunii-2/, Accessed on 14 Oct. 2023.

[28]National Adminitration of Meteorology, Romania, 2023, https://www.meteoromania.ro/, Accessed on 14 Oct. 2023.

[29]National Institute of Statistics, 2023, www.insse, ro, Accessed on 14 Oct. 2023.

[30]National Institute of Statistics, 2023, Press Release No.77/31 March, Vegetal production for the main crops in the year 2022, https://insse.ro/cms/sites/default/files/com_presa/com_pdf/prod_veg_r22.pdf, Accessed on Oct. 14, 2023.

[31]Panaitescu, L., Lungu, M., Niţă, S., Albu, A.N., Beleniuc None, G., 2010, Studies Regarding the Behavior of Certain Varieties of Autumn Wheat in the Current Agroclimatic Conditions of Dobrogea, Research Journal of Agricultural Science, Vol.42(1), 239-243.

[32]Panaitescu, L., Lungu, M., Niţă, S., 2011, Agro-meteorological conditions for the cu,tivation of autumn wheat in South Dobrogea, Present Environment and Sustainable Development, Vol.5(1), 169-179.

[33]Popescu, A., 2006, Gross margin–a barometer of profitability in agriculture, International Symposium "Durable Agriculture–the agriculture of the future ", Craiova, 23-24.

[34]Popescu, A., 2018, Maize and Wheat - Top agricultural products produced, exported and imported by Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.18(3), 339-352

[35]Popescu, A., 2020, Variation of the agricultural crops yield due to climate change in Constanta County compared to Dobrogea Regions and Romania in the period 2010-2019, Annals of Academy of Romanian Scientists, Vol. 9, No.2, pp.37-46.

[36]Popescu, A., Dinu, T.A., Stoian, E., 2018, The comparative efficiency in Romania's foreign trade with cereals, 2007-2016, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.18(1), 371-384.

[37]Popescu, A., Dinu, T.A., Stoian, E., Serban, V., 2020, Variation of the main agricultural crops yield due to drought in Romania and Dobrogea region in the period 2000-2019, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.20(4), 397-415.

[38]Popescu, A., Tindeche, C., Marcuta, A., Marcuta, L., Hontus, A., 2022, Cereals production between climate change and price boom in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.22(4), pp. 549-564.

[39]Popescu, A., Stanciu, M., Serban, V, Ciocan, H.N., 2022, Cereals production and price in the European Union, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol.22(4), pp.565-578.

[40]Popescu, A., Dinu, T.A., Stoian, E., Serban, V., 2023, Climate change and its impact on wheat, maize and sunflower yield in Romania in the period 2017-2021, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.23(1), 597-602.

[41]Prăvălie, R., Bandoc, G.,, 2015, Aridity Variability in the Last Five Decades in the Dobrogea Region, Romania, J. Arid Land Research and Management, Vol. 29(3), 265-287.

[42]Sandu, I., Mateescu, E., Vatamanu, V., 2010, Climate change and the effects on agriculture (Schimbarile climatice si efectele asupra agriculturii), Sitech Publishing House, Craiova, pp. 20-30.

[43]Sport Agra Ltd, 2023, http://www.firme.info/sport-agra-srl-cui5782048/, Accessed on Oct.14, 2023.

[44]Statista, 2023, Wheat statistics and facts, https://www.statista.com/topics/1668/wheat/#topicOverview,
Accessed on Oct.14, 2023.

[45]Statista, 2023, Leading 10 wheat producers worldwide from 2016/2017 to 2022/2023 (1,000 MT), https://www.statista.com/statistics/237908/global-top-wheat-producing-countries/#:~:text=Global%20leading%20wheat%20pr

oducing%20countries%202016%2F2017%2D%202022%2F23&text=The%20European%20Union%20was%20the,wheat%20production%20in%202022%2F23., Accessed on Oct.14, 2023.

[46]Timar, O., 2023, USDA Report, August 2023; Romania's wheat production - 10.2 million tons, for maize the harvest is decreasing. Agrointel.ro, https://agrointel.ro/268551/raport-usda-august-2023-estimari-recolta-cereale/, Accessed on Oct.14, 2023.

[47]Tsenov, T, 2009, Relation between time to heading and date of maturity of winter common wheat varieties (*Triticum aestivum* L.) Journal of Agricultural Science and Technology. Vol.1(4), 126-132.

[48]Tsenov, N., Atanasova, D., Stoeva, I., Tsenova, E., 2015. Effects of drought on grain productivity and quality in winter bread wheat. Bulg. J. Agric. Sci., 21: 589–595

[49]Ziua de Constanta, 13 June 2022, Constanta, among the top counties for wheat yield over 5 tons per ha, https://www.ziuaconstanta.ro/stiri/actualitate/constanta-printre-primele-judete-la-randamente-de-peste-cinci-tone-de-grau-la-hectar-786632.html, Accessed on Oct.14, 2023.

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CEREAL PRODUCTION OF DOLJ COUNTY IN THE REGIONAL AND NATIONAL CONTEXT (2017-2021), ROMANIA

Dragoș Mihai MEDELETE, Radu Lucian PÂNZARU

University of Craiova, Faculty of Agronomy, 19 Liberty Street, , 200421, Craiova, Romania, Phone: +40 741 180 976, Fax: + 40 251 418 475, E-mails: dragosmedelete@gmail.com, rlp1967craiova@gmail.com

Corresponding author: rlp1967craiova@gmail.com

Abstract

The purpose of the paper was to analyze cereal production in Dolj County and in Romania in the period 2017-2021 in order to identify the main trends, based on the statistical data provided by National Institute of Statistics and processing them by comparison method and time and structural indices. Dolj County has a total area of 741,401 ha (7th place at national level – 3.11% of the total), an agricultural area of 585,135 ha (2nd place at national level – 32.57%) and an arable area of 488,560 ha (2nd place at national level – 39.03%). The county is characterized by favorable agro-productive conditions for cereal cultivation, taking into account climatic factors and soils specific to the county (for example, sandy soils for rye cultivation). The county cultivated (on average) 331,450.80 ha with cereals, predominantly wheat and grain maize (60.5, and 26.53% of the total), obtained a total production of 1,567,667 t (predominantly wheat and maize with 54.89 and 33.96% of the total), and the average yield per hectare reached 4,728 kg. It can be said that Dolj County can decisively influence, in certain situations, the cereals market in Romania and the South-West Oltenia Region, but it must be aimed at improving the performance of this side of vegetal activity, in order to capitalize on the existing potential.

Key words*: *cereals, production, yield, area under cultivation

INTRODUCTION

Dolj County is located in the South-Western part of Romania, being part of the South-West Oltenia Development Region. The county stands out through a total area of 741,401 ha (7th place nationally – 3.11% of the total), an agricultural area of 585,135 ha (2nd place nationally – 3.99%) and an arable area of 488,560 ha (2nd place nationally – 5.20%). Starting from these aspects and agro-pedo-climatic characteristics, it can be said that the county presents favorable conditions for grain cultivation, although here may occur the drought phenomenon that affects the production potential of some cereal species [1].The county presents a wide range of solutions, for which the winter wheat crop is abundantly suitable, as some authors specify [2], but at the same time the crop is sensitive to extreme weather phenomena [12].

The idea of writing the paper appeared as a result of the fact that Romania is a large cereal grower [8] [13], so that cereal production is predominant in the agricultural sector [4], and Dolj County has tradition for those crops. For Dolj County, the fluctuation of cereal production is directly related to variations in environmental factors [6], such as drought – for which sorghum shows increased resistance to other species due to its root system [11].

The group of cereals is important, in terms of the important characteristics they present, in relation to their multiple use at social level [3]. This group includes a number of crops, as follows: wheat, rye, barley, barley, oats, maize, sorghum, rice, etc. Cereals are used in human food with a significant role [5]. For example, corn is appreciated for its fiber and carbohydrate content, due to the proteins included in its grain [7] or for its approximately 400 products with various uses [10]. At the same time, we can say that rice is one of the most important cereals used in food worldwide [9].

In this context, the goal of the research was to analyze cereal production in Dolj County and in Romania in the period 2017-2021 in order to identify the main trends, based on the statistical data provided by National Institute of Statistics and processing them by comparison method and time and structural indices.

MATERIALS AND METHODS

The paper refers to the defining indicators of cereal production (cultivated area - ha, total production - t, average production - kg / ha), which are collected from the level of the specific national database [14].The indicators shall be presented at the general level of the product group for winter wheat, rye, barley and barley, oats, grain maize, sorghum and 'other cereals' respectively.

The analysis presents the state of affairs specific to the period 2017-2021, and anchoring the county in a national and regional context is achieved by establishing the average weights for the area and total production, respectively by positioning the average yields compared to the reference levels.

The method of comparison in time and space, as well as the method of percentages, helps to carry out the analysis we set out to carry out.

RESULTS AND DISCUSSIONS

Cultivated area with cereals

Table 1 shows the area under cultivation at crop group level and for the main cereal species.

The total area varied from 326,327 ha in 2017 to 338,231 ha in 2019. It can be noted that the indicator increased from 2017 to 2019 (+0.6% in 2018 – 328,291 ha, +3.65% for 2019), after which it decreases to the level of 2020 and 2021 (exceedances by 2.37 and 1.23%, respectively, of the comparison term, given that the actual level of the indicator reached 334,070 and 330,335 ha).

Table 1. Area under cultivation (ha)

No.	Specify	Year								
		2017	2018		2019		2020		2021	
		Ef.*	Ef.*	Ibf**	Ef.*	Ibf**	Ef.*	Ibf**	Ef.*	Ibf**
1	Total	326,327	328,291	100.60	338,231	103.65	334,070	102.37	330,335	101.23
2	Wheat	198,238	200,534	101.16	199,203	100.49	202,360	102.08	202,280	102.04
3	Rye	2,606	2,462	94.47	2,381	91.37	2,545	97.66	1,854	71.14
4	Barley and two row barley	29,094	29,005	99.69	28,796	98.98	30,180	103.73	33,208	114.14
5	Oats	4,199	4,124	98.21	4,036	96.12	3,500	83.35	4,045	96.33
6	Grain maize	85,294	85,006	99.66	97,165	113.92	88,872	104.19	83,335	97.70
7	Sorghum	1,349	852	63.16	856	63.45	531	39.36	428	31.73
8	"Other cereals"	5,592	6,308	112.80	5,794	103.61	6,082	108.76	5,185	92.72

*http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table (26.05.2023) – AGR108A-Area cultivated with main crops, by forms of ownership, macro regions, development regions and counties [14].
Source: **own calculations.

For wheat, it is found that the indicator was between 198,238 ha in 2017 and 202,360 ha in 2020. Compared to 2017, there is an increase in cultivated areas as follows: +0.49% in 2019 (199,203 ha), +1.16% for 2018 (200,534 ha), +2.04% in 2021 (202,280 ha) and +2.08% in 2020.

Regarding the areas cultivated with rye, it can be noted that they were 2,606 ha in 2017, 2,462 ha in 2018 (-5.53% in dynamics), 2,381 ha for 2019 (-8.63%), 2,545 ha in 2020 (-2.34%) and 1,854 ha in 2021 (-28.86%).

As regards the areas occupied by barley and two rows barley, their uneven evolution can be observed for the analysis period. Thus, from 29,094 ha cultivated in 2017, it reaches 29,005 ha in 2018 (-0.31%), 28,796 ha for 2019 (-1.02%), 30,180 ha in 2020 (+3.73%) and 33,208 ha in 2021 (+14.14%).

The oat crop occupied variable land areas, ranging from 3,500 to 4,199 ha in 2020 (-16.65% compared to the reporting deadline) and 2017, respectively. Under these conditions, there are decreases in the indicator in 2018 and 2019 (-1.79 and -3.88% - actual areas of 4,124 and 4,036 ha, respectively), decreases that also occur for 2021 (-3.67% - 4,045 ha).

Grain maize has consistently exceeded a level of 83,000 ha of cultivated area. Thus, 83,335 ha were cultivated in 2021 (-2.30% in dynamics), 85,006 ha in 2018 - 0.34%), 85,294 ha in 2017 (reference term), 88,872 ha in 2020 (+4.19%) and 97,165 ha in 2019 (+13.92%).

Sorghum was cultivated on areas between 428 and 1,349 ha in 2021 and 2017, respectively, observing the downward trend of the indicator compared to the first term of the dynamic series as follows: -36.84% in 2018 (852 ha), -36.55% for 2019 (856 ha), -60.64% in 2020 (531 ha) and -68.27% in 2021.

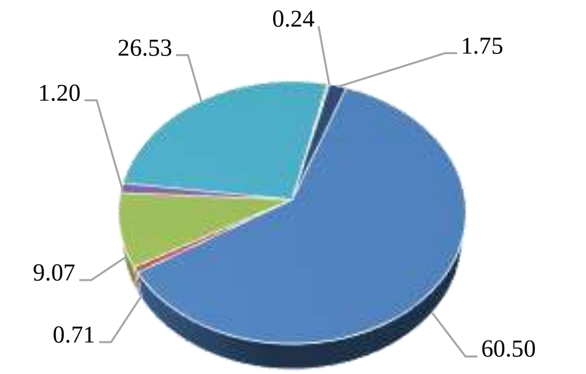

Fig. 1. Structure of area under cereals — average of period (%)
Source: own calculation.

If we refer to "other cereals", there are levels of 5,185 to 6,308 ha of cultivated area, in the case of 2021 and 2018, respectively (-7.28 and +12.80%). The indicator varied unevenly, compared to the specific situation of 2017 – 5,592 ha: +3.61% in 2019 (5,794 ha), +8.76% for 2020 (6,082 ha).

Starting from the situations presented above, the structure of the indicator for the average period (331,450.80 ha) was determined: 60.50% wheat (200,523 ha), 26.53% grain corn (87,925.40 ha), 9.07% barley and barley (30,0056.60 ha), 1.75% "other cereals" (5,792.20 ha), 1.20% oats (3,980.80 ha), 0.71% rye (2,369.60 ha) and 0.24% sorghum (803.20 ha) (Figure 1).

Total cereal production

Information on total production is presented in Table 2.

Total cereal production exceeded the threshold of 1,250,000 t throughout the dynamic series analyzed. Thus, the lowest level was 1,250,576 t in 2020 (-24.56% in dynamics), followed by annual statements of 1,497,602 t in 2021 (-9.66%), 1,657,750 t for 2017 (base term), 1,680,949 t in 2019 (+1.40%) and 1,751,457 t for 2018 (+5.65%).

Wheat is characterized by variable yields from 661,670 t in 2020 (-25.99%) to 945,187 t in 2021 (+5.73%). For the rest of the years, there were situations of: 894,001 t in 2017, 894,700 t in 2019 (+0.08%), 906,619 t in 2018 (+1.41%).

Rye production was 6,631 t in 2017, compared to which the following positions were recorded: 93.09% in 2018 (6,173 t), 90.11% in 2019 (5,975 t), 80.76% for 2020 (5,335 t) and 76.31% in 2021 (5,060 t).

Barley and barley provided total variable yields from 125,574 to 140,096 t in 2020 and 2021, respectively (-7.45 and +3.25% compared to the reporting deadline – 2017, 135,684 t). In the rest of the years (2019 and 2018), yields of 131,830 and 136,720 t were recorded, which represented 97.16 and 100.76% of the level of the first term of the dynamic series respectively.

For oats, the indicator exceeded the threshold of 7,500 t, falling to a level of 10,800 t, as follows: 7,623 t in 2020 (74.65% in dynamics), 8,946 t in 2019 (87.61%), 10,211 t in 2017, 10,416t in 2018 (102.01%), 10,747 t in 2021 (105.25%).

Total grain maize production exceeded 370,000 t but did not exceed 670,000 t.

Thus, annual situations are found, as follows: 584,754 t in 2017, 661,290 t for 2018 (113.09% in dynamics), 615,240 t in 2019 (105.21%), 427,134 t in 2020 (73.05%), 373,749 t for 2021 (63.92%).

For sorghum, total yields between 718 and 1,905 t are observed in 2020 and 2018 (48.25 and 128.02% dynamics, respectively). For the rest of the dynamic series terms, the situation was as follows: 1,452 t in 2019 (97.58%), 1,488 t for 2017, 1,671 t in 2021 (112.30%).

In the case of "other cereals", the indicator was as follows: 24,981 t in 2017, 28,334 t in 2018 (+13.42% in dynamics), 22,806 t in 2019 (-8.71%), 22,502 t in 2020 (-9.92%), 21,092 t in 2021 (-15.57%).

Table 2. Total production (t)

No.	Specify	Year								
		2017	2018		2019		2020		2021	
		Ef.*	Ef.*	Ibf**	Ef.*	Ibf**	Ef.*	Ibf**	Ef.*	Ibf**
1	Total	1,657,750	1,751,457	105.65	1,680,949	101.40	1,250,576	75.44	1,497,602	90.34
2	Wheat	894,001	906,619	101.41	894,700	100.08	661,670	74.01	945,187	105.73
3	Rye	6,631	6,173	93.09	5,975	90.11	5,355	80.76	5,060	76.31
4	Barley and two row barley	135,684	136,720	100.76	131,830	97.16	125,574	92.55	140,096	103.25
5	Oats	10,211	10,416	102.01	8,946	87.61	7,623	74.65	10,747	105.25
6	Grain maize	584,754	661,290	113.09	615,240	105.21	427,134	73.05	373,749	63.92
7	Sorghum	1,488	1,905	128.02	1,452	97.58	718	48.25	1,671	112.30
8	"Other cereals"	24,981	28,334	113.42	22,806	91.29	22,502	90.08	21,092	84.43

*http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table(26.05.2023) – AGR109A-Vegetal agricultural production by main crops, by forms of ownership, macro regions, development regions and counties [14].
Source: **own calculations.

If we analyze the total production in terms of values related to the average of the period, there is a general county level of 1,567,667 t, level based on sequential contributions of: 0.09% sorghum (1,446.80 t), 0.37% rye (5,8387.80 t), 0.61% oats (9,588.6 t), 1.53% "other cereals" (23,943 t), 8.55% barley and barley (133,980.80 t), 33.96% grain corn (532,433.40 t), 58.49% wheat (860,435.40 t) (Figure 2).

Average production per ha

The average production performance per surface unit (kg/ha) is shown in Table 3.

At the general level of the crop group, there are positions between 3,743 and 5,335 kg / ha in the case of 2020 and 2018, respectively (weights of 73.68 and 105.02%, respectively, compared to the reference land – 2017 characterized by a level of 5,080 kg / ha). In 2021, the indicator exceeded the level of 4,500 kg/ha (4,534 kg/ha – 89.25%), and for 2019 it stood at 4,970 kg/ha (97.83% compared to 2017).

The average wheat production per hectare constantly exceeded the threshold of 4,000 kg / ha, except for 2020 when it was 3,743 kg / ha (73.68% compared to 4,510 kg / ha, situation specific to 2017). For 2018 and 2019, the indicator was "almost constant" compared to the reporting deadline (+0.24 and -0.42% respectively in 2018 and 2019), only in 2021 a larger difference was found (+3.61%).

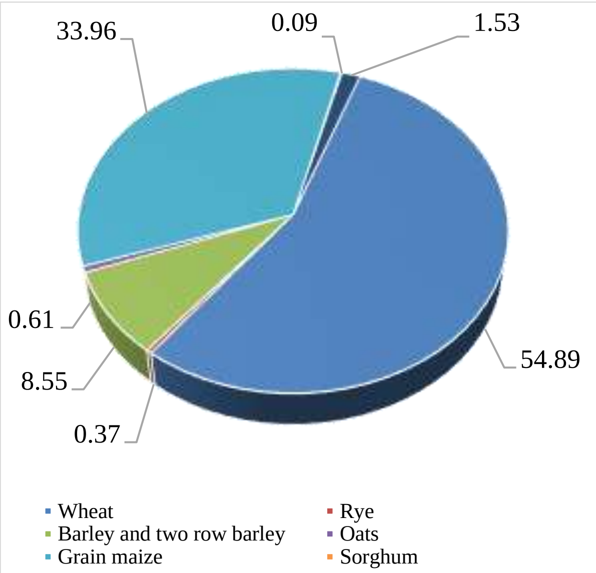

Fig. 2. Structure of total cereal production — average of period (%)
Source: own calculation.

In rye, the county shows low levels of average production per productive unit (between 2,000 and 3,000 kg/ha), levels that varied unevenly:

2,545 kg/ha in 2017, -1.49% for 2018 (2,507 kg/ha), -1.41% in 2019 (2,509 kg/ha), -17.33% in 2020 (2,104 kg/ha), +7.27% for 2021 (2,730 kg/ha).

If we refer to the specific situation of barley and two rows barley crops, there are variable levels of average production, from 4,161 to 4,714 kg / ha in the case of 2020 and 2018 respectively (89.21 and 101.07% respectively compared to the first year of the dynamic series).

Table 3. Yields by cereal type (kg/ha)

No.	Specify	Year								
		2017	2018		2019		2020		2021	
		Ef.*	Ef.*	Ibf**	Ef.*	Ibf**	Ef.*	Ibf**	Ef.*	Ibf**
1	Total	5,080	5,335	105.02	4,970	97.83	3,743	73.68	4,534	89.25
2	Wheat	4,510	4,521	100.24	4,491	99.58	3,270	72.51	4,673	103.61
3	Rye	2,545	2,507	98.51	2,509	98.59	2,104	82.67	2,730	107.27
4	Barley and two row barley	4,664	4,714	101.07	4,578	98.16	4,161	89.21	4,219	90.46
5	Oats	2,432	2,526	103.87	2,217	91.16	2,178	89.56	2,657	109.25
6	Grain maize	6,856	7,779	113.46	6,332	92.36	4,806	70.10	4,485	65.42
7	Sorghum	1,103	2,236	202.72	1,697	153.85	1,351	122.48	3,904	353.94
8	"Other cereals"	4,467	4,492	100.56	3,936	88.11	3,700	82.83	4,068	91.07

*http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table (26.05.2023) – AGR110A-Average yield per hectare, main crops, by forms of ownership, macro regions, development regions and counties [14].
Source: **own calculations.

The reference level (4,664 kg/ha) in 2017 was not reached for 2019 and 2021 (4,578 and 4,219 kg/ha).

For oats, there are average yield levels per hectare, as follows: 2,432 kg in 2017, 2,526 kg in 2018 (+3.87% in dynamics), 2,217 kg for 2019 (-8.84%), 2,178 kg in 2020 (-10.44%) and 2,657 kg for 2021 (+9.25%).

For grain maize, we can assume that the situation for the first three years is favorable (levels between 6,332 and 7,779 kg/ha in 2019 and 2018 respectively), while for 2020 and 2021 the indicator was below 5,000 kg/ha (4,806 and 4,485 kg).

For sorghum, it is found that 2017 (reference date – 1,103 kg/ha) was exceeded by the rest of the terms of the dynamic series – ahead of 1.22, 1.53, 2.02 and 3.53 times for 2020, 2019, 2018 and 2021 respectively (13,351, 1,697, 2,236 and 3,904 kg/ha).

For crops in the 'other cereals' group, levels ranged from 3,700 kg/ha in 2020 to 4,492 kg/ha in 2018. Compared to the first analyzed year (2017 – 4,467 kg / ha), there are three sub-unit levels of the indicator in 2020, 2019 and 2021 (82.82, 88.11 and 91.07%) and a supra-unitary level (2018 – 100.56%).

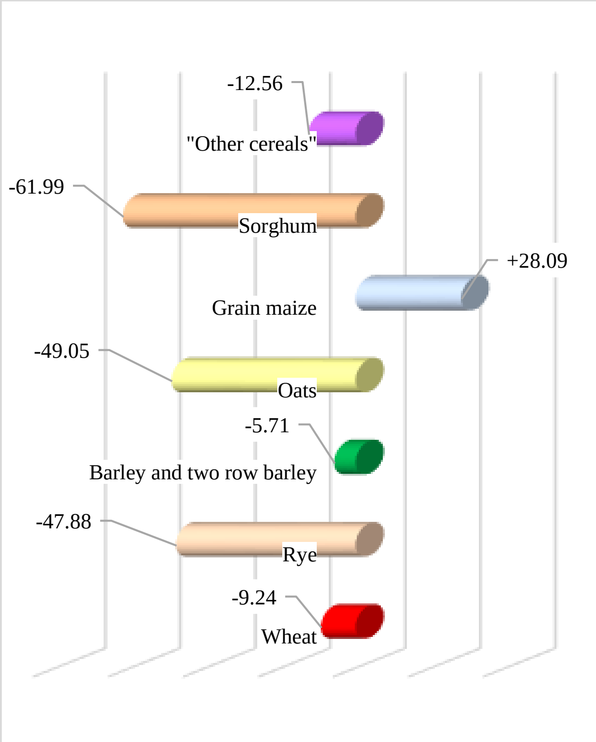

Fig. 3. Average production per hectare, positioning compared to the general level – average of the period (±%)
Source: own calculation.

Based on our own calculations, we determined the average of the period that reached 4,728 kg / ha, against which the crops were positioned as follows: +28.09% grain corn (6,056 kg / ha), -5.71% barley and barley (4,458 kg / ha), -9.24% wheat (4,291 kg / ha), -12.56% "other cereals" (4,134 kg / ha), -47.88% rye (2,464 kg / ha), -49.05% oats (2,409 kg / ha), -61.99% sorghum (1,801 kg / ha) (Figure 3).

If we relate the county situation to the existing realities at national and regional level, we find the following aspects:

- For cultivated area, the county accounted for 6.21% of the total national area and 40.52% of the total regional area. For component crops, the county held between 2.94 and 22.54% of the national total for oats and rye, respectively, and at regional level, the extreme shares were 23.21% for oats and 89.68% for rye (Figure 4).
- In terms of total production, variable shares are observed at national level from 2.78% for sorghum to 19.92% for rye crops, with a share of 5.80% for the entire product group.

-In the regional context, the county accounted for 39.71% of the total grain production and made extreme contributions to sorghum and rye crops respectively (26.38 and 88.15%) (Figure 5).

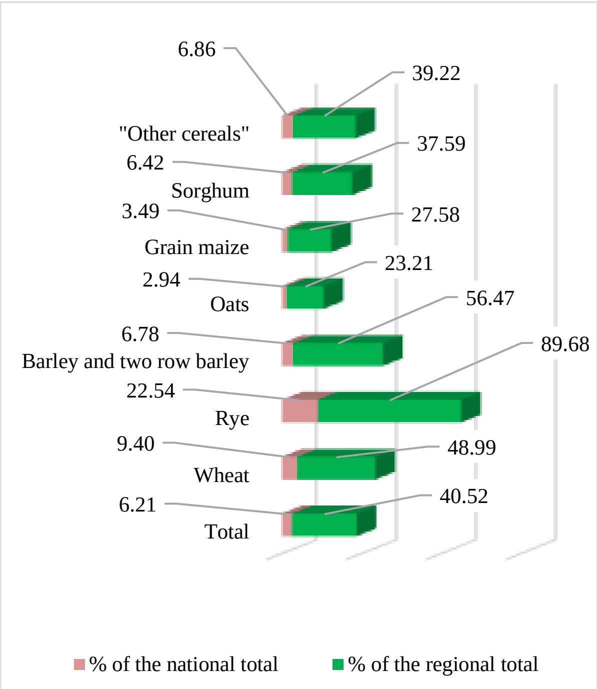

Fig. 4. Cultivated area, share of the county at national and regional level – average of the period (%)
Source: own calculation.

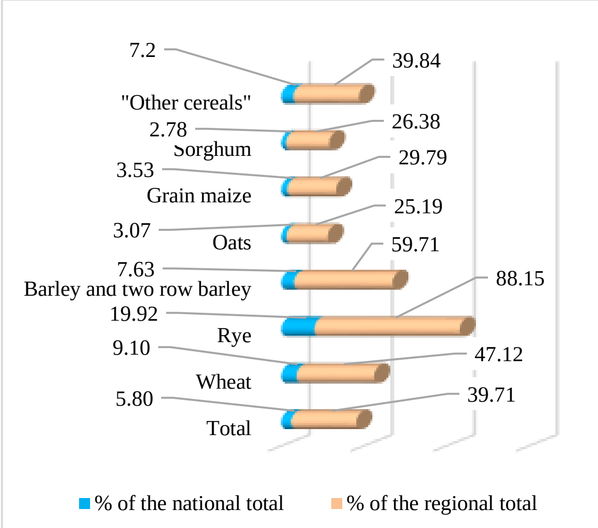

Fig. 5. Total production, share of the county at national and regional level – average of the period (%)
Source: own calculation.

- The average yield per hectare, places Dolj County below the national level for wheat, for the total group, for rye and sorghum (from -3.23 to -56.67%) and above it for the rest of the crops (exceeded from 1.34 to 12.69% for grain corn, respectively for barley and two rows barley.

In the regional context, the county has exceeded the specific situation for other cereals, barley and barley, grain corn and oats, while for the rest of the crops, the county is placed below the regional level (Figure 6).

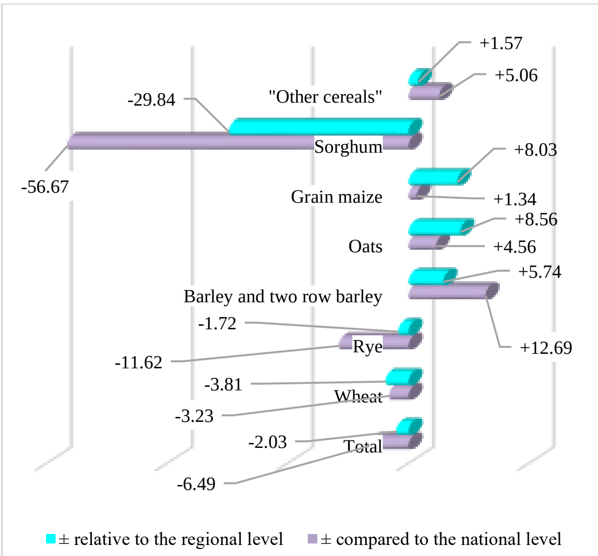

Fig. 6. Average yield per hectare, positioning of the county in relation to the national and regional level – average of the period (±%)
Source: own calculation.

CONCLUSIONS

At national level, Dolj County stands out by cultivating the largest grain and wheat area, ranks 2nd in the case of barley and barley respectively rye, 5th place in sorghum, 6th place in oats and only 13th place for grain corn. As such, we can say that the county is one of the most important grain growers in Romania, if not the most important. This situation must be linked to the agro-pedo-climatic context and the degree of capitalization of producers (sandy soils for rye cultivation, lack of significant irrigated areas if we refer to grain maize, especially for seed production).

In terms of total productions, it can be noted that the county ranks 4th nationally in terms of total cereal production, 1st place for wheat, 2nd place for rye, 3rd place for barley and barley, 6th place for oats and sorghum respectively and only 16th place for grain corn.

Starting from the above-mentioned spectrums, it is noted that the performances of Dolj cereal producers are lower than those obtained in other counties (positioning around the 10th place at the level of oats, sorghum, respectively barley and barley crops, in terms of average yield per hectare, around the 20th place for wheat and rye, 28th place for corn and 35th place at the general level of the product group).

It can be said that Dolj County decisively influences the production of cereals in Romania and implicitly in the South-West Oltenia Region, but producers and implicitly decision makers must be more active to improve performance, to better exploit the county potential for this side of the vegetal activity of the agricultural sector.

REFERENCES

[1]Bonea, D., 2020, Screening for drought tolerance in maize hybrids using new indices based on resilience and production capacity, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 20(3), 151-156.

[2]Chiurciu, I.-A., Soare, E., 2020, Research on the wheat market in the South-Muntenia Region, Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 20(2), 453-458.

[3]Chiurciu, I.-A., Soare, E., Constantin (Oprea), D.M., Grigore, E., Bogan, E., 2020, Analysis regarding the evolution of the cereal sector in the North-East Region of Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 20(4), 139-145.

[4]Chiurciu, I.-A., Soare, E., Voicilaș, D. M., Certan, I., 2023, Aspects regarding the production and marketing of cereals in the Black Sea basin area, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 23(1), 139-146.

[5]Dunăreanu, I., C., Bonea, D., Radu, V. L., 2021, Performance of Romanian barley varieties for grain yield and some quality traits under rainfed conditions, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 21(2), 243-248.

[6]Dunăreanu, I.C., Bonea, D., 2022, Comparative performance and stability of some maize hybrids in the agroclimatic conditions of Craiova, Dolj county, Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(3), 203-209.

[7]Ghiorghe, I., A., Turek-Rahoveanu, A., 2022, The evolution of maize cultivated area and production in Romania (2011-2021), Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(3), 255-260.

[8]Lungu, E., Turek-Rahoveanu, M.-A., 2023, Research on agroecological zoning for winter wheat (*Triticum Aestivum* L.) in South-Eastern Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 23(1), 363-372.

[9]Omeje, E., Okpukpara, B., Okereke, C., Ume, C., Okpukpara, V., 2022, Incentivizing the adoption of biofortified rice for increasing farmers' productivity and income during COVID19 era: evidence from smallholder farmers in Nigeria, 2022, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(4), 497-510.

[10]Özdemir, F.N., Bilgiç, A., 2023, Determining the short and long term volatility spillovers between wheat, cotton and corn prices in Turkey using the asymmetric Bekk-Garch-Mean equation model, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 23(1), 475-490.

[11]Popescu, A., Dinu, T. A., Stoian, E., 2018, Sorghum - an important cereal in the world, in the European Union and Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 18(4), 271-284.

[12]Popescu, A., Dinu, T. A., Stoian, E., Şerban, V., 2023, Climate change and its impact on wheat, maize and sunflower yield in Romania in the period 2017-2021, 2023, Scientific Papers Series Management,

Economic Engineering in Agriculture and Rural Development Vol. 23(1), 587-602.

[13]Popescu, A., Stanciu, M., Stanciu, C., 2023, Romania's vegetal production in the post access period to the European Union, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 23(1), 627-638.

[14]Tempo- Online data base, National Institute of Statistics, http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table, Accessed on 26.05.2023.

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STUDY ON BRAND STRATEGIES AND BRAND ARCHITECTURE IN THE WINE INDUSTRY – CASE STUDY: DRĂGĂȘANI VINEYARD, VALCEA COUNTY, ROMANIA

Daniel Marian MICU, Silviu BECIU

University of Agricultural Sciences and Veterinary Medicine of Bucharest 59 Marasti Boulevard, District 1, 011464, Bucharest, Romania, E-mails: micudm@gmail.com, beciu.silviu@managusamv.ro

Corresponding author: micudm@gmail.com

Abstract

Given the growing importance of brands in the wine industry, the purpose of this study is to conduct an analysis of brand strategies and brand architecture used by Romanian wine producers in the Dragășani Vineyard. Academic literature has been reviewed to present the up-to-date theoretical concepts that underpin this research. The research methodology was based on the „honeycomb model", and the research strategy was qualitative. Secondary data were collected from 13 wine producers in the Dragășani Vineyard. The main results of this study focus on the number of brands in each producer's portfolio, the brand strategies and architecture they use, the brand elements that contribute to increasing brand awareness and equity, as well as the means and elements used for differentiation strategy. The study reflects the growing importance that producers in the Dragășani Vineyard place on brands, as well as the increasing need for them to adopt a unified and integrated approach to brand portfolio management.

Key words: *brands, brands in wine industry, brand strategy, brand portfolio, brand architecture, brand elements*

INTRODUCTION

The main objective of this study is to conduct a multi-criteria analysis of the brands developed and marketed by wine producers in the Dragășani Vineyard. The main criteria used for analysis are: brand strategy, brand architecture, and the brand elements employed by these wine producers.

This multi-criteria analysis is justified by the increasing importance of brands in the wine industry, both at the local and international levels. These wine markets are dynamic, volatile, and highly competitive. This is because wine is distinct from other agricultural products. Unlike milk, flour, fruits, or vegetables, consumers seek information about when, where, and how the wine was made, and these represent important criteria in their purchasing decisions [16].

In an attempt to define the wine brand, [29] proposes the following version: „a wine product is something made in a winery; a brand is something that is bought by the consumer. A wine can be copied by a competitor; a successful brand is unique."

On the other hand, the wine brand is also defined as „the perception of the wine product and its name in the consumer's mind" [23]. A wine brand is much more than a wine label. Building a brand is crucial in a wine market where the consumer can be overwhelmed by too many options [34], and the wine market is particularly challenging for brand differentiation due to the presence of thousands of brands [17]. Traditionally, the wine industry has had a dual approach: a brand strategy versus an appellation strategy [22]. Many observers believe that a brand-oriented approach is more suitable to meet the current expectations of consumers, while others argue that a system-based approach using appellations is more effective, especially with educated consumers. Brand strategies in the wine industry tend to focus more on product characteristics and attributes and their ability to stimulate greater consumption among consumers [34].

Next, we aim to summarize the academic literature regarding brand strategy and portfolio, brand architecture and elements. A company must define its brand strategy, which impacts all its products. This strategy will also guide the branding of new products [21]. The brand strategy reflects the number and nature of common and distinctive elements of a brand applied to various products sold by the company [21]. These are a crucial factor in determining the strength of association between the brand, the company, and any other existing brands [20]. It guides marketers on what brand names, logos, symbols to apply to new and existing products [20]. Combining the product-brand matrix and brand hierarchy with customer, company, and competition considerations helps formulate an optimal brand strategy [20].

Every company has five options when it comes to brand strategy. It can pursue line extensions, brand extensions, multiple brands, new brands and co-brands [21]. There are also three main branding options for a new product: creating a new brand, adopting or modifying an existing brand, or combining an existing brand with a new brand [20].

The traditional approach to brand management has focused on individual brands, but in recent times, managers have shifted their attention to managing and increasing the value of the entire brand portfolio of the company [26]. Companies' desire to expand, to respond to changing consumer needs, and develop new distribution channels is often achieved by adding new brands to their portfolio, thereby justifying the increased importance of brand portfolio strategy [19], [14]. Brand portfolio gains exceptional importance when a company is faced with aggressive growth objectives or impending mergers, acquisitions, and alliances. It allows to the companies to formulate a distinct strategy for each brand, assess the necessity for repositioning and recognize brands that are underperforming [32]. Consequently, the role of managers no longer revolves solely around creating strong brands but also involves managing complex brand portfolios [31]. Some researchers equate brand strategy and brand architecture [21]. Brand architecture defines both the boundaries and complexity of the brand and helps us to find answers to questions such as: what different products should have the same brand name? How many variations of that brand name should we use? [20]. There is also a nuanced approach [1], where brand architecture is defined as a „structural organization of the brand portfolio that specifies the roles of brands and the nature of relationships between brands”. It enables brands to grow, expand, support each other, thereby increasing the value of individual brands and the overall portfolio [26]. Brand architecture serves as a mechanism of the company which assist consumers to understand its offer of products and services and to structure them in their mind [28].

Academic literature is abundant with terminologies and brand architecture structures, many of which are similar [1], [30], [19], but despite the common elements, these approaches vary in terminology and level of detail [34]. One of the most important models for brand architecture structure is the „brand relationship spectrum” [1]. It proposes four strategies and nine sub strategies for organizing brand portfolios. The location on the spectrum indicates the extent to which brands differentiate in implementing their strategies and, eventually, in the perceptions of consumers. For devising effective brand strategies, understanding each of these primary and subordinate strategies is crucial [1]. Despite the criticisms [32], this model is considered to be the most comprehensive and complex in the study of brand architecture [34]. Brand portfolio strategy and brand architecture, though sharing similarities in market approach, hold distinct places in addressing consumer needs. Each company must tailor its brand portfolio strategy to align with market, product, or customer needs, while weighing the inherent risks and opportunities in each market.

On the other hand, brand architecture should not be mismanaged when deciding the optimal operational approach, such as practices for product positioning. Brand architecture serves as a blueprint for how consumers mentally categorize which product best suits their needs at a given life stage. Once this alignment is achieved, consumers can then navigate through the company's brand portfolio [28]. Brand elements (brand identities) are those items that serve for brand identification and differentiation. The main elements include: brand name, URLs, logos, symbols, characters, slogans, jingles, and packaging. They have the role to enhance brand awareness and increase brand equity [20]. Six criteria are proposed for selecting brand elements: memorability, meaning, likability, transferability, adaptability, and protectability [20]. Also, some specific considerations are linked to brand items.

First, packaging/labelling. Structural changes in the European food industry entail an increased need for competitiveness, and packaging (labelling) is an item that can make a difference for many products in this industry [27]. Often associated with or used as a synonym for a brand, the label on a wine bottle is the tangible evidence of the brand. Along with the brand name, image, picture and logo, a label provides information about the wine's style (taste and aroma), a description of it, food pairing options, awards and medals won, producer, wine region, and production year [25, 34]. While the front label is typically considered for evocation, the back label is expected to provide technical information [2]. Secondly- the geographical indication is a distinctive sign allowing producers to secure their established reputation against imitation and fraud [34]. However, trade brands are rights held individually, while the geographical indication can be considered an asset belonging to a certain group of companies [18]. It is considered [34] that the PDO/PGI certification scheme is primarily a mechanism for protecting the interests of national/regional producers, rather than a marketing tool.

Third- the awards won at wine exhibitions and competitions and the scores received from some wine gurus. All of these can be classified as third-party endorsement brands. According to the content of the information provided by the third-party endorsement brands, these can be classified into three main categories: factual certification, evaluative certification, and warranty certification. The wine exhibition awards and the scores belong to the group of evaluative certifications that provide specific evaluation of attributes [25]. They are of particular interest to retailers and producers as they are considered to be easily recognizable and support consumer choice by communicating superior quality.

In this context, the paper aimed to carry out an analysis of brand strategies and brand architecture used by Romanian wine producers in the Dragășani Vineyard, Romania.

MATERIALS AND METHODS

This analysis targets the wine producers from the Drăgășani Vineyard. This vineyard is part of the wine-growing region of the Muntenia and Oltenia Hills and is the oldest vineyard in Oltenia. The controlled designation of origin “Drăgășani” is attributed to wines made from grapes produced in the area demarcated for this designation. This area extends between the Getic Sub Carpathians to the north and the Romanian Plain to the south and southeast.

The most important wine producers that are part of the Drăgășani Vineyard are: Crama Avincis, Crama Bauer, Crama Stirbey, Domeniul Drăgași, Crama Venetic, Casa de vinuri Isărescu, Casa de vinuri Iordache, Casa de vinuri Negrini, Via Sandu, Crama Cepari, Crama Spârleni, Crama Mennini, Ferma Măgureni [24]. The research methodology is based on the honeycomb model developed by [35]. This model has six distinct stages: research philosophy, research approach, research strategy, research plan, data collection and analysis. From the viewpoint of research philosophy, the epistemological approach is interpretivist and the ontological approach is based on subjectivism [35]. The research approach is inductive strategy is of a qualitative type (which implies an "inside-out" approach) and is based on an open research question. The type of research is exploratory and its plan combines elements of an action plan and case study.

The data used are secondary being collected from websites of the wine producers from the Drăgășani Vineyard. The data interpretation is qualitative with elements of quantitative analysis. For the analysis of strategies and brand portfolios, the starting point was the definitions proposed by [21], while for the analysis of brand architecture, the brand relationship spectrum model developed by [1] was used, which involves the existence of four basic strategies and nine sub-strategies. These are: 1) House of Brands (with the sub-strategies Not-Connected and Shadow Endorser); 2) Endorsed Brands (with the sub-strategies Token Endorsement, Linked Name, and Strong Endorsement); 3) Sub-brands (with the sub-strategies Co-Drivers and Master Brand as Driver); and 4) Branded House (with the sub-strategies Different Identity and Same Identity). Finally, for the analysis of brand elements, the starting point was the evaluation criteria proposed by [20].

RESULTS AND DISCUSSIONS

The entire analysis of this study is summarized in Table 1 and Table 2.

Table 1. Analysis of wine producers in Drăgășani Vineyard (part 1)

Criteria		Casa de vinuri Iordache	Casa de vinuri Isărescu	Casa de vinuri Negrini	Crama Avincis	Crama Bauer	Crama Cepari
No. of Brands In Portfolio		1 (Casa de vinuri Iordache)	3 (Casa Isărescu; Casa Isărescu Rezervă; Casa Isărescu Vintage)	3 (Negrini; Negrini Hexagon; Ag/um)	4 (Avincis; Avincis Cuvee; Domnul de Rouă; Vila Dobrușa)	3 (Bauer; Bauer Ceva Nou; Bauer Altceva)	3 (Crama Cepari; Criva; Salcament)
Wine Type	White	x	x	x	x	x	x
	Red	x	x	x	x	x	x
	Rose	x	x	x	x	x	x
	Sparkling				x	x	
Brand Strategy	Line Extension	x	x	x	x	x	
	Brand Extension						
	Multi Brands			x	x		x
	New Brands						
	Co-Brands						
Brand Architecture - House of Brands	Not Connected						x
	Shadow Endorser			x	x		x
Brand Architecture - Endorsed Brands	Token Endorsement						
	Linked Name						
	Strong Endorsement						
Brand Architecture - Sub-Brands	Co-Drivers						
	Master Brand as Driver		x	x	x	x	
Brand Architecture - Branded House	Different Identity						
	Same Identity	x	x	x	x	x	x
Brand Elements - Corporate Brand Name		Casa de vinuri Iordache	Casa Isărescu	Negrini	Avincis	Crama Bauer	Crama Cepari
Brand Elements - Brand Name	Vineyard Name				x	x	x
	Winemaker Name	x	x	x	x		
	Other Name			x	x		x
Brand Elements - Front Label	Logo	x	x	x	x	x	x
	Picture/Visual	x	x		x		x
	Prize/Points						
	IGP/DOP	x	x	x	x	x	x
	Grape Variety	x	x	x	x	x	x
	Wine Sweetness	x	x	x	x	x	x
Brand Elements - Back Label	Region/Place		x	x	x	x	x
	Grape Variety		x	x	x	x	x
	Description of the wine		x	x	x	x	x
	No. of bottles per vintage		x	x	x	x	x
	Food pairing		x	x	x	x	x
	Wine Sweetness		x	x	x	x	x
Brand Elements - Slogan/Differentiator		Tradition ("Founded in 1880")					

Source: Own research.

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Table 2. Analysis of wine producers in Drăgășani Vineyard (part 2)

Criteria		Crama Mennini	Crama Spârleni	Crama Știrbey	Crama Venetic	Domeniul Drăgași	Ferma Măgureni	Via Sandu
No. of Brands In Portfolio		7 (Moments; Domeniul Mennini; Le Reve; Paolo Mennini; Irruma; Stelle di Mare; Cu Bule)	2 (Șani/ Spârleni; Spârleni Selecții)	2 (Prince Știrbey; Vin Știrbey)	1 (Venetic)	2 (Arhon; Pelerin)	5 (Pasiuni; Lacrimi de Lună; Diamant; Inspirație; Orange)	2 (Via Sandu; Cab Stejar)
Wine Type	White	x	X	x	x	x	x	x
	Red	x	X	x	x	x	x	x
	Rose	x	X	x	x	x	x	x
	Sparkling			x				
Brand Strategy	Line Extension			x	x		x	
	Brand Extension							
	Multi Brands	x	X			x	x	x
	New Brands							
	Co-Brands							
Brand Architecture - House of Brands	Not Connected	x					x	x
	Shadow Endorser					x	x	
Brand Architecture - Endorsed Brands	Token Endorsement							
	Linked Name							
	Strong Endorsement		X					
Brand Architecture - Sub-Brands	Co-Drivers							
	Master Brand as Driver		X	x				
Brand Architecture - Branded House	Different Identity							
	Same Identity				x			
Brand Elements - Corporate Brand Name		Crama Mennini	Crama Spârleni	Crama Știrbey	Crama Venetic	Domeniul Drăgași	Ferma Măgureni	Via Sandu
Brand Elements - Brand Name	Vineyard Name	x	X		x			x
	Winemaker Name	x		x				
	Other Name	x	X			x	x	x
Brand Elements - Front Label	Logo	x	X	x	x	x	x	x
	Picture/Visual	x	X		x		x	x
	Prize/Points						x	
	IGP/DOP	x	X				x	x
	Grape Variety	x	X	x	x	x	x	x
	Wine Sweetness	x	X	x	x	x	x	x
Brand Elements - Back Label	Region/Place	x	X	x	x	x	x	
	Grape Variety	x	X	x	x	x	x	
	Description of the wine	x	X	x	x	x	x	
	No. of bottles per vintage	x		x		x		
	Food pairing	x				x		
	Wine Sweetness	x	X	x	x	x	x	
Brand Elements - Slogan/Differentiator		Aspirational (”Ho sognato di essere qui”)	Tradition (”1892”)	Tradition (Family crest)				

Source: Own calculation.

The thirteen producers in the Drăgășani Vineyard manage a total of 38 wine brands, with an average of 2.9 brands per producer. The distribution of the number of wine brands per producer is presented in Table 3. It is observed that the producers with 2 and 3 brands in their portfolio ([10], [11], [13], [33] and [4], [5], [7], [8] respectively) represent 62% of the total producers. In this context, [9] stands out, having no fewer than 7 brands in its portfolio.

Table 3. Distribution of the number of wine brands per producer

No of brands in portfolio	**No of producers**	**% of Total producers**
1	2	15.4%
2	4	30.8%
3	4	30.8%
4	1	7.7%
5	1	7.7%
6	0	0.0%
7	1	7.7%
Total no. of brands	**38**	
Total no. of producers	**13**	
Avg. no. of brands/producer	**2.9**	

Source: Own calculation.

Based on the type of wine produced (white, red, rose, and sparkling), the situation of the producers in the Drăgășani Vineyard is presented in Table 4.

Table 4. Wine producers based on the type of wine

Wine type	No of Producers	% of Total Producers
White, Red, Rose	10	76.9%
White, Red, Rose, Sparkling	3	23.1%
Total number of producers	13	

Source: Own calculation.

It is observed that only 3 out of the 13 producers ([6], [7], [11]) produce all four varieties of wines (white, red, rose, and sparkling). Another noteworthy point here is that none of the producers have chosen a specialization strategy, to exclusively produce one among the four varieties.

From the perspective of brand strategy, 10 producers apply only one type of strategy: 5 of them apply line extension ([3], [4], [7], [11] [12]) and the other 5 apply a multi-brands strategy ([8], [9], [10], [13] [33]). The remaining 3 producers resort to a combination of line extension and multi-brands strategies ([5], [6], [15]) (Table 5).

Table 5. Applied brand strategies

Applied brand strategies	No. of producers	% of Total Producers
Line extension	5	38.5%
Multi-brands	5	38.5%
Line extension & Multi-brands	3	23.1%
Total number of producers	**13**	

Source: Own calculation.

In the case of brand architecture structure, 6 out of the 13 producers use a single brand architecture structure ([3], [9], [11], [12], [13], [33]), 4 of them use a double brand architecture structure ([4], [7], [10], [15]) and 3 use a triple brand architecture structure ([5], [6], [13]).

The most common brand architecture structure is the Branded House/Same Identity with 7 mentions ([3], [4], [5], [6], [7], [8], [12]) followed by Sub brands/Master Brand as Driver with 6 mentions each ([4], [5], [6], [7], [10], [11]) (Table 6).

Table 6. Brand architecture structures used

Brand architecture structures used	Usage number	% of Total
Branded House - Same Identity	7	30.4%
Sub-brands - Master Brand as Driver	6	26.1%
House of Brands - Shadow Endorser	5	21.7%
House of Brands - Not Connected	4	17.4%
Endorsed Brands - Strong Endorsement	1	4.3%
Total no. of structures used	**23**	

Source: Own calculation.

From the viewpoint of brand names, the most commonly encountered approaches are those that use the name of the vineyard domain or a distinct name (with 7 instances each), followed by those based on the name of the producer (with 6 instances). There are only 2 producers ([6], [9]) who use all three options in choosing the brand name (the name of the vineyard domain, the name of the producer, and a distinct name).

In the case of front labels, there is only one producer [15] who uses the symbol of awards won at competitions as an indicator of product quality. However, it should be mentioned that all other producers use the symbol of the awards won or the scores given by wine gurus on presentation websites and their own online stores. Regarding the back labels, it should be noted that 2 out of the 13 producers do not use back labels at all, having the information concentrated on the front label.

Last but not least, it must be emphasized that only 4 out of the 13 producers use a slogan or a visual identity element as a means of differentiation from other producers (Table 7).

Table 7. Usage of slogan or visual element as mean of a differentiation strategy

Usage of slogan or visual element	Usage number	% of Total Producers	% of Producers using slogan or visual element
Not using slogan or visual element	9	69.2%	
Using slogan or visual element (from which)	4	30.8%	
Tradition as differentiation strategy	3		75.0%
Aspirational as differentiation strategy	1		25.0%
Total number of producers	**13**		

Source: Own calculation.

Three of the producers use tradition as a differentiating element [3], [10], [11], and one of them [9] uses an aspirational type of slogan as a differentiating element. However, none of the producers use a slogan or a visual identity element as a means of differentiation at the brand level.

CONCLUSIONS

A first conclusion is that the wine producers from the Drăgășani Vineyard recognize the importance of wine brands in the current context of the local and international market. The vast majority (85%) manage a limited number of brands (a maximum of 4), the exception being a single producer who has 7 brands in their portfolio.

A second conclusion is related to the fact that all producers make white, red and rose wines, and three of them also produce sparkling wine. It is surprising that none of the producers have chosen a specialization strategy, which might be particularly advisable for smaller companies with significantly limited financial resources, unable to sustain a wide variety of products and brands on the market.

A third conclusion concerns brand strategies, and producers use the extremes of these strategies (line extensions and multi brands). Regarding brand architecture, the structures used are not clear, evident, there are many confusions, overlaps, and intercalations. A detailed analysis of the product lines and brand portfolio combined with a brand audit could help producers in optimizing brand architecture and improving their financial performance.

The fourth conclusion relates to the very small number of producers/brands that use the awards received at wine competitions or the scores from wine gurus to signal the superior quality of their products on the label.

The fifth conclusion is related to the lack of slogans or visual identity elements that act as differentiators at the brand level. This is a situation that should concern producers, especially since the competition is fierce and the differentiation strategy is a guarantee of a strong brand and steady, substantial revenue. Producers are essentially obligated to invest in improving all the intangible elements that influence consumer choices.

In the end, it must be emphasized that producers need to adopt a unified and integrated approach to brand portfolio management, including from the broader perspective of integrating them under the umbrella of a sectoral brand or a country brand.

REFERENCES

[1]Aaker, D.A., Joachimsthaler, E., 2000. The brand relationship spectrum: the key to the brand architecture challenge, California Management Review, 2000, 42(4): 8-23.

[2]Barber, N., Almanza, B.A., Donovan, J.R., 2006. Motivational factors of gender, income and age on selecting a bottle of wine, International Journal of Wine Marketing, 2006, 18(3): 218.

[3]Casa de vinuri Iordache (Iordache Wine House), https://cvi-dragasani.ro/. Accessed on Sept.12, 2023.

[4]Casa de vinuri Isărescu (Isarescu Wine House), http://casaisarescu.ro/ Accessed on Aug.21, 2023.

[5]Casa de vinuri Negrini (Negrini Wine House), https://www.negrini.ro/ Accessed on Aug.21, 2023.

[6]Crama Avincis(Aincis Wine Cellar) - https://www.avincis.ro/ Accessed on Aug.21, 2023.

[7]Crama Bauer (Bauer Wine Cellar), http://www.cramabauer.com/ Accessed on Aug.21, 2023.

[8]Crama Cepari (Cepari Wine Cellar), https://www.crama-cepari.ro/ Accessed on Aug.28, 2023.

[9]Crama Mennini (Mennini Wine Cellar), https://cramamennini.ro/ Accessed on Aug.28, 2023.

[10]Crama Spârleni (Spârleni Wine Cellar), https://www.sparleni.ro/ Accessed on Aug.28, 2023.

[11]Crama Stirbey (Stirbey Wine Cellar), https://stirbey.com/ Accessed on Aug.31, 2023.

[12]Crama Venetic (Venetic Wine Cellar), https://venetic.ro/ Accessed on Aug.31, 2023.

[13]Domeniul Drăgași (Drăgași Domain), https://domeniul-dragasi.ro/ Accessed on Aug.31, 2023.

[14]Fang, X., Wang, X., 2018. Examining consumer responses to cross-border brand acquisitions, European Journal of Marketing, 2018, 52(7/8):1727-1749.

[15]Ferma Măgureni, (Măgureni Farm), https://vinuriecologice.ro/2_ferma-magureni Accessed on Aug.31, 2023.

[16]Harvey, M., Frost, W., White, L., 2014, Exploring wine and identity, in: Harvey, M., Frost, W., White, L., (Eds.), Wine and Identity, branding, heritage, terroir. Routledge, New York, 2-3.

[17]Johnson, R., Bruwer J., 2007, Regional brand image and perceived wine quality: the consumer perspective, International Journal of Wine Business Research, 2007, 19(4): 276.

[18]Josling, T., 2006, The war on terroir: geographical indications as a transatlantic trade conflict, Journal of Agricultural Economics, 2006, 57(3): 337.
[19]Kapferer, J.N., 2008, The New Strategic Brand Management, Kogan Page, London, 347-398.
[20]Keller, K.L., 2013, Strategic Brand Management - Building, Measuring and Managing Brand Equity, Pearson Education Limited, Harlow, 141-170.
[21]Kotler, P., Keller, K.L., 2012, Marketing Management, Prentice Hall, New Jersey, 240-274.
[22]Mora, P., 2008, Les Vins de Marque avec 25 études de cas, Editions Dunod, Malakoff, 13.
[23]Nowak, L.I., Newton, S. K., 2006, Using the tasting room experience to create loyal customers, International Journal of Wine Marketing, 18(3): 157.
[24]Oficiul National al Viei si Produselor Vitivinicole (National Office of Vine and Wine Products) - https://www.onvpv.ro/sites/default/files/pdfs/caiet_de_sarcini_doc_dragasani_247ro.pdf. Accessed on Aug.16, 2023.
[25]Orths, U.R., Krska, P., 2002, Quality signals in wine marketing: the role of exhibition awards, International Food and Agribusiness Management Review, 4: 385-397.
[26]Petromilli, M., Morrison, D., Million, M., 2002, Brand architecture: building brand portfolio value, Strategy and Leadership, 30(5): 22-28.
[27]Rundh,B., 2005, The multi-faceted dimension of packaging: Marketing logistic or marketing tool? British Food Journal 107(9): 670.
[28]Sousa, S.E.C., 2018, Brand portfolio strategy and brand architecture: A comparative study, Cogent Business & Management, 5: 1483465.
[29]Spawton, A., 1998, Building Brands in the Wine Sector, The Australian and New Zealand Wine Industry Journal, 13: 417-420.
[30]Strebinger, A., 2004, Strategic brand concept and brand architecture strategy – a proposed model, Advances in Consumer Research, 31(1): 656-661.
[31]Uggla, H., Filipsson, D., 2009, Business and brand strategy: a framework for integration, ICFAI Journal of Business Strategy, 6(2): 27-42.
[32]Uggla, H., Nyberg, B., 2014, Need states: the missing link to the brand portfolio strategy paragon, IUP Journal of Brand Management, 11(2): 28-37.
[33]Via Sandu (Sabdu vineyard), https://viasandu.ro/ Accessed on Aug.31, 2023.
[34]Vlachvei, A., Notta, O., Efterpi, T., 2012, Branding strategies in Greek wine firms, International Conference On Applied Economics (ICOAE): 421-430.
[35]Wilson, J., 2014, Essential of business research – a guide to doing your research project, Sage Publications, London, 25-42.

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DYNAMICS OF VEGETABLE AGRICULTURAL PRODUCTION IN VRANCEA COUNTY, ROMANIA

Steliana MOCANU

The Bucharest University of Economic Studies, 6 Romană Square, District 1, 010374, Bucharest, Romania, Phone: +4 021 319.19.00; Email: mocanusteliana18@stud.ase.ro

Corresponding author: mocanusteliana18@stud.ase.ro

Abstract

This paper aims to present an updated evolution of vegetable agricultural production in Vrancea county, during the period 2017-2021, with focus on the county's contributions in total at the country level, using the National Institute of Statistics (NIS) as principal data source. In order to meet the objectives, the methodology of research was based on indicators frequently used in papers about vegetable agricultural production, represented as values and/or percentage units. In 2021, Vrancea county detained 108 civil employment population (with 17% less than in 2017), through 22 employers in agriculture (52% less than in 2017). Among the main findings from the analyse are the following: the areas cultivated with corn grains, oat, sunflower, vegetables (all), dried onion, tomatoes, total fruits trees, plum, apples, pears, cherries and burgundy decreased among the county between 2017 and 2021 period and the areas cultivated with wheat, barley and vineyards in bearing increased. About the production, at the county level, the production of wheat, oat, barley, total fruit trees, plum, apple, pears, cherries, burgundy and grapes increased and the productions like: corn grains, sunflowers, vegetables (all), dried onion, tomatoes, decreased in the analysed period (2017-2021). From the conclusions of this paper, we found out that besides the good image in terms of wine fields, is observed that total fruit production increased by 50%, which can mean a new growth area of the county, regarding of vegetable agricultural production.

Key words: *agriculture, area cultivated, vegetable production, Vrancea county*

INTRODUCTION

Vegetables sector in Romania's agriculture is of high importance for assuring a large variety of products for human diet and for processing industry [2, 10].

Vrancea county is one of the most important regions in terms vegetable production and especially of wine.

Vrancea, the Country of Vineyards and Wines, is located outside the Curvature Carpathians, at the intersection of the three historical regions: Moldova, Tara Romaneasca and Transylvania. Its surface is 4,863 sqkm [3] and in 2022 the county had a resident population of 334,056 people, from which 33% living in urban area, and 67% in rural area. [5] In 2014, 53% from the total surface of Vrancea county it was occupied with agricultural land, from which: 40% it was occupied with forests and other forest vegetation, 31% with arable land, 9% with pastures and 21% it was used for other types of lands [5].

In the context in which, Vrancea county is composed of 148,729 ha arable land (in 2014) [5], it is important to know the dynamics and the distribution of the surfaces cultivated with main cultures.

Map 1. Map of Vrancea County
Source: [3].

Through this purpose, the following pages of this research aims to present an updated evolution of vegetable agricultural production in Vrancea County, during the period 2017-2021, with focus on the county's contributions in total at the country level, using the National Institute of Statistics (NIS) as principal data source.

MATERIALS AND METHODS

In order to analyze the evolution of vegetable agricultural production in Vrancea, a lot of indicators from the National Institute of Statistics (NIS) were presented in this research papers, after a large documentation about the subject. To meet the objectives of the study was processed and analyzed a series of statistical data available nationally for the period 2017-2021. The methodology was based on indicators frequently used in papers about vegetable agricultural production, represented as values (area cultivated or the obtained production) and/or percentage units (the contribution of Vrancea county in the total level of area cultivated/production). All of the analyzed indicators were compared with the total at the country level, for a better understanding of county contribution.
In this research it was used a series of indicators (secondary data) like: total civil employments in agriculture, surface cultivated with the main cereals, vegetables, fruits and vineyards and the production made on these surfaces.

RESULTS AND DISCUSSIONS

In Vrancea county climate is suitable for field crops, and especially for vineyard cultivation and wine production [9] (17% of Romania's vineyards in 2021) [5] and wine production (19% of Romania's grapes production in 2021). Vrancea County being the largest wine-growing county in the country, is an exporter to Europe, America and Japan [1]. It is important to have an overview of Vrancea county's indicators because in this county stands out some factors that discourage the development of agriculture like: work force less qualified or high fragmentation of farms [7].
The following tables, graphics and calculations will help to understand the exactly potential of county in terms of vegetable agricultural production, compared with the total at the country level.
Table 1 presents the evolution of civil employment population in agriculture per county and per country between 2017 and 2021. Vrancea country detain approx. 1.5% civil employment population from the total at the country level, and approx. 2.6% from the total civil population employment in agriculture (2021 data reference). From 2017 to 2021 employed population in agriculture in Vrancea decreased by 52% and by 51% at the country level.

Table 1. Overview of civil employment population

Indicator/Year	2017	2018	2019	2020	2021	2021/2017
	thousand persons					*Percent*
Civil employed population - RO	8,367	8,408	4,893	8,441	7,601	91%
Civil employed population in agriculture - RO	1,742	1,760	1,747	1,681	847	49%
Civil employed population - VN	130	130	131	131	108	83%
Civil employed population in agriculture - VN	45	46	46	44	22	48%

Source: Own calculation on the basis of data from Tempo online data base 2017-2021, NIS. [5]
*RO=Romania; *VN=Vrancea

From 2017 to 2021 the surface cultivated with corn grains increased by 6% at country level and decreased by 47% in Vrancea. The surface with wheat increased by 6% in Romania and with 11% in Vrancea (Table 2).

Table 2. Area cultivated with main cereals (ha)

Indicator /Year	2017	2018	2019	2020	2021
Corn grains					
Romania	2,402,082	2,439,842	2,678,504	2,537,104	2,549,281
Vrancea	54,522	54,561	54,707	55,533	28,878
Wheat					
Romania	2,052,917	2,116,154	2,168,370	2,155,254	2,175,077
Vrancea	23,776	23,690	24,614	24,848	26,392
Oat					
Romania	165,757	161,484	161,188	101,340	87,018
Vrancea	4,648	4,637	4,625	4,620	4,643
Barley					
Romania	268,826	250,797	285,065	292,079	333,007
Vrancea	1,463	1,280	1,845	1,590	2,816

Source: Own calculation on the basis of data from Tempo online data base 2017-2021, NIS, [5].

Area cultivated with oat decreased by 48% in 2017-2021 in Romania, and remained the same (approx. 4,645 ha) in Vrancea. The area cultivated with barley present an increase from 2017 to 2021 on both indicators: in Romania increased by 24% and in Vrancea by 92% (Table 2).

In 2021, the area cultivated with main cereals in Vrancea, represented a small area of the entire cultivated area at the national level, as follows:

-Corn grains: 1.1% of the total area per country;
-Wheat: 1.2% of the total area per country;
-Oat: 5.3% of the total area per country;
-Barley: 0.8% of the total area per country.

From the data source it turns out that in 2021 the area cultivated with oat in Vrancea was on the 4th place nationally, after Suceava, Satu Mare and Mures counties.

From 2017 to 2021 the production of corn grains increased by 3% at country level and decreased by 48% in Vrancea. The production of wheat increased by 4% in Romania and with 9% in Vrancea. The production of oat decreased by 49% in 2017-2021 in Romania, and increased by 4% in Vrancea. The production of barley presents an increase from 2017 to 2021 on both indicators: in Romania increased by 25% and in Vrancea by 210% (Table 3).

Table 3. The production of main cereals (tons)

Indicator /Year	2017	2018	2019	2020	2021
Corn grains					
Romania	14,326,097	18,663,939	17,432,223	10,096,689	14,820,693
Vrancea	317,381	381,769	268,803	81,659	165,954
Wheat					
Romania	10,034,955	10,143,671	10,297,107	6,392,369	1,043,3751
Vrancea	106,350	106,837	103,193	31,425	116,395
Oat					
Romania	407,795	383,722	361,573	196,659	209,845
Vrancea	9,647	9,521	9,026	4,308	10,048
Barley					
Romania	1,271,734	1,276,620	1,340,389	847,241	1,593,802
Vrancea	4,197	4,218	8,213	2,192	12,995

Source: Own calculation on the basis of data from Tempo online data base 2017-2021, NIS, [5].

In 2021, the production of main cereals in Vrancea, represented a small production of the entire production area at the national level, as follows:

-Corn grains: 1.1% of the total production per country;
-Wheat: 1.1% of the total production per country;
-Oat: 4.8% of the total production per country;
-Barley: 0.8% of the total production per country.

Between 2017-2021, at country level the area cultivated with sunflower increased by 13% and the areas cultivated with vegetables (all), dried onion and tomatoes decreased by 12%, 3% respectively 13%. At the county level, the areas cultivated with the 4 cultures decreased by 14% for sunflower, 8% for vegetables (all), 2% for dried onion and with 22% for tomatoes in the analyzed period (Table 4).

Table 4. Area cultivated with main cultures excepting the cereals (ha)

Indicator /Year	2017	2018	2019	2020	2021
Sunflower					
Romania	998,415	1,006,994	1,282,697	1,142,841	1,123,960
Vrancea	6,940	7,236	7,805	6,841	5,998
Vegetables (all)					
Romania	224,571	226,328	227,720	200,501	19,7677
Vrancea	4,747	4,769	4,768	4,566	4,344
Dried onion					
Romania	30,025	30,269	30,346	29,201	29,251
Vrancea	891	880	888	874	873
Tomatoes					
Romania	40,041	40,741	40,845	34,115	34,747
Vrancea	1,020	1,009	1,014	991	791

Source: Own calculation on the basis of data from Tempo online data base 2017-2021, NIS, [5].

In 2021, the area cultivated with main cultures excepting the cereals in Vrancea, represented the following percentages from the total country area:

-Sunflower: 0.5% of the total area per country;
-Vegetables (all): 2.2% of the total area per country;
-Dried onion: 3.0% of the total area per country;
-Tomatoes: 2.3% of the total area per country.

From the data source it turns out that in 2021 the area cultivated with dried onion in Vrancea was on the 11th place nationally, with 873 ha cultivated, and represented 2.98% from Romania's production of dried onion.

In the analyzed period (2017-2021), at country level the production of sunflower and all vegetables decreased by 2% respectively 4%; the production of dried onion and tomatoes increased by 1% respectively 11%. Referring to county production, the production of all 4 cultures decreased by 12% for sunflower, 7% for vegetables (all), 13% for dried onion and with 9% in the analyzes period (Table 5).

Table 5. Production of main cultures, excepting the cereals (tons)

Indicator /Year	2017	2018	2019	2020	2021
Sunflower					
Romania	2,912,743	3,062,690	3,569,150	2,122,865	2,843,531
Vrancea	17,119	15,891	19,780	7,255	15,139
Vegetables (all)					
Romania	3,638,447	3,797,436	3,529,648	3,483,035	3,495,105
Vrancea	61,711	62,813	60,750	71,887	57,115
Dried onion					
Romania	352,165	350,159	340,635	372,953	357,213
Vrancea	9,822	9,237	9,294	10,888	8,574
Tomatoes					
Romania	679,807	742,899	689,401	745,682	753,377
Vrancea	14,504	14,470	14,153	19,004	13,226

Source: Own calculation on the basis of data from Tempo online data base 2017-2021, NIS, [5].

In 2021, the production of main cultures, excepting the cereals in Vrancea, represented the following percentages from the total country production:

-Sunflower: 0.5% of the total production per country;

-Vegetables (all): 1.6% of the total production per country;

-Dried onion: 2.4% of the total area production country;

-Tomatoes: 1.8% of the total area production country.

Fruits sector

Between 2017-2021, at country level the number of fruit trees decreased by 1% for plum and apples, increased by 6% in case of pears and remain the same for the total fruit trees, cherries and burgundy. In Vrancea, the number of total fruit trees decrease with 11%, remain at the same for plum trees, and for apple, pears, cherries and burgundy also the number of trees decreased by a percent of 26%, 49% respectively 2% (Table 6).

In 2021, the area covered by fruit trees had the following shares in the total cultivated area in Vrancea County:

-Total fruit trees: 2.9% of the total number of fruit trees per country;

-Plum trees: 3.5% of the total number of fruit trees per country;

-Apple trees: 2.7% of the total number of fruit trees per country;

-Pears trees: 1.2% of the total number of fruit trees per country;

-Cherry and burgundy trees: 3.1% of the total number of fruit trees per country.

Table 6. The number of fruit trees

Indicator /Year	2017	2018	2019	2020	2021
Total fruit trees					
Romania	75,279,182	78,929,084	73,866,869	73,586,476	74,914,434
Vrancea	2,482,202	2,208,529	2,208,455	2,197,646	2,204,143
Plum					
Romania	34,591,325	34,534,473	34,459,654	34,214,693	34,195,891
Vrancea	1,187,970	1,190,848	1,187,970	1,182,478	1,182,969
Apple					
Romania	25,304,145	28,689,430	23,655,918	24,014,734	24,950,006
Vrancea	898,980	664,988	664,241	663,507	669,637
Pears					
Romania	3,153,616	3,192,913	3,147,062	3,313,645	3,331,620
Vrancea	78,808	40,329	40,311	40,298	40,226
Cherries and burgundy					
Romania	5,346,627	5,323,535	5,333,720	5,404,675	5,354,406
Vrancea	172,065	170,042	171,193	168,417	168,559

Source: Own calculation on the basis of data from Tempo online data base 2017-2021, NIS, [5].

Although are observed decreases, or only small increases for the indicator "The number of fruit trees" (Table 6), for "Fruit production by tree species (tones)" indicator (Table 7) can be noted some big increases in the production of fruits per Romania and Vrancea (from 2017 to 2021), as follow:

The increases per country:

-Total fruit trees increased by 61%;

-Plum trees increased by 84%;

-Apple trees increased by 73%;

-Pears trees increased by 8%;

-Cherries and burgundy trees increased by 34%;

The increases per county:

-Total fruit trees increased by 50%;

-Plum trees increased by 105%;

-Apple trees increased by 9%;

-Cherries and burgundy trees increased by 5%.

I order to have a clearer view of the previous increased it is important to notice Vrancea's production contribution in the total tons of fruits from the whole country:

-Total fruits: 2.8% of Romania's total fruit production;

-Plums: 3.7% of Romania's total fruit production;

-Apples: 1.8% of Romania's total fruit production;

-Pears: 1.3% of Romania's total fruit production;

-Cherries and burgundy: 3.5% of Romania's total fruit production.

Table 7. Fruit production by tree species (tones)

Indicator /Year	2017	2018	2019	2020	2021
Total fruit trees					
Romania	1,058,494	1,813,420	1487,,450	1,590,795	1,704,550
Vrancea	32,417	54,602	48,898	45,872	48,480
Plum					
Romania	444,922	842,132	704,817	769,874	819,358
Vrancea	14,688	33,940	29,764	27,974	30,074
Apple					
Romania	348,656	643,856	501,515	546,118	602,630
Vrancea	10,160	12,026	11,492	10,808	11,111
Pears					
Romania	48,878	60,440	49,268	49,657	52,592
Vrancea	940	781	719	680	679
Cherries and burgundy					
Romania	58,474	90,837	77,168	74,737	78,590
Vrancea	2,621	3,421	2,856	2,654	2,748

Source: Own calculation on the basis of data from Tempo online data base 2017-2021, NIS, [5].

In terms of fruits contribution at the total level of country production, plum production put up a percent of 3.7% and it is known that important plum areas are located in the counties like: Arges, Valcea, Buzau, Prahova, Dambovita, Caras Severin, Gorj, Mehedinti, Olt and Vrancea [12].

Grapes sector

Vrancea has three important vineyards, respectively Panciu, Coteşti and Odobeşti [9].

Grapes field is a very important in Vrancea's economy and through the two indicators like "Area of the vineyards in bearing (ha)" (Figures 1 and 2) and "Total production of grapes" (Figures 4 and 5) the dynamic of this field will be analyzed.

Vrancea County is the leader of wine production because of the high natural potential. Regarding, the soil, the county detains the following zone characteristics: the plain area, the sub-Carpathian hills area and the mountain area [8]. Also, the wine contributes at touristic part of the county. The existing wine route in the county of Vrancea includes seven wineries and wine cellars located in the most important vineyards in the county: Coteşti, Odobeşti and Panciu [6]. The interest of local authorities to develop local wine tourism is shown by the projects such as Vrancea –The Land of Vine and Wine, Wine Road or Vineyards Road [4].

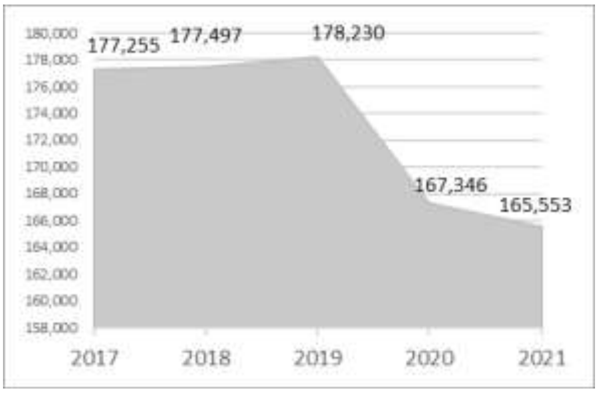

Fig. 1. Area of the vineyards in bearing in Romania (ha)

Source: Own calculation on the basis of data from Tempo online data base 2017-2021, NIS, [5].

According to Figure 1, the area of vineyards in bearing in Romania decreased by 7% between 2017 and 2021. The total area of vineyards in bearing it was 177 thousand ha in 2017 and by 12 thousand ha less in 2021.

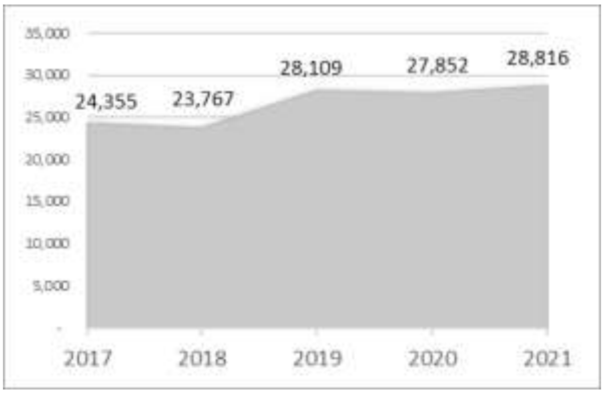

Fig. 2. Area of the vineyards in bearing in Vrancea county(ha)

Source: Own calculation on the basis of data from Tempo online data base 2017-2021, NIS, [5].

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In Vrancea the area of vineyards in bearing in 2021 was by 18% higher than in 2017. In 2017 the area of vineyards in bearing was 24 thousand ha, and in 2021 by almost 5 thousand ha more (Figure 2).

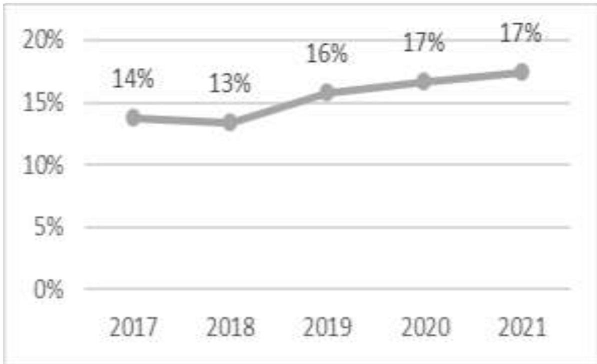

Fig. 3. The percent from Romania's vineyards in bearing detained by Vrancea (%)
Source: Own calculation on the basis of data from Tempo online data base 2017-2021, NIS, [5].

The area of vineyards in bearing from Vrancea increased their contribution on the total level of vineyards in bearing per country, according to Figure 3. In the last 2 years analyzed the percent of contribution was 17%.

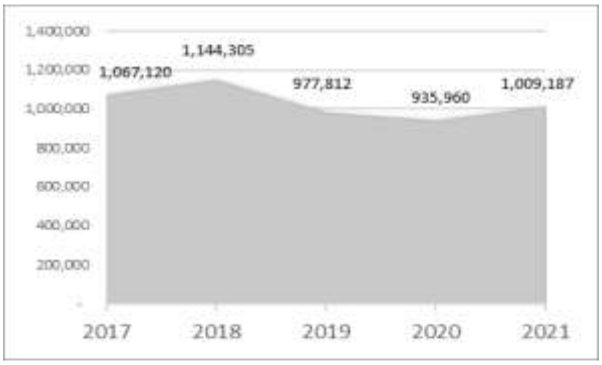

Fig. 4. Total production of grapes in Romania (tons)
Source: Own calculation on the basis of data from Tempo online data base 2017-2021, NIS, [5].

In Romania, total production of grapes in 2017 was 1,067,120 tons and in 2021 it was by 5.5% (57,933 tons) smaller (Figure 4).
According to Figure 5, the production of grapes in Vrancea increased by 10% (17,609 tons) between 2017 and 2021.
Grape production detained by Vrancea increased their contribution on the total level of vineyards in bearing per country, as shown in Figure 6. In the last year analyzed (2021) the percent of contribution was 19%.

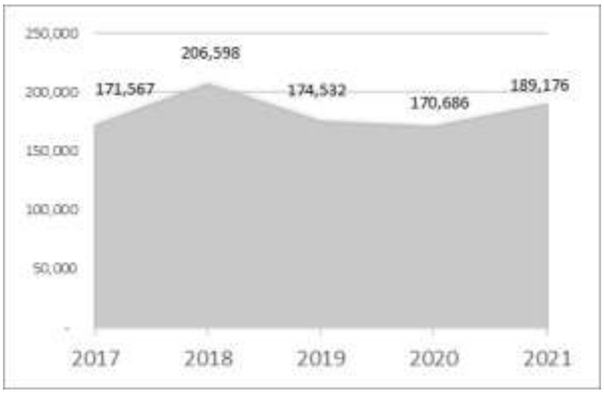

Fig. 5. Total production of grapes in Vrancea (tons)
Source: Own calculation on the basis of data from Tempo online data base 2017-2021, NIS, [5].

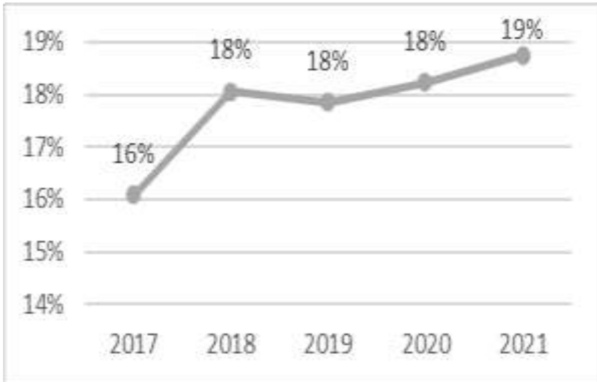

Fig. 6. The percent from Romania's grape production detained by Vrancea (%)
Source: Own calculation on the basis of data from Tempo online data base 2017-2021, NIS, [5].

Prahova County has the most certified wines, 24 in number, followed by Vrancea County with 11 certified wines highlighting specific areas with a tradition in vine cultivation [11].

CONCLUSIONS

Following the analysis of vegetable agricultural production in Vrancea, with focus on the county's contributions in total at the country level, resulted a lot of interesting and accurate aspects.
Starting with the information that 53% from the total surface of Vrancea county it was occupied with agricultural land, from which: 40% it was occupied with forests and other forest vegetation, 31% with arable land, 9% with pastures and 21% it was used for other types of lands, it was interesting to see what crops are covered these lands.
Corn grains (28,878 ha in 2021) and wheat (26,392 ha in 2021) are the main cereals

cultivated in Vrancea, with productions of 165,954 tons, respectively 116,395 tons in 2021.

The areas cultivated decreased by 14% for sunflower, 8% for vegetables (all), 2% for dried onion and with 22% for tomatoes in the analyzed period (2017-2021) and the production of all 4 cultures decreased by 12% for sunflower, 7% for vegetables (all), 13% for dried onion and with 9% in the analyzes period.

In Vrancea, the number of total fruit trees decrease with 11%, remain at the same for plum trees, and for apple, pears, cherries and burgundy also the number of trees decreased by a percent of 26%, 49% respectively 2%.

The indicator “fruit production by tree species” allowed us to see big increases in production, in Vrancea, as follow: total fruit trees increased by 50%; plum trees increased by 105%; apple trees increased by 9%; cherries and burgundy trees increased by 5%.

The total area of vineyards in bearing it was 177 thousand ha in 2017 and with 12 thousand ha less in 2021.

In 2017 the area of vineyards in bearing was 24 thousand ha, and in 2021 with almost 5 thousand ha more.

The total production of grapes in 2017 was 1,067,120 tons and in 2021 it was with 5.5% (57,933 tons) less.

The production of grapes in Vrancea increased by 10% (17,609 tons) between 2017 and 2021.

REFERENCES

[1]5th International Scientific Conference – EMAN 2021 – Economics and Management: How to Cope With Disrupted Times, Online/Virtual, March 18, 2021, Conference Proceedings, Association of Economists and Managers of the Balkans, Belgrade, Serbia, https://eman-conference.org/eman-2021-375/, Accessed on 31.02.2023.

[2]Alboiu, C., 2018, Romanian vegetable sector - a study on its current development, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.18(4), 19-22. https://managementjournal.usamv.ro/pdf/vol.18_4/Art2.pdf, Accessed on May 29, 2023.

[3]County Council Vrancea, Discover Vrancea, County Description, https://cjvrancea.ro/en/descopera_vrancea/county-description/, Accessed on 31.03.2023.

[4]Mănilă, M., 2012, Wine tourism - A conceptual approach with application in Vrancea County, Lucrările Seminarului Geografic" Dimitrie Cantemir", No. 34.

[5]NIS, National Institute of Statistics, Tempo On-line Database, 2023, www.insse.ro, Accessed on 31.02.2023.

[6]Olteanu, F., 2011. Wine Tourism. International Case Studies for Hospitality and Tourism Management Students and Trainees. Vol. 2. 72-81. https://www.researchgate.net/profile/Elizabeth-Ineson/publication/365993182_International_Case_Studies_for_Hospitality_and_Tourism_Management_Students_and_Trainees_Volume_2_edited_by/links/638bad137d9b40514e102789/International-Case-Studies-for-Hospitality-and-Tourism-Management-Students-and-Trainees-Volume-2-edited-by.pdf#page=88, Accessed on 31.02.2023.

[7]Rădulescu, C.V., Angheluță, P. S., Ioan, I., 2015, The perspective of agriculture in teh context of socio-economic development potential in Vrancea County. Annals of' "Constantin Brancusi" University of Targu-Jiu. Economy Series, Vol. 0, 87-94.

[8]Slave, C., 2020, The influence of the geographical area on wine products. A case study. Conference Proceedings, Third International Scientific Conference, ITEMA 2019 Recent Advances in Information Technology, Tourism, Economics, Management and Agriculture, pp.93-99.

[9]Slave, C., 2021, The wine road in Vrancea County, Proceedings of EMAN Conference 2021–Economics & Management: How to Cope with Disrupted Times, pp.375-380. https://eman-conference.org/wp-content/uploads/2021/10/EMAN_2021-Proceedings-WEB.pdf, Accessed on 31.02.2023.

[10]Soare, E., Dobre, I., David, L., 2016, Economic analysis in vegetable sector of Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.16(4), 333-338. https://managementjournal.usamv.ro/pdf/vol.16_4/Art45.pdf, Accessed on May 29, 2023.

[11]Sterie, C.M., Dumitru, E.A., 2021, Current situation of Romanian certified products, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 21(4), 555-560.

[12]Toma, I., Pipirigeanu, M., Haddad, F.M. Garlea, C, 2019, Quantitative and qualitative screening of the traditional plum jam from Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 19(2), 443-448.

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UTILIZATION OF SOIL MULCH FOR INCREASING SURFACE IRRIGATION PERFORMANCE AND WATER PRODUCTIVITY

Harby MOSTAFA, Mohamed ALI, Mohamed EL ANSARY

Benha University, Faculty of Agriculture, Agricultural and Biosystems Engineering. Department, Moshtohor, Qalyobia, Egypt, E-mails: Harby.mostafa@fagr.bu.edu.eg, harby_sorour@yahoo.com, mzinhom6@gmail.com, myansary@fagr.bu.edu.eg

***Corresponding author*:** Harby.mostafa@fagr.bu.edu.eg

Abstract

Maximizing water productivity is one of the most important strategies in arid and semi-arid regions. Therefore, the aim of this study was to investigate the using of plastic mulch at field scale for improving the performance of surface irrigation in contrast to conventional practices in irrigated agriculture. The experiment was laid out in furrow and border irrigation system with three main treatments namely non-mulched furrows (NMF) (as control), plastic mulched furrows (FM) and plastic mulched-hole border (MB), and the sub main treatments were three lengths (15, 30 and 40 m). Each of the three main plots consisted of 9 irrigation parts each three of them represent one of the sub main treatments (furrow and border lengths). The spacing was 0.7m between all treatments. Squash crop was planted in April for two successive seasons. The results indicated that applied water was low in case of MB where the mulch effect reduced the number of irrigation times to the half. The maximum total yield was obtained from treatment with 30m length under MB (31.89 t/ha) followed by 15 m under MB (30.46 t/ha). As regard different irrigation practices with plastic mulch, maximum irrigation water productivity (8.33 to 9.15 kg/m^3) was measured in MB for all lengths, followed by MF (5.11 to 5.41 kg/m^3). The water saving was thus 10.44% and 46.3% under treatments MF and MB, respectively, when compared to NMF. The result of this study indicates that, using hole-mulching resulted a corresponding increasing of water productivity and water saving.

Key words: *plastic mulch, surface irrigation, squash, water productivity*

INTRODUCTION

Optimized water management techniques at the farm level are required in view of increasing water demand and limited resources. Flood irrigation method is the most effective and ready to adopt surface irrigation system and widely used for all crops [9]. Basin, border and furrow are the traditional surface irrigation methods, which are used to irrigate crops in Egypt. Closely related furrow irrigation is the surface irrigation which utilizes the water for irrigation more efficiently as compared to other surface irrigation methods [4].

At present, the effects of plastic film mulching technology are mainly on border irrigation and furrow irrigation. In border irrigation, the membrane is laid on the border fields, where crops are grown. In furrow irrigation, crops are planted on groove slope or ridge back, while membrane is tiled on the bottom of the ditch, groove slope and part of the ridge back [18, 20].

Mulching is one management method that can be used to conserve water by preventing surface evaporation, controlling weeds, regulating soil surface temperature, improving overall soil quality by increasing soil organic matter, stimulating soil activity, increasing nutrient availability and increase crop yield [12]. Likewise, mulching is an economical and effective management method for controlling the moisture of the soil in root zone of crop [7, 13].

Under mulched furrow experiment done by Shelemew et al. [14], total yield harvested of head cabbage from black plastic mulch were 9.33ton/ha. High yield of 16.60 ton/ha was recorded from full irrigation that is 100%ETc and when half of irrigation water applied the yield were 9.4 ton/ha which showed significant difference between the two irrigation level. Water productivity of 4.3kg/m^3 and 3.8kg/m^3 were produced under 50%ETc and 100%ETc or full irrigation water respectively. The effects of mulching materials and furrow irrigation techniques on maize yield and water productivity under semiarid conditions indicate that both grain yield and water productivity were affected by the main effect of furrow irrigation techniques and mulching materials (P≤0.05) [2]. The conventional furrow irrigation (8,193 kg/ha) and white plastic mulch (7,930 kg/ha) resulted in the maximum grain yield.

The grain yield and nitrogen fertilizer utilization under border with 40 m length irrigation were significantly higher than those under irrigation of other border lengths and was considered as the best border irrigation length [21]. The saving percentages of water under treatments were 52.22% and 31% under furrow bottom with plastic sheet without plastic Sheet respectively, as compared to the saving of water under traditional irrigation practice [10]. Overall, better performance, in terms of crop production and water saving, was obtained with use of plastic sheet integrated with bottom of furrows. Hence, it is suggested that the furrow irrigation method with plastic sheet may be used to preventing moisture and minimize deep percolation losses from furrow bottom. The overall objective of the study was to investigate the using of plastic mulch of furrow and border irrigation on squash crop yield and its water productivity, as well as on improving the performance of irrigation method and its water distribution uniformity.

MATERIALS AND METHODS

Site Description

Field experimental study was conducted in private farm at Minya Alqamh, Sharkia governorate, Egypt - during two summer seasons of 2021 and 2022 from mid-April to end July. The location represents clay soil conditions of the Nile Delta region. The dominant soil of the experimental site was clay textured throughout the profile (5.4% coarse sand, 10.2% fine sand, 14.2% silt and 70.2% clay). The field capacity, wilting point and electrical conductivity values were 38%, 18.7% and 2.1 dSm^{-1} respectively.

Experimental layout and design

The experiment was laid out in furrow and border irrigation system with three main treatments namely non-mulched furrows (NMF) (as control), plastic mulched furrows (FM) and plastic mulched-hole border (MB), and the sub main treatments were three lengths (15, 30 and 40 m) as in Fig (1). Each of the three main plots consisted of 9 irrigation parts each three of them represent one of the sub main treatments (furrow and border lengths). The spacing was 0.7m between all treatments.

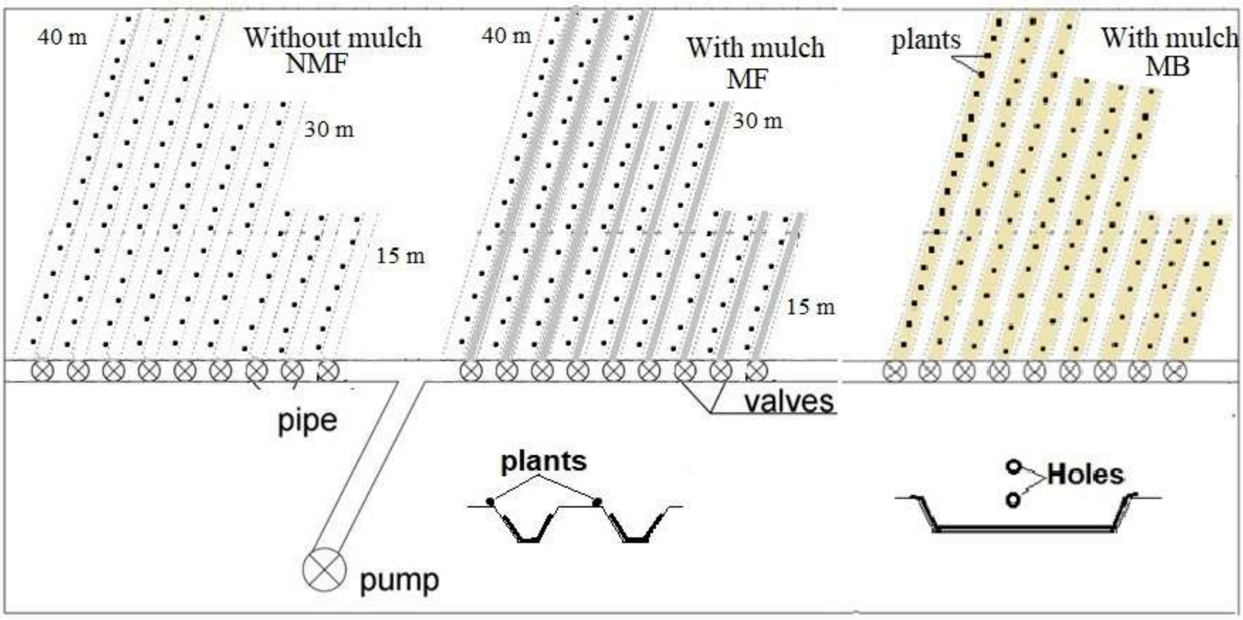

Fig. 1. A schematic diagram of the experimental treatments and the irrigation network components
Source: Authors' determination.

The experimental irrigation network consisted of (i) 6.5 HP gasoline engine water pump, (ii) Main lines of 75 mm diameter P.V.C pipes (iii) the pipe was provided with several 1 inch valves to control the amount of water add to each furrow or border. In the mulched furrow treatments, black polyethylene sheet of 0.08 mm thickness was manually laid out on the furrow bottom and fixed at sides of furrow to two third of the ridges for sowing the crop. The process of supplying the plant with water was based on filling the furrow with water to the level of the plastic cover, then the water will infiltrate into the furrow sides. In the mulched-hole border treatment, the surface of the borders was covered with plastic sheet and the edges were well fixed with the edges of the raised borders manually. The planting holes were performed in the sheet-hole with the help of 5 cm diameter pipe with sharpen edge [16]. The plant to plant spacing and row to row width was set as 70 cm (planting distance). After the cultivation process, water was added using the valves.

Type of crop under study

The selected crop for experimentation was squash (zucchini) (Aziad Hybrid F1) variety. It was sown by seeding rate of (8 kg/ha) in April of the two seasons. Two seeds were sown in each hole with 70 cm between holes and 70 cm spacing between furrows and border. After full germination, the best plant has been selected to be left in each hole for production. Fertilizer requirements for zucchini have been applied according to the recommendations of Agricultural Research Center, ARC.

Irrigation management

The amount of irrigation requirement for squash crop was calculated according to the climatic balance irrigation that established with numerical models by Central Laboratory for Agricultural Climate (CLAC), Ministry of Agriculture and Land Reclamation for experiment location. Water consumptive use (ETo, mm/day) was calculated according to the climate data using the Penman-Monteith method [5]. The crop water requirements (ETc) were estimated using the crop coefficient according to following equation:

ETc= ETo x Kc..................................(1)

where:

ETc is the crop water requirement (mm day^{-1}), and Kc is the crop coefficient.

The duration of the different crop growth stages were 20, 35, 20, and 15 days for initial, crop development, mid-season and late season stages, respectively and the crop coefficients (Kc) of initial, mid and end stages were 0.60, 1.00 and 0.75, respectively [3].

Soil moisture was monitored gravimetrically through soil depths (0-20, 20-40 and 40-60cm) layers. Soil samples were taken from each 20cm layer up to 60cm soil depth at four points along each furrow.

For high yield, soil water depletion should not exceed 65% of the total available water (p=65%) [1]. Soil moisture depletion (SMD) at any soil moisture level was observed with the following expression as:

SMD= (FC- MC) x Dzr........................(2)

where:

FC = Volumetric soil moisture content at field capacity (%), MC = Volumetric moisture content at time of irrigation (%) and Dzr = Depth of effective root zone (mm).

Regular soil samples were collected from experimental plots before and after irrigation for gravimetric soil moisture determination. The gravimetric soil moisture is then determined using the expression:

MC (%) = [(Ww - Wd)/ Wd]. 100.........(3)

where:

MC is the soil moisture content at time of sampling (%), Ww is weight of wet soil (gm) and Wd is weight of dry soil (gm).

Water distribution uniformity of furrow irrigation

To fully express the efficiency of an irrigation system, the distribution uniformity of water applied needs to be evaluated. Distribution Uniformity (Du) is the ratio of minimum infiltrated amount to the average infiltrated depth over the field [19]. DU was directly measured from soil moisture content difference before and after irrigation of the soil along the furrow and border length, and the root depth of the crop was taken as zone of distribution and finally it was computed by equation given below:

$$D_u = \frac{Z_{min}}{Z_{Av}} * 100 \quad ....(4)$$

where:

Du is distribution uniformity (%), Z_{min} is the minimum infiltrated depth, and Z_{Av} is the mean of depths infiltrated over the length.

Soil moisture distribution

For each treatment, four locations were taken along the row of plants. The soil water content was determined using the gravimetric method. Moisture content for each treatment was measured at 0.2 m increments to a depth of 0.60 m before irrigation and 48 hours after irrigation.

Growth parameters of squash (zucchini) crop

Three vegetative samples were taken during the growth period at the middle and end of the growing seasons. The following characteristics were measured:

1. Germination ratio (the germinated plants were counted along with non-grown plants. On the basis of numbers of grown and non-grown plants, germination percentages were determined).

2.Vegetative growth (length, weight, number and area of leaves, and root length and weight)

3.Productivity (The fruits were harvested by collecting in the appropriate phase for fresh consumption and the consumer's taste. They are easy fruits that are quick to perish, and trained workers collected them).

Irrigation water productivity (WP)

Irrigation water productivity is an indicator of effective use of irrigation unit for increasing crop yield. WP was calculated from following equation [5]:

$$WP\ (kg/m^3) = \frac{yield\ (kg/ha.)}{Total\ applied\ irrigation\ water\ (m^3/ha)} \quad ....(5)$$

Data Analysis

The least significant difference (LSD) test was applied at 5% level of significance to compare means showing significant differences.

RESULTS AND DISCUSSIONS

Effect of plastic mulch on soil moisture Content and water distribution uniformity

The average values of moisture amount for each replication of the treatments and soil depth (0-60 cm) in mid-season of squash under different systems of planting with and without polythene mulch are shown in Figures 2, 3 and 4 between to irrigations. The mulched furrow planting system (MF) recorded significantly (P< 0.05) high moisture content over without mulched furrow (NMF) treatment as shown in Figures 2 and 3. However, there is no significant difference among the mulched furrow lengths. Before irrigation, the highest moisture content was 26.7 % under MF as an average for the three lengths. The moisture content directly before the irrigation in MF planting system registered 17.4 % increase over NMF.

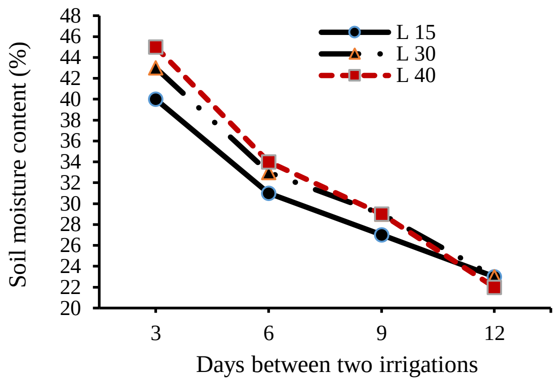

Fig. 2. Moisture content between two irrigations for NMF under different lengths
Source: Authors' determination.

The MB recorded significantly (P < 0.05) high moisture content. However, there is no significant difference among the MB lengths but there is significant difference among NMF lengths.

Before irrigation, furrow treatments required to irrigate after 12 days where soil moisture content reached 24.6% and (soil water depletion should not exceed 65% of the total

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available water (p=65%)) while MB treatments continued to 25 days to soil moisture content reach 25.7% as an average for the three lengths (Fig 4).

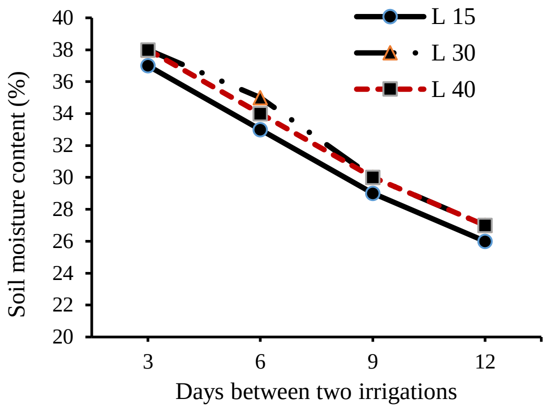

Fig. 3. Moisture content between two irrigations for MF under different lengths
Source: Authors' determination.

From the above observation on moisture content, it can be said that the plastic mulches are effective in water storage. Mulches were increasing the stored water in root zone than without mulched treatments and it could be inferred that the plastic mulches are competent enough to reduce evaporation loss there by effective in conserving moisture as a result moisture is available to meet the water requirement of the crop [17].

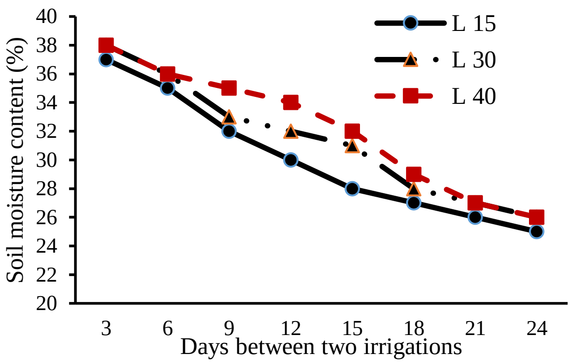

Fig. 4. Moisture content between two irrigations for MB under different lengths
Source: Authors' determination.

To determine the moisture uniformity, soil samples were collected from the head, middle and tail reaches of the field from mulched and conventional plots two days after irrigation. The field results are given in Table (1). It is clear from the table that moisture percentage is high at head and gradually decreased to the tail of the field with mulched and conventional irrigation. For border, it was observed that moisture level was high at head and gradually decreased to the tail with differences of 3 – 4% under mulched-hole border for all lengths. It is fact that in open field opportunity time was more as compared to tail of the field but in mulched border case due to covered surface of the field water moved rapidly to the downward direction, therefore moisture level differences was less than non-mulched furrow.

Distribution uniformity (Du) calculated for NMF were 79%, 75.2% and 70.3% at 15, 30, and 40 m, respectively, as shown in Table (1). For MF, calculated Du increased to 87.2%, 85.1% and 84.3% at 15, 30, and 40 m, respectively. The MB was more effective and homogenous that recorded 88.3%, 86.4% and 85.9% at 15, 30, and 40 m, respectively. Soil water storage in the 0–40 cm layer decreased in conventional treatments while in mulched treatments slightly increased in case of MF and high increase for MB. This was mainly because plastic mulch reduced the soil water evaporation. The integrative effect of plastic film mulch on soil water retention was better than the non-mulched treatments [6]. Furthermore, we found that soil water storage also varied between different lengths, where was no significant difference among 30 m and 40 m but 15 m treatment was less in water storage in all treatments.

Table 1. Moisture distribution and distribution uniformity (Du) for mulched and conventional treatments

Field Location	Length (m)	NMF (%)	MF (%)	MB (%)
Head	15	39	39	37
	30	43	40	38
	40	47	40	38
Middle	15	37	38	36
	30	41	38	36
	40	38	38	37
Tail	15	36	38	35
	30	37	38	34
	40	35	37	35
DU	15	79	87.2	88.3
	30	75.2	85.1	86.4
	40	70.3	84.3	85.9

Source: Authors' determination.

Irrigation water application

The total depths of irrigation water applied in mm through both irrigation methods were varied (Table 2). The gravimeter soil moisture content revealed that the total net of irrigation water determined in mm for each treatment were 525.7, 470.8 and 348.8 mm for NMF, MF and MB respectively, at the entire growing of the crop as it was determined from multiplication of total available water and depletion fraction (p=65%). The variation of application depth occurred between these irrigation methods were due to presence of plastic mulch except in sowing irrigation, the applied water was almost the same because the initial soil moisture content was the same for all experimental area.

Table 2. Total seasonal water application for mulched and non-mulched treatments

Number of irrigation	The amount of applied water (mm)		
	NMF	MF	MB
Sowing irrigation	110	110	110
1	78.6	70.7	Not irrigated
2	50.0	45.0	78.6
3	70.7	57.9	Not irrigated
4	63.2	53.6	81.2
5	94.3	76.8	Not irrigated
6	58.9	56.8	79
Total	525.7	470.8	348.8

Source: Authors' determination.

Applied water value was low in MF by 10%, than NMF may be due to the higher moisture content (26.6%) before irrigation than NMF (22.7%) as a direct effect of mulch.

The difference in applied water was higher in case of MB by 33.6% than NMF, where the mulch effect reduced the number of irrigation times to the half.

Effects of mulching on squash growth parameters

The germination of squash seed in mulched and conventional plots under different lengths are shown in Figure 5. It was observed that seed germination rate was 92 to 98% and mortality rate was 2-8% of MF. On the other hand the seed germination rate was observed as 80 to 89% and mortality rate was noted only as 11-20% in case of NMF. It was observed that germination rate was higher in the short furrows (15 m) in NMF, due to the low moisture uniformity in long furrows, while in MF, there was no significant difference between different lengths. It was also noted that moisture level remained more mulch treated furrows because of less evaporation and continuously soil moisture available in contrast to conventional furrows. Seed germination rate was 97 to 100% and mortality rate was 0-5% in MB with no significant difference between different lengths.

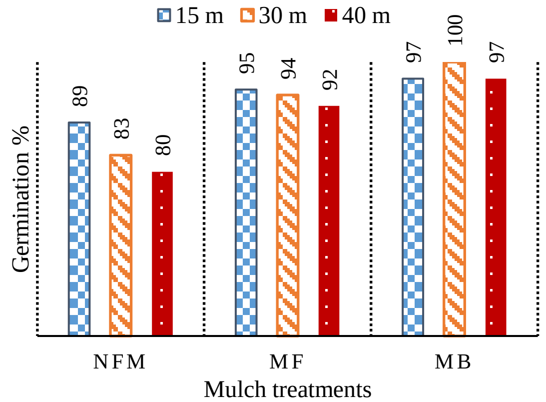

Fig. 5. Effect of different treatments on germination percentage after sowing squash
Source: Authors' determination.

The analysis of variance ($p<0.05$), showed that the plant heights and plant weight for selected 10 different plants were significantly changed by using plastic hole-sheet at border (MB) (Table 3). It was determined that the average values of plant height were noted 81, 80.5 and 79.4 cm were recorded for the treatment MB with increasing 44.1, 50.7 and 52.4% than NMF for 15, 30 and 40 m respectively. It was determined that the average values of plant height were recorded for MF an increase with 3.7, 8.2 and 3.2% more than NMF for 15, 30 and 40 m respectively. The increase in plant height under MB might be due to more availability of soil moisture in the root zone and better nutrient use efficiency and their uptake by plants as reported by [1]. MB treatments showed an increase in plant weight with average of 38.6% as compared to those under NMF (Table 3). In case of using plastic sheet at furrow bottom, the changes were moderate. It was determined that the average values of plant weight were increased by 0.01, 4.6 and 3.8 % under treatment MF as compared to those under NMF for 15, 30 and 40 m respectively. For mulching treatments, results are in line with those of [22] who reported that, plant weight were significantly affected by the mulching treatments.

Table 3. Effect of irrigation techniques on squash growth and yield parameters

Treat.	Length (m)	Plant high (cm)	Plant weigh (g)	Leaves area (cm^2)	N. Leaves
NMF	15	56.2	910	403.3	34.1
	30	53.4	900	384.4	34.4
	40	52.1	896	371.3	33.2
MF	15	58.3	919	470.4	35.2
	30	56.4	942	465.9	35.2
	40	55.1	930	465.0	35.3
MB	15	81.0	1261	627.2	38.2
	30	80.5	1249	622.3	37.1
	40	79.4	1240	618.0	36.2

Source: Authors' determination.

Plant leaf area was significantly affected by mulching in both MF and MB. In contrast, number of leaves per plant were not significantly affected by mulching on MF but was significantly affected by mulching at MB. Between the mulched treatments, number of leaves per plant under (MF) increased by 3% as an average than those under NMF, while it was increased under MB by 9 % in comparable with NMF. The difference in plant leaf area either between the mulched and non-mulched treatments or between the mulched treatments was significant.

The MF treatment showed good performance for root length and weight with non-significant effect in comparable with NMF (Table 4). These results are supported by [1] who reported same root growth, and root weight in furrow method. This may be due to availability of more soil moisture and soluble nutrients in the root zone where plastic sheets were used, facilitating it to uptake and stopping leaching.

Hence, it created better conditions for the growth and a well development of plant root system. These results are supported by [15], which stated that the higher crop production with mulched method, it might be the reason that more moisture and nutrient contents in the leaves, roots, and grains in mulched treatments.

Table 4. Effect of irrigation techniques on root length and weight

Parameters	Length m	Irrigation Techniques			LSD
		NMF	MF	MB	
Root length (cm)	15	46.2^{bc}	49.1^{b}	58.8^{a}	4.5
	30	46.3^{bc}	49.2^{b}	54.5^{a}	
	40	44.7^{bcd}	48.3^{b}	55.1^{a}	
Roots weight (g)	15	25.2^{c}	26.2^{bc}	29.2^{a}	2.1
	30	23.3^{c}	27.0^{bc}	28.1^{ab}	
	40	25.0^{c}	26.0^{bc}	27.2^{ab}	

Source: Authors' determination.

Effect of mulching on yield and water productivity (WP)

The yield of squash was significantly affected by mulched irrigation techniques.

Table (5) revealed that, the application of furrow plastic mulch, and mulch-hole border showed a significant increase in total yield of the crop as compared to non-mulched treatment for all different lengths.

However, total yield were not affected within the same length under plastic mulch. The maximum total yield was obtained from treatment with 30m length under MB (31.89 t/ha) followed by 15 m under MB (30.46 t/ha) while, the 40 m showed a little decrease total yield (29.04 t/ha).

There was also significant difference observed under MF with increase of 31.2 % and 40.2 % more than NMF in 30 and 40 m respectively, but there was no observed effect in yield on 15 m length for both NMF and MF.

Based on the results, MB method was resulted in increased yield by 50.6 % and 23.1% as compared to NMF and MF, respectively.

There was also significant difference observed between mean at ($p < 0.05$). These results are in agreement with those reported by [11].

The data related to the effect of different irrigation practices with plastic mulch on water productivity (WP) of squash are given in Figure 6. This figure clearly indicates that different irrigation practices with plastic mulch had significant effect on WP of squash.

Table 5. Effect of mulch on yield

Parameters	Length (m)	Irrigation Techniques NMF	MF	MB	LSD
Yield (kg/ha)	15	24.95 c	25.47c	30.46 ab	2.64
	30	19.04 d	24.95 c	31.89 a	
	40	17.14 de	24.04 c	29.04 b	

Source: Authors' determination.

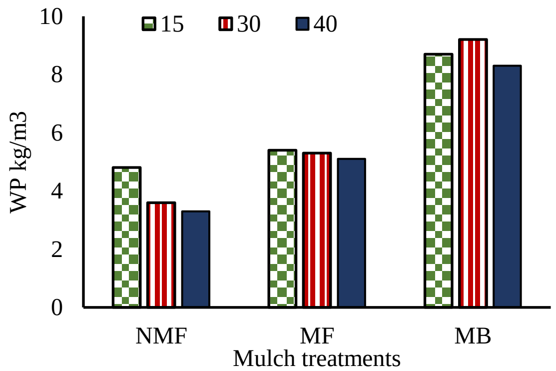

Fig. 6. Effect of irrigation techniques on WP
Source: Authors' determination.

As regard different irrigation practices with plastic mulch, maximum WP (8.33 to 9.15 kg/m^3) was measured in mulched-hole border for all lengths, followed by furrow irrigated sowing with plastic mulch (5.11 to 5.41 kg/m^3). In general, WP values decreased with increasing amount of irrigation applied. Mulching increased WP and yield due to reduction in evaporation, enhanced transpiration and deep percolation, leading to increased yields and WP [23]. Soil mulching with plastic reduced water loss, conserve soil moisture and more even regulated soil temperature.

Effect of mulching on water saving

The water saving was thus 10.44% and 46.3% under treatments MF and MB, respectively, when compared to NMF (Fig. 7).

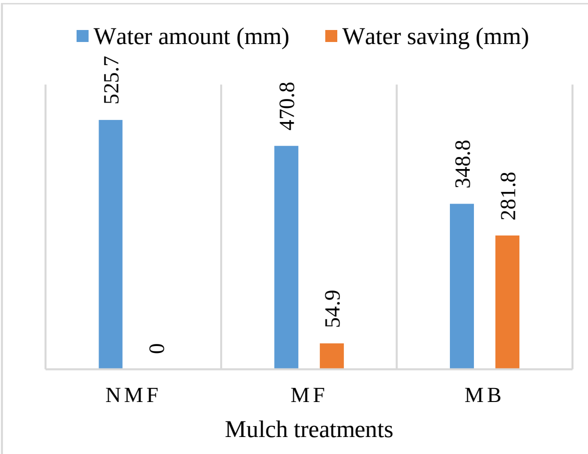

Fig. 7. Effect of mulch treatments on water saving
Source: Authors' determination.

These results are matching with [15] who reported that placing a plastic sheet on the bottom of the furrow prevents direct vertical infiltration from the bottom of the furrow which increase the water saving efficiency of furrow irrigation method.

These results are also similar to [8] who reported 22.73%-40.38% increase in water saving efficiency with plastic sheet mulching in furrow irrigation method.

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CONCLUSIONS

Generally, mulching showed significant effect on soil moisture conservation and agronomic parameters.

According to the findings of this experiment, the highest soil water content was obtained using plastic mulch in border followed by mulched furrow bottom. In this experiment, application of mulch played a greater role in distribute water uniformly, due to this available water to plants root not varied appreciably. Therefore, the total yield of squash was increased by 38% and 49.7% for MF and MB respectively, while water saving was thus 10.44% and 46.3% under treatments MF and MB, respectively, when compared to NMF. The availability of high soil moisture resulting in increases in photosynthetic rate and thereby increasing vegetative growth such as plant height, leaf area, and root length. The increment in number of leaves must have led to an increment in leaf area; hence, increased light interception and photosynthesis. These effects are translated in terms of total fresh weights of fruits, which showed a positive response to increasing moisture conservation practice and total yield.

Finally, the use of plastic mulch on the border produced the best performance in reducing water losses. Moreover, considering the soil moisture storage, the use of plastic mulch treatment in furrow irrigation was suggested as a favorable approach in water and soil management as well as increasing crop yield and water productivity.

REFERENCES

[1]Abd El-Mageed, T. A., Semida, W. M., Abd El-Wahed, M. H., 2016, Effect of mulching on plant water status, soil salinity and yield of squash under summer-fall deficit irrigation in salt affected soil. Agric. Water Manag. 173: 1–12. http://dx.doi.org/10.1016/j.agwat.2016.04.025

[2]Abebe N., Alemayehu, Y., Abegaz, F., 2020, Effect of mulching materials and furrow irrigation techniques on yield, water productivity and economic return of maize (*Zea mays* L.) at werer, middle awash valley, Ethiopia. Int. J. Agri. Biosci., 9(4): 156-162.

[3]Allen, R.G., Pereira, L.S., Raes, D., Smith M., 1998, Crop evapotranspiration guidelines for computing crop water requirements. Irrigation and Drainage Paper 56. FAO, Rome, 300.

[4]Altaf, A.S., Bristowc, K.L., Simunek, J., 2012, Minimizing nitrogen leaching from furrow irrigation through novel fertilizer placement and soil surface management strategies. Agric Water Manag, 115: 242–251.

[5]FAO. (Food and Agricultural Organization), 2002, Deficit irrigation practices. Water Reports No. 22. FAO, Rome, Italy.

[6]Gaimei, L., Yuguo, W., Baoliang, C., Nana, Li, Wenliang, C., Wei, Q., 2017, Exploring optimal soil mulching to enhance maize yield and water use efficiency in dryland areas in China, Acta Agriculturae Scandinavica, Section B — Soil & Plant Science, DOI:10.1080/09064710.2017.1394486

[7]Javed, A., Iqbal, M., Farooq, M., Lal, R., Shehzadi, R., 2019, Plastic film and straw mulch effects on maize yield and water use efficiency under different irrigation levels in Punjab, Pakistan. J. Agric. Biol. 21, 767–774. DOI:10.17957/IJAB/15.0955

[8]Jiang, S., Gao, X., Liang, J. , Wang, P., Gao, J., Qu, Y., Feng, B., 2012, Effect of different furrow and mulched ridge on water moisture conversation and water saving of spring mung bean planted farmland. J. Agric. Sci., 4 (7):132-141.

[9]Maurya, R.C., Singh, A.K., Singh, S., Singh, A., Sahay, R., Tiwari, D.K., Chandra, V., 2018, Impact of plastic mulching with furrow irrigation on tomato crop at farmer's field in Unnao District. Int. J. of Agriculture Sciences, Vol 10 (6), 509-5512.

[10]Memon, M. S., Ali, K., Siyal, A. A., Guo, J., Memon, S. A, Soomro, S. A, 2018, Effects of plastic sheet on water saving and yield under furrow irrigation method in semi-arid region. Int J Agric & Biol Eng, 11(1): 172–177.

[11]Parmar, H.N., Polara, N.D., Viradiya, R.R., 2013, Effect of mulching material ongrowth, yield and quality of watermelon (*Citrullus lanatus* thunb) Cv. kiran. Uni. J. Agric. Res. 1, 30–37.

[12] Patil, S.S., Kelkar, T.S., Bhalerao, S.A., 2013, Mulching: A soil and water conservation practice. Res. J. Agri. Forestry Sci., 1, 26–29.

[13]Shaikh, I. A., Wayayok, A., Mangrio, M., Alhussain, Z.A., Chandio, F. A., Khan, Z., Rahman, J. U., 2022, Optimizing approach of water allocation to off-takes during reduced flows. Water Resources Management, 1-23.

[14]Shelemew, Z., Ambomsa, A., Hussen, D., Jelde, A., 2022, Evaluation of the effect mulching practice under furrow irrigation on growth, yield and water productivity of head cabbage at Adami Tulu Agricultural Research Center. Science Research,10(2): 37-44. doi: 10.11648/j.sr.20221002.13

[15]Siyal, A.A., Bristow, K.L., Jirka, S., 2012, Minimizing nitrogen leaching from furrow irrigation through novel fertilizer placement and soil surface management strategies. J. Agric. Water Manag. 115:242- 251.

[16]Sun, X.J., Ma, X.Y., Liu, J.L., Zhan, G.L., 2010, Mathematical simulation of point source average infiltration depth under Film-hole irrigation. Chinese Journal of Applied Ecology.
[17]Temesgen, K., 2010, Evaluation of different mulch of types for soil moisture conservation and yield of Tomato (*Lycopersicon esculentum* Mill.) in Dila Woreda of South Ethiopia. M.Sc. Thesis. Alemaya University, Ethiopia.
[18]Wang, J., Lv, S., Zhang, M., Chen, G., Zhu, T., Zhang, S., Luo, Y., 2016, Effects of plastic film residues on occurrence of phthalates and microbial activity in soils. Chemosphere, 151, 171–177.
[19]Wang, W., Wenying, P., 2011, Simple estimation method on Kostiakov infiltration parameters in border irrigation, Water Resource and Environmental Protection (ISWREP), International Symposium on 20-22 May, (Vol:3).
[20]Xie, J.H., Zhang, R.Z., Li, L., Chai, Q., Luo, Z., Cai, L., Qi, P., 2018, Effects of plastic film mulching patterns on maize grain yield, water use efficiency, and soil water balance in the farming system with one film used two years. J. Acta. Ecol.Sci, 29(6).
[21]Yan, F., Shi, Y., Yu, Z., 2022, Optimized border irrigation improved nitrogen accumulation, translocation of winter wheat and reduce soil nitrate nitrogen residue. Agronomy, 12, 433. https://doi.org/10.3390/agronomy12020433
[22]Yaseen, R., Shafi, J., Ahmad, W., Rana, M.S., Salim, M., Qaisrani, S.A., 2014, Effect of deficit irrigation and mulch on soil physical. Science 19, 37–45.
[23]Zhang, Y.L., Xiao, R., Cheng, Z.Y., 2008, Water-saving and yield-increasing technology of film-hole irrigation in inland irrigation District of Hexi. Journal of Agricultural Mechanization Research. http://en.cnki.com.cn/Article_en/ CJFDTOTAL-NJYJ200804068.htm.

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INFLUENCE OF BREED AND SEASON ON THE FATTY ACID COMPOSITION OF GOAT MILK

Oleksandr MYKHALKO*, Victor OPARA*, Iryna LEVCHENKO, Mykola PRIHODKO*, Igor RUBTSOV***, Tetiana CHERNIAVSKA*****

Sumy National Agrarian University, *Department of Feed Technology and Animal Feeding, **Department of Technology of Production and Livestock Processing and Cynology, ***Department of Animal Breeding and Selection and Aquatic Bioresources, 160, H. Kondratiiev Street, Sumy, Ukraine, Phones: +38(099)7373370, +38(095)5488087, +38(066)2231449, +38(096)2822483, +38(067)9912896, +38(066)2406516, E-mails: oleksandr.mykhalko@snau.edu.ua, vopara@ukr.net, irunalevchenko@ukr.net, nikprihodk@gmail.com, rubtsov_igor68@ukr.net, chernyavska.t@gmail.com

Corresponding author: snau.cz@ukr.net

Abstract

It was analyzed how the content of fatty acids in the milk of Saanen goats and goats of Ukrainian breeding depended on the breed of goats. The experiment was based on a comparison of the content of fatty acids in the milk of 20 goats, of which 10 were Saanen goats and 10 were of Ukrainian local selection. Milk samples were taken monthly and analyzed for total and individual fatty acid content. The content of individual fatty acids was determined using the ion-exchange liquid column chromatography method. The results of the experiment showed that the profile of individual fatty acids was significantly affected by breed and season, but the amount of unsaturated fatty acids was unchanged throughout the year in Saanen and Ukrainian local breed goats. Goats of local Ukrainian selection gave milk with a higher content of monounsaturated fatty acids compared to their counterparts. The content of unsaturated fatty acids, including polyunsaturated acids, increased in warm months in goats of both breeds.

Key words: *goat's milk, fatty acid profile, saturated fatty acids, unsaturated fatty acids*

INTRODUCTION

Such a component of the diet of many people, as goat milk and dairy products from it, is complete and balanced in terms of micro and macro elements [8]. The content of fatty acids in goat milk directly affects the quality of dairy products [32]. One of the ways to determine the effect of goat milk on the functioning of the human body is to study its fatty acid composition, which is very different compared to cow's milk in terms of the amount of saturated and unsaturated fatty acids. Also, the milk of goats and cows has a different content of individual fatty acids, which have a noticeable effect on the nutritional value of milk and the human diet [6]. Determining the quality and biological value of goat milk includes the analysis of its fat profile [26]. The antimicrobial, anti-inflammatory and anti-carcinogenic function of goat milk is formed by smaller fat and casein micelles, as well as an increased concentration of short and medium-chain both free and bound acids, which are the fat-forming component of milk [25, 30].

Previously, it was stated that the hypoallergenicity of goat milk is based on the low content of s1-casein (a protein that has the highest degree of allergenicity). But these judgments were refuted, and instead it was found that the hypoallergenicity of goat milk does not depend on the content of s1-casein, which still causes allergic reactions in goat milk, even at a lower level than in cows. At the same time, it turned out that the genetic polymorphism of milk proteins is related to the mass proportions of certain fatty acids, and in the future it will be possible to select animals with the required ratio of fatty acids to allergenic proteins [2, 5, 24]. Goat milk is characterized by a unique ratio between the mass fractions of lauric and capric fatty acids. Not only is this ratio two times lower than that of cow's milk, but because of the small variation in the average value, it can be used to demonstrate that goat's milk is adulterated by cow's milk [12]. The study of the properties of milk fat, especially the triglycerides of fatty acids, opens wide possibilities for research on the properties useful for humans and the criteria for authenticity of dairy products from goat milk. The composition of the fat content in milk fat is influenced by the goat breed [10], its lactation period [11], feeding conditions [7, 16] and seasonal factors [1, 3].

It is known that the composition of milk fat is subject to significant seasonal variations, especially when comparing summer and winter periods, mainly due to the introduction of green grass [33] in the feed ration. The content of stearic and oleic acids increases in summer, and that of myristic and palmitic acids in winter [4]. The content of biologically important polyunsaturated fatty acids (linoleic, linolenic and arachidonic) is higher in spring and summer than in autumn and winter, but at the same time the degree of oxidation of these acids increases. Therefore, it is necessary to have information about the natural antioxidants of milk, such as carotenoids and tocopherols, in order to control the biological value of milk (A, D, E) [23, 27]. The greatest differences were found in the concentration of α-linolenic acid (C18:3n3), which was almost double. The content of this acid was higher in summer than in winter [17, 18]. These data are consistent with similar data from foreign researchers, who assume that the use of green fodder in summer, when the grass is actively growing, contributes to the accumulation of the proportion of polyunsaturated fatty acids in both goats [28] and other ruminants [13].

The fatty acid profile of milk depends on the breed of goat. One of the most common goat breeds in dairy goat breeding worldwide is the *Saanen* goat, in addition to which *Alpine* and *Nubian* breeds are also used in some farms. The German White goat was created by long-term crossbreeding of goats of local breeds in Germany with purebred goats of the *Saanen* breed. German White goats practically do not differ from Saanen goats, although the latter have a stronger constitution [44]. There is a widespread opinion among scientists that the genotype of goats and the composition of fatty acids in their milk are closely related [14, 41]. To confirm this view, the different fatty acid profile in the milk of goats of different breeds is often cited as an example. In particular, it has been demonstrated that the milk of *Saanen* goats has a higher saturated fatty acid content than that of goats of local breeds [11]. who studied the fatty acid composition of goat milk from the Saanen and Swedish Landrace breeds reported a difference in this indicator between the breeds. Thus, the Zaane breed had the highest content of non-fatty acids, and the content of palmitic acid and oleic acid were dominated by goats of the *Swedish Landrace* breed [43]. Some works show the dependence of fatty acid composition of goats' milk only on the lactation period [40] or exclusively on the characteristics of feeding [29, 33, 42] and to a lesser extent on the breed [37].

Although *Saanen* goats were bred in Germany in the mid-19th century [31], in the last 150 years they began to be kept in temperate latitudes around the world, including Ukraine. The goats of the *Saanen* breed spread to the western, central and southern regions of Ukraine and were initially used to improve the reproductive and performance characteristics of local goats of Ukrainian breeding [35]. However, today there are farms that exclusively use *Saanen* goats for milk production. In Ukrainian agriculture, these goats are mainly bred in small farms. The *Saanen* breed is appreciated by farmers for its productivity and the milk for its high quality, proven usability and moderate fat content [36]. Due to the general decline of goat breeding in Ukraine, the population of *Saanen* goats has recently decreased. Today, of the seven state goat breeders, three breed *Saanen* goats. Despite the war, the demand for these goats is recovering as there are government subsidies for farmers, which indicates a new potential for goat breeding in the future [15].

Since goats of different breeds differ significantly in terms of fatty acid composition of milk under the influence of seasonal factors, there is a need to make a comprehensive evaluation of these animals in order to use them in the most effective and targeted way for milk production throughout the year.

MATERIALS AND METHODS

The experiment was executed on twenty goats in their second lactation with an average weight of 50 kg and a milk yield of seven hundred kilogrammes. Three groups were formed from thirty goats: Control group I – 10 lactating *Saanen* goats, experimental group II – 10 lactating goats of a local Ukrainian selection. The goats were kept in the experimental vivarium of the Sumy National Agrarian University, Sumy region, Ukraine. Groups are formed according to the principle of pairs of analogs. The terms of the goats were the same. The goats were provided with free access to water. Feed was distributed 3 times a day. Experimental goats were offered diets for autumn-winter period and spring-summer period (Tables 1, 2) that corresponded to their individual nutritional needs.

Table 1. Diet of goats in the autumn-winter period of keeping (October-May)

Diet ingredient	Value
Hay, kg	2.5
Root vegetables (beetroot, carrot), kg	2.0
Grain (dry peas, barley, oats, corn, sprouted wheat), kg	0.9
Table salt, kg	0.01
Crushed chalk, kg	0.01

Source: Own calculations.

Table 2. Diet of goats in the spring-summer period of keeping (June-September)

Diet ingredient	Value
Green grass, kg	7.0
Root vegetables (beetroot, carrot), kg	2.0
Grain (dry peas, barley, oats, corn, sprouted wheat), kg	0.9
Table salt, kg	0.01
Crushed chalk, kg	0.01

Source: Own calculations.

The diet used in the experiment in both studied periods satisfied the energy and nutrient needs of the goats (Table 3).

Table 3. Energy nutritional content of the goat diet during the experimental period per goat per day

Indicator	Value
Exchange energy, MJ	18.0
Dry matter, kg	2.0
Crude protein, g	282.0
Digestive protein, g	171.0
Table salt, g	15.5
Calcium, g	8.5
Phosphorus, g	6.1
Magnesium, g	0.9
Sulphur, g	5.2
Iron, mg	89.0
Copper, mg	15.5
Zinc, mg	89.1
Cobalt, mg	0.86
Manganese, mg	87.9
Iodine, mg	0.67
Carotene, mg	20.9
Vitamin D, MO	918.0

Source: Own calculations.

The goats were milked manually twice daily during the lactation period of 305 days. Milk samples for evaluation of fatty acid composition were collected from healthy goats once a month in each seasons according to ISO 707:2008 [22], filtered and chilled to a temperature of +6±2 ºC. Analysis of selected milk samples for the content of fatty acids and their profile was carried out within 24 hours after collection using the ion-exchange liquid column chromatography method (ISO 18252:2006) [20]. Volatile fatty acids of milk were determined by the method of gas-liquid chromatography (ISO 15885:2002) [19] in the laboratory of the Institute of Animal Breeding of the National Academy of Sciences of Ukraine in Kharkiv, which is accredited according to the requirements (ISO /IEC 17025:2006) [21], Accreditation Certificate No. 2T621 issued by the National Accreditation Agency of Ukraine, Kyiv.
The keeping and handling of the goats during the experiment was humane and in accordance with the policy set out in Council Directive 86/609/EEC [10].

Statistical data analysis was performed using MS Excel 2016 based on generally accepted biometric methods of data evaluation. The reliability of exceeding the average values was determined using the Student's t-test.

RESULTS AND DISCUSSIONS

The study of the content of saturated fatty acids in goat milk in winter showed a higher content of myristic acid, palmitic acid and behenic acid of 1.75%, 0.65% and 0.05%, respectively ($p<0.01$) in representatives of *Saanen* breeds. However, in the summer season, *Saanen* goats had higher levels of undecylic, lauric, margaric, and arachidic acids by 0.01%, 0.77%, 1.46%, and 0.05%, respectively ($p<0.01$) (Table 4).

It should be noted that the analogues of local Ukrainian selection during the hot summer months had higher values of caproic and pentadecanoic acids by 0.02% and 0.12% ($p<0.001$). In the winter season, goats of local Ukrainian selection were distinguished by a higher content of myristic acid by 1.24% ($p<0.001$), palmitic acid by 1.47% ($p<0.001$), stearic acid by 1.71% ($p<0.001$), behenic acid by 0.07% ($p<0.001$), tridecanoic acid by 0.01% ($p<0.05$). In the summer season, goats of Ukrainian local selection had a higher content of undecyl acid in milk by 0.02% ($p<0.01$), lauric acid by 0.68% ($p<0.05$), arachinic acid by 0.21% ($p<0.05$), tridecanoic acid by 0.02% ($p<0.001$) and pentadecanoic acid by 0.22% ($p<0.001$).

Table 4. The content of saturated fatty acids in goat milk, %, (n=24)

Fatty acids	Breed			
	Group I – *Saanen*		Group II – Local Ukrainian selection	
	Spring-summer period	Autumn-winter period	Spring-summer period	Autumn-winter period
Caproic acid	0.07±0.005	0.06±0.004	0.07±0.002^{a3}	0.05±0.003
Caprylic acid	1.11±0.004	1.12±0.010	1.09±0.008	1.11±0.009
Capric acid	4.78±0.255	4.39±0.196	5.41±0.232	5.34±0.227^{b2}
Undecyl acid	0.04±0.003^{a1}	0.03±0.003	0.06±0.005^{b2}	0.05±0.004^{b3}
Lauric acid	5.75±0.232^{a1}	4.98±0.216	6.43±0.212^{b1}	6.83±0.286^{b3}
Myristic acid	15.01±0.109^{b3}	16.76±0.112^{a3b3}	12.99±0.144	14.23±0.149^{a3}
Palmitic acid	19.14±0.189^{b3}	19.79±0.123^{a2b3}	17.40±0.173	18.87±0,154^{a3}
Margaric acid	1.49±0.098	1.31±0.076	1.55±0.090	1.67±0.011^{b3}
Stearic acid	14.56±0.071^{a3b3}	13.10±0.064^{b3}	13.85±0.052	12.14±0.047
Arachinic acid	0.80±0.012^{a2}	0.75±0.008	1.01±0.093^{b1}	1.2±0.101^{a3b3}
Behenic acid	0.51±0.012^{b3}	0.56±0.010^{a2b3}	0.43±0.009	0.50±0.010^{a3}
Pelargonic acid	0.03±0.004	0.02±0.005	0.04±0.003	0.03±0.004
Tridecanoic acid	0.12±0.002	0.12±0.001	0.14±0.002^{b3}	0.15±0.003^{a1b3}
Tetradecadienoic acid	0.79±0.064	0.75±0.035	0.98±0.075	0.87±0.058
Pentadecanoic acid	2.02±0.008	2.01±0.007	2.24±0.007^{a3b3}	2.12±0.008^{b3}
The sum of saturated fatty acids	66.22±2.223	65.75±2.083	63.69±2.108	65.16±2.220

^{a1} – $p<0.05$; ^{a2} – $p<0.01$; ^{a3} - $p<0.001$ – comparison between seasons within the same breed.
^{b1} – $p<0.05$; ^{b2} – $p<0.01$; ^{b3} – $p<0.001$ – comparison between breeds within one season.
Source: own calculations.

In the warm season, *saanen* goats differed from their counterparts of Ukrainian local breeding by a higher content of myristic acid by 2.02% ($p<0.001$), palmitic acid by 1.74% ($p<0.001$), stearic acid by 0.71% ($p<0.001$), behenic acid by 0.08% ($p<0.001$).

In the winter season, the analysis of milk samples from goats of Ukrainian local breeding compared to *Saanen* goats revealed a higher content of capric acid by 0.95% ($p<0.01$), undecyl acid by 0.02% ($p<0.001$), lauric acid by 1.85% ($p<0.001$), margaric acid by 0.36% ($p<0.001$), arachinic acid by 0.45% ($p<0.001$), tridecanoic acid by 0.03% ($p<0.001$) and pentadecanoic acid by 0, 11% ($p<0.001$). Goats of the *Saanen* breed in the cold season compared to peers of local Ukrainian selection who were distinguished by a higher content of myristic, palmitic and stearic acids by 2.52%, 0.92% and 0.96% ($p<0.001$).

Our analysis of the unsaturated fatty acids of goat milk of both breeds showed that the *Saanen* breed during the winter months had a higher content of Myristooleic acid by 0.15% ($p<0.05$), pantadecenoic acid by 0.01% ($p<0.05$) and in addition higher content of genicosanic, erucic, docosatetraenoic acids by 0.01%, 0.07% ($p<0.001$) and 0.01% ($p<0.05$), respectively (Table. 5). In the warm season, the control herd of the *Saanen* breed had a higher milk content of oleic acid by 2.05% ($p<0.001$), isocaprylic acid by 0.01% ($p<0.01$), linoleic acid by 0.94% ($p<0.001$), linolenic acid by 0.21% ($p<0.001$), arachidonic acid by 0.02% ($p<0.05$). According to the amount of unsaturated fatty acids, the milk of *Saanen* goats had a higher content in the summer season by 3.17% ($p<0.001$), of which the higher content in this period was polyunsaturated by 1.23% ($p<0.05$).

During three summer months, experimental local goats of Ukrainian breeding demonstrated higher content indicators of oleic acid by 2.09% ($p<0.001$), isocaprylic acid by 0.01% ($p<0.05$), lauroleic acid by 0.08% ($p<0.05$), isopalmitic acid by 0.03% ($p<0.01$), heptadecenoic acid by 0.03% ($p<0.01$), linoleic acid by 0.87% ($p<0.001$), linolenic acid by 0.19% ($p<0.001$), erucic acid by 0.03% ($p<0.001$), docosatrienoic acid by 0.01% ($p<0.05$). The analysis of winter milk showed a comparatively higher content of such unsaturated fatty acids as pentadecenoic and eineicosanoic acids by 0.01% each ($p<0.001$).

Table 5. The content of unsaturated fatty acids in goat milk, %, (n=24)

Fatty acids	**Breed**			
	Group I – *Saanen*		**Group II – Local Ukrainian selection**	
	Spring-summer period	**Autumn-winter period**	**Spring-summer period**	**Autumn-winter period**
Myristooleic acid	2.32±0.057	2.38±0.041^{a1}	2.46±0.040	2.51±0.038^{b1}
Palmitoleic acid	3.25±0.074	3.30±0.062	4.20±0.060^{b3}	4.25±0.058^{b3}
Oleic acid	19.16±0.164^{a3b3}	17.11±0.142^{b3}	17.44±0.148^{a3}	15.35±0.122
The sum of monounsaturated fatty acids	24.73±0.775	22.79±0.752	24.10±0.653^{a1}	22.11±0.642
Isocaprylic acid	0.06±0.003^{a2}	0.05±0.003	0.06±0.002^{a1}	0.05±0.003
Isolauric acid	0.05±0.004	0.06±0.003	0.06±0.005	0.05±0.006
Lauroleic acid	0.46±0.011	0.48±0.010^{b2}	0.47±0.021^{a1}	0.39±0.026
Isomyristic acid	0.19±0.011	0.20±0.012^{b1}	0.16±0.010	0.15±0.017
Pentadecenoic acid	0.12±0.003	0.13±0.002^{a1}	0.14±0.001^{b3}	0.15±0.002^{a3b3}
Isopalmitic acid	0.30±0.004	0.31±0.005	0.37±0.003^{a2b3}	0.36±0.004^{b3}
Hexadecadienoic acid	0.74±0.015	0.72±0.014	0.94±0.027^{b3}	0.96±0.026^{b3}
Heptadecenoic acid	0.46±0.006^{b3}	0.45±0.007^{b3}	0.41±0.007^{a2}	0.38±0.006
Linoleic acid	3.25±0.033^{a3}	2.31±0.024	3.92±0.027^{a3b3}	3.05±0.025
Linolenic acid	1.25±0.011^{a3}	1.04±0.012	1.26±0.015^{a3}	1.07±0.013
Geneicosanoic acid	0.14±0.001^{b3}	0.15±0.002^{a3}	0.13±0.002	0.14±0.001^{a3}
Arachidonic acid	0.11±0.006^{a3}	0.09±0.005	0.14±0.031	0.10±0.022
Erucic acid	0.36±0.002^{a3}	0.29±0.002	0.37±0.001^{a3b3}	0.34±0.002^{b3}
Docosadienoic acid	0.16±0.006^{b1}	0.15±0.007	0.14±0.004	0.15±0.005
Docosatrienoic acid	0.08±0.003	0.07±0.004	0.09±0.002^{a1b1}	0.08±0.003
Docosatetraenoic acid	0.04±0.003	0.05±0.002^{a1}	0.05±0.004	0.05±0.003
Docosahexaenoic acid	0.18±0.007	0.17±0.010	0.24±0.003^{b3}	0.23±0,005^{b3}
The sum of polyunsaturated fatty acids	7.95±0.399^{a1}	6.72±0.399	8.91±0.290^{a2}	7.70±0.265
The sum of unsaturated fatty acids	32.68±0.871^{a1}	29.51±0.871	33.01±0.924^{a2}	29.81±0.336

^{a1} – $p<0.05$; ^{a2} – $p<0.01$; ^{a3} - $p<0.001$ – comparison between seasons within the same breed.
^{b1} – $p<0.05$; ^{b2} – $p<0.01$; ^{b3} – $p<0.001$ – comparison between breeds within one season.
Source: own calculations.

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The study of the interbreeding difference in the profile of unsaturated fatty acids in goat milk in the summer period made it possible to state that the content of palmitoleic acid in the Ukrainian local breeding stock was higher by 0.95% ($p<0.001$), pantadecenoic acid by 0.02% ($p<0.001$), isopalmitic acid by 0.07% ($p<0.001$), hexadecadeic acid by 0.2% ($p<0.001$), linoleic acid by 0.67% ($p<0.001$), erucic acid by 0.01% ($p<0.001$), docosatrienoic acid by 0.01% ($p<0.05$), docosahexaenoic acid by 0.06% ($p<0.001$).

The study of the profile of unsaturated fatty acids revealed that its indicators were higher in goats of the *Saanen* breed in the summer season by the content of oleic acid by 1.72% ($p<0.001$), heptadecenoic acid by 0.05% ($p<0.001$), geneicosanoic acid by 0.01 %. ($p<0.001$), docosadienoic acid by 0.02% ($p<0.05$).

Analysis of the profile of unsaturated fatty acids in the winter period found a higher content of myristoleic acid by 0.13% ($p<0.001$), palmitoleic acid by 0.95% ($p<0.001$), pentadecenoic acid by 0.02% ($p<0.001$), isopalmitic acid by 0.05% ($p<0.001$), hexadecadeic acid by 0.23% ($p<0.001$), erucic acid by 0.05% ($p<0.001$), docosahexaenoic acid by 0.08% ($p<0.001$).

The study of the content of unsaturated fatty acids during the cold season of the *Saanen* breed showed a higher content of oleic acid by 1.76% ($p<0.001$), lauroleic acid by 0.09% ($p<0.01$), and isomyristic acid by 0.05% ($p<0.05$), heptadecenoic acid by 0.07% ($p<0.001$).

During the summer season, goats of Ukrainian local selection showed a 3.2% advantage in the amount of unsaturated fatty acids over their counterparts ($p<0.01$). At the same time, goats of the Saanen breed were inferior to goats of Ukrainian local breeding in the content of polyunsaturated fatty acids and monounsaturated fatty acids by 1.21% ($p<0.01$) and 1.99% ($p<0.05$), respectively.

The population of goats in Ukraine has a tendency to decrease over the last 8 years be 12.17% (Fig. 1).

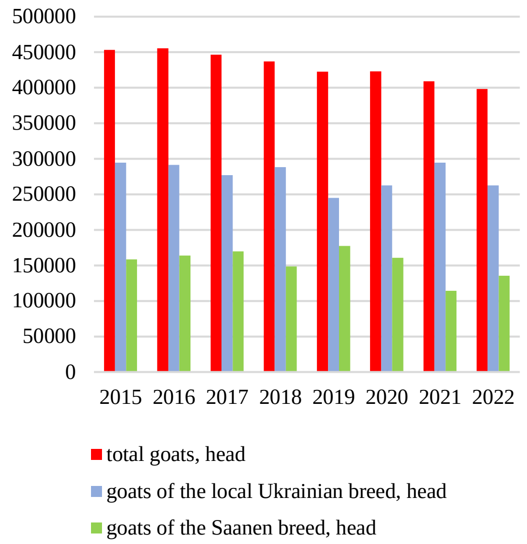

Fig. 1. Dynamics of the goat population in 2015-2022, heads
Source: 38, 39.

Over the past 3 years, the total number of goats of all breeds has also decreased by 5.95%. The population of goats of the *Saanen* breed decreased from 2015 to 2022 by 14.68% and decreased by 15.85% in 2022 compared to 2021.

Milk production had negative dynamics and showed a steady decline (Fig. 2).

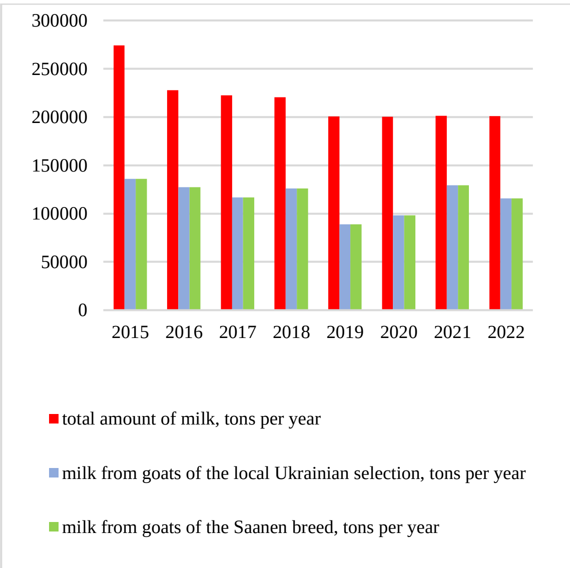

Fig. 2. Production of goat milk in 2015-2022, tons per year
Source: 38, 39.

Milk yield of *Saanen* breed goats decreased by 14.62% in 2022 compared to 2015, due to the general decrease in the population of this breed. In general, 14.97% of milk was not obtained from goats of the local Ukrainian breed in 2022 compared to 2015, which is also related to the decrease in the local goat population.

However, it should be noted that the milk yield per goat per year did not significantly decrease by 2.36% in the last 3 years (Fig. 3).

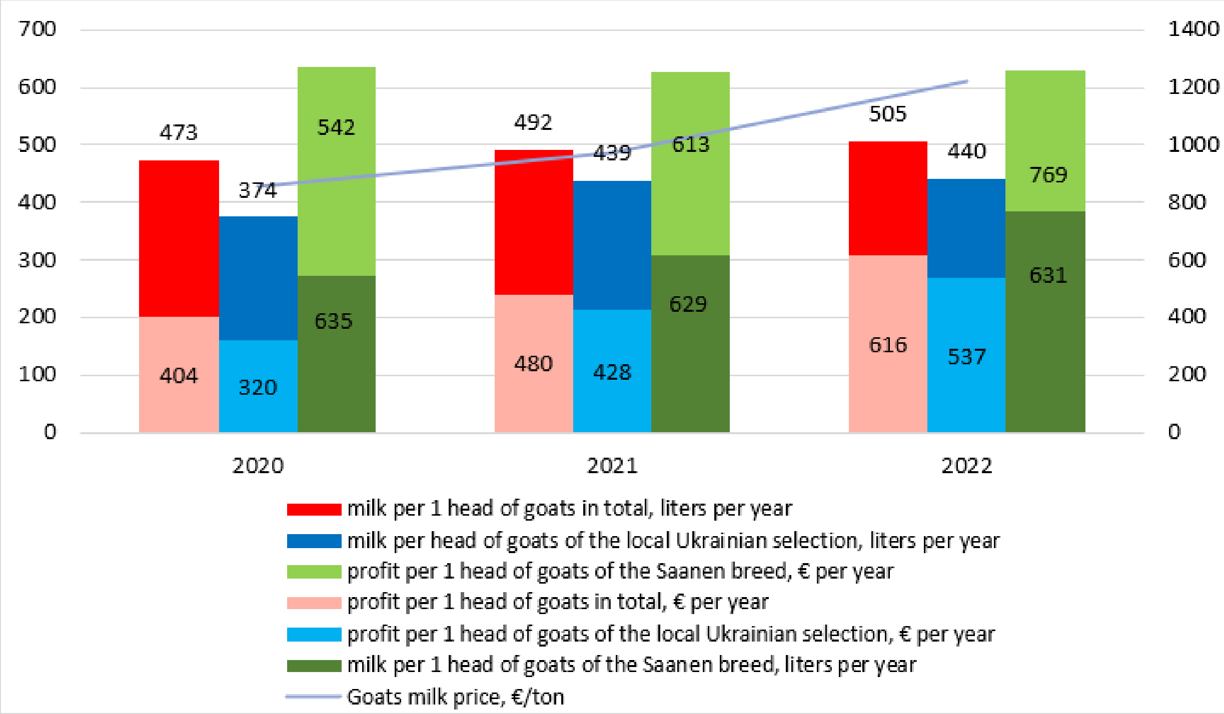

Fig. 3. Productivity of milk per 1 goat, litters per year and profitability per 1 goat, Euros per year
Source: own calculations and 38, 39

Milk productivity per 1 goat in total per year increased by 6.7%, per 1 goat of local Ukrainian breeding by 17.6% in 2022 compared to 2020. However, milk yield per 1 goat per year of *Saanen* breed decreased by 0.7% in three years. At the same time, the profit for 1 goat per year increased by 52.4% overall, 41.9% for 1 goat of local Ukrainian selection, and 68.0% for 1 goat of the *Saanen* breed, as the price of 1 liter of milk increased by 42.9% between 2020 and 2022. Milk productivity per 1 goat in total and per year increased by 6.7%, per 1 goat of local Ukrainian breeding by 17.6% in 2022 compared to 2020. However, milk yield per 1 goat per year of *Saanen* breed decreased by 0.7% in three years. At the same time, the profit for 1 goat per year increased by 52.4% overall, 41.9% for 1 goat of local Ukrainian selection, and 68.0% for 1 goat of *Saanen* breed, as the price of 1 liter of milk increased by 42.9% between 2020 and 2022.

Thus, even in the event of a greater decline in the goat population of the *Saanen* breed, the milk productivity of this breed can still ensure a higher profitability than that of goats of other breeds for some time.

Our data on the influence of goat breed on the fatty acid profile of their milk were in agreement with the general conclusions [9, 14, 41]. However, we found no agreement with the report [11] indicating a lower unsaturated fatty acid content in the milk of crossbred goats compared to *Saanen* goats. According to the results of our experiment, the total unsaturated fatty acid content did not differ by goat breed, but by individual fatty acids, similar to the data [43].

As a result of the experiment conducted, similar to other researchers [1, 3], we found that seasonal factors affect the profile of fatty acids in the milk of both breeds, especially when comparing the indicators of summer and winter seasons, which was also reported by other authors [34]. The increase in stearic and oleic acid content in the warm season, reported in scientific work [14], was fully confirmed. It was also confirmed [14] that the growth of myristic and palmitic acid content in winter showed similar dynamics as the growth in our experiment. Our results coincided with the findings [23, 27] about an increase in the content of linoleic, linolenic and arachidonic acids in the warm season and their decrease in the cold months. It should be noted that the specified seasonal fluctuation of the indicators of the content of linoleic, linolenic and arachidonic fatty acids was detected both in goats of the *Saanen* breed and in goats of the Ukrainian local breed, which also coincides with the data of [17, 18], which obtained a similar result.

Our results are also in agreement with similar data [28], which assume that the use of more green forage in summer increases the accumulation of polyunsaturated fatty acid content. In our experiment, polyunsaturated fatty acids increased significantly during the summer period in goats of both genotypes.

CONCLUSIONS

The composition of fatty acids in the milk of *Saanen* goats and goats of local Ukrainian selection was influenced by both breed and seasonal factors.

In particular, goats of local Ukrainian selection and goats of the *Saanen* breed had different content of saturated and unsaturated fatty acids.

In summer, goats of both breeds had a lower content of saturated fatty acids and a higher content of unsaturated fatty acids.

REFERENCES

[1]Ataşoğlu, C., Uysal-Pala, Ç., Karagül-Yüceer, Y., 2009, Changes in milk fatty acid composition of goats during lactation in a semi-intensive production system. Archiv Tierzucht., Vol. 52: 627–636. https://d-nb.info/1149683392/34 Accessed on 28.04.2023.

[2]Ballabio, C., Chessa, S., Rignanese, D., Gigliotti, C., Pagnacco, G., Terracciano, L., Fiocchi, A., Restani, P., Caroli, A.M., 2011, Goat milk allergenicity as a function of αS1-casein genetic polymorphism, Journal of Dairy Science, Vol. 94(2): 998–1004. https://doi.org/10.3168/jds.2010-3545.

[3]Bernabucci, U., Lacetera, N., Baumgard, L. H., Rhoads, R. P., Ronchi, B., Nardone, A., 2010, Metabolic and hormonal acclimation to heat stress in domesticated ruminants. Animal: an international journal of animal bioscience, Vol. 4(7): 1167–1183. https://doi.org/10.1017/S175173111000090X

[4]Blasko, J., Kubinec, R., Gorova, Renata F., Lorenz, S., 2010, Fatty acid composition of summer and winter cows' milk and butter. Journal of food and nutrition research, Vol. 49: 169–177. https://www.researchgate.net/publication/236236057_Fatty_acid_composition_of_summer_and_winter_cows'_milk_and_butter Accessed on 28.04.2023.

[5]Caira, S., Pizzano, R., Picariello, G., Pinto, G., Cuollo, M., Chianese, L., Addeo, F., 2012, Allergenicity of Milk Proteins. InTech. https://doi.org/10.5772/52086

[6]Cardak, A., Brueckner, H., Yetişmeyen, A., 2003, Quantitative comparison of camel, goat and cow milk fatty acids. Milchwissenschaft. Vol. 58: 34–36. https://www.researchgate.net/publication/258628697_Quantitative_comparison_of_camel_goat_and_cow_milk_fatty_acids Accessed on 28.04.2023.

[7]Chilliard, Y., Toral P.G., Shingfield K.J., Rouel, J., Leroux, C., Bernard, L., 2014, Effects of diet and physiological factors on milk fat synthesis, milk fat composition and lipolysis in the goat: A short review. Small Rumin Res., Vol. 122: 31–37. https://doi.org/10.1016/j.smallrumres.2014.07.014

[8]Chung, I.M., Kim, J.K., Lee, K.J., Son, N.Y., An, M.J., Lee, J.H., An, Y.J., Kim, S.H., 2018, Discrimination of organic milk by stable isotope ratio, vitamin E, and fatty acid profiling combined with multivariate analysis: A case study of monthly and seasonal variation in Korea for 2016-2017. Food chemistry, Vol. 261: 112–123. https://doi.org/10.1016/j.foodchem.2018.04.017

[9]Council Directive 86/609/EEC of 24 November 1986 on the approximation of laws, regulations and administrative provisions of the Member States regarding the protection of animals used for experimental and other scientific purposes.

[10]Coppa, M., Ferlay, A., Chassaing, C., Agabriel, C., Glasser, F., Chilliard, Y., Borreani, G., Barcarolo, R., Baars, T., Kusche, D., 2013, Prediction of bulk milk fatty acid composition based on farming practices collected through on-farm surveys. J. Dairy Sci., Vol. 96, 4197–4211. https://doi.org/10.3168/jds.2012-6379

[11]Curro, S., Manuelian, C., De Marchi, M., Salvatore, C., Rufrano, D., Neglia, G., 2019, Effects of Breed and Stage of Lactation on Milk Fatty Acid Composition of Italian Goat Breeds. Animals, Vol. 9: 764. https://doi.org/10.3390/ani9100764.

[12]Demiati Wahyuni, W.T., Rafi, M., Budy R.P., 2023, The detection of goat milk adulteration with cow milk using a combination of voltammetric fingerprints and chemometrics analysis. Chem. Pap. https://doi.org/10.1007/s11696-023-02780-w

[13]Elgersma, A., 2015, Grazing increases the unsaturated fatty acid concentration of milk from grass-fed cows: A review of the contributing factors, challenges and future perspectives. European Journal of Lipid Science and Technology, Vol. 117: 1345–1369. https://doi.org/10.1002/ejlt.201400469.
[14]Farah, N., Talpur, M.I., Bhanger, Nusrat N., 2009, Memon, Milk fatty acid composition of indigenous goat and ewe breeds from Sindh, Pakistan, Journal of Food Composition and Analysis, Vol. 22(1): 59–64. https://doi.org/10.1016/j.jfca.2008.09.005.
[15]Fedorovych, Ye.I., Salyha, Yu.T., Fedorovych, V.V., Mazur, N.P., Bodnar, P.V., 2022, Rozvytok kozivnytstva v Ukraini [Development of goat breeding in Ukraine]. Tvarynnytstvo, veterynarna medytsyna [Animal husbandry, veterinary medicine], Vol. 2 (827): 42–49. https://doi.org/10.31073/agrovisnyk202202-06
[16]Freitas, N.E., Araújo, M.J., Oliveira, R.L., Lanna, D.P.D., Marques, C.A.T., Torreão, J.N.C., Santos, C.B., Silva Júnior, J.M., Edvan, R.L., Bezerra, L.R., 2020, Production, composition, fatty acid profile and sensory traits of milk from goats fed crude glycerin from waste frying oils used in biodiesel production, Livestock Science, Vol. 238: 104060. https://doi.org/10.1016/j.livsci.2020.104060
[17]Gortzi, O., Malissiova, E., Katsoulis, K., Alibade, A., Liappis, D., Lalas, S., Graikou, K., 2022, Comparative Analysis of Fatty Acid Profile and Fat-Soluble Vitamin Content in Sheep and Goat Milk of Organic and Conventional Origin. Applied Sciences. Vol. 12: 2809. https://doi.org/10.3390/app12062809.
[18]Hanuš, O., Samková, E., Křížová, L., Hasoňová, L., Kala, R., 2018, Role of Fatty Acids in Milk Fat and the Influence of Selected Factors on Their Variability-A Review. Molecules (Basel, Switzerland), Vol. 23(7): 1636. https://doi.org/10.3390/molecules23071636
[19]ISO 15885:2002 [IDF 184:2002] Milk fat – Determination of the fatty acid composition by gas-liquid chromatography. International Organization for Standardization, Geneva, Switzerland.
[20]ISO 18252:2006 [IDF 200:2006] Anhydrous milk fat – Determination of sterol composition by gas liquid chromatography (Routine method). International Organization for Standardization, Geneva, Switzerland.
[21]ISO/IEC 17025:2006 General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025:2005, IDT) Kyiv, Ukraine http://online.budstandart.com/ua/catalog/doc-page.html?id_doc=50873 Accessed on 28.04.2023.
[22]ISO 707:2008 [IDF 50:2008] Milk and milk products – Guidance on sampling. International Organization for Standardization, Geneva, Switzerland.
[23]Iussig, G., Renna, M., Gorlier, A., Lonati, M., Lussiana, C., Battaglini, L.M., Lombardi, G., 2015, Browsing ratio, species intake, and milk fatty acid composition of goats foraging on alpine open grassland and grazable forestland. Small Rumin Res., Vol. 132: 12–24. https://doi.org/10.1016/j.smallrumres.2015.09.013
[24]Jung, T.H., Hwang, H.J., Yun, S.S., Lee, W.J., Kim, J.W., Ahn, J.Y., Jeon, W.M., Han, K.S., 2017, Hypoallergenic and Physicochemical Properties of the A2 β-Casein Fractionof Goat Milk. Korean journal for food science of animal resources, Vol. 37(6): 940–947. https://doi.org/10.5851/kosfa.2017.37.6.940
[25]Kompan, D., Komprej, A., 2012, The Effect of Fatty Acids in Goat Milk on Health. InTech. https://doi.org/10.5772/50769
[26]Kyselov, O., Mykhalko, O., Bondarchuk, L., Levchenko, I., Prihodko, M., Popsuy V., 2022, Influence of the season and genotype of goats on the qualitative composition of their milk. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(4): 343–357. https://managementjournal.usamv.ro/pdf/vol.22_4/volume_22_4_2022.pdf Accessed on 28.04.2023.
[27]La Terra, S., Marino, V.M., Schadt, I., 2013, Influence of season and pasture feeding on the content of CLA isomers in milk from three different farming systems in Sicily. Dairy Sci. & Technol., Vol. 93: 1–10. https://doi.org/10.1007/s13594-012-0091-4
[28]Murney, R., Burggraaf, V., Mapp, N., Ganche, E., King, W., 2019, The effect of cultivated mixed-species green fodder on intake, milk production and milk composition of housed dairy goats. Animal: an international journal of animal bioscience, Vol. 13(12): 2802–2810. https://doi.org/10.1017/S1751731119000867
[29]Palmquist, D.L., Denise Beaulieu, A., Barbano, D.M., 1993, Feed and Animal Factors Influencing Milk Fat Composition. J. Dairy Sci., Vol. 76: 1753–1771. https://doi.org/10.3168/jds.S0022-0302(93)77508-6.
[30]Prosser, C.G., 2021, Compositional and functional characteristics of goat milk and relevance as a base for infant formula. Journal of Food Science, Vol. 86: 257–265. https://doi.org/10.1111/1750-3841.15574
[31]Rahmann, G., 2001, Breeding goats for organic production in Germany. “Breeding and feeding for health and welfare”, 4th NAHWOA Workshop 24-27 March, Wageningen, Holland. https://orgprints.org/id/eprint/596/1/rahmann-2001-goats-nahwoa.pdf3 Accessed on 04.05.2023.
[32]Renna, M., Lussiana, C., Cornale, P., Fortina, R., Mimosi, A., 2012, Changes in goat milk fatty acids during abrupt transition from indoor to pasture diet. Small Rumin Res., Vol. 108: 12–21. https://doi.org/10.1016/j.smallrumres.2012.06.007
[33]Ryzhkova T.M., Bondarenko T.A., Livoshchenko I.M., 2011, Pidvyshchennia biolohichnoi tsinnosti kozynoho moloka u fermerskomu hospodarstvi «Shevret» [Increasing the biological value of goat milk in the "Shevret" farm], Zbirnyk naukovykh prats VNAU: Hodivlia tvaryn ta tekhnolohiia kormiv [Collection of scientific works of VNAU: Animal feeding and feed technology], Vol. 10(50): 55–58. [in Ukrainian] http://socrates.vsau.org/repository/view_doc.php?filename=3341.pdf, Accessed on 28.04.2023.

[34]Salari, F., Altomonte, I., Lidiany Ribeiro, N., Ribeiro, M.N., Bozzi, R., Martini, M., 2016, Effects of season on the quality of Garfagnina goat milk, Italian Journal of Animal Science, Vol. 15(4): 568–575. https://doi.org/10.1080/1828051X.2016.1247658

[35]Serbina, V.O., 2012, Istoriia ta suchasnyi stan kozivnytstva v Ukraini [The history and current state of goat breeding in Ukraine]. Naukovyi visnyk "AskaniiaNova" [Scientific bulletin "AskaniaNova"], Vol. 5(1): 196–200. http://irbis-nbuv.gov.ua/cgi-bin/irbis_nbuv/cgiirbis_64.exe?C21COM=2&I21DBN=UJRN&P21DBN=UJRN&IMAGE_FILE_DOWNLOAD=1&Image_file_name=PDF/nvan_2012_5%281%29__31.pdf Accessed on 04.05.2023.

[36]Skoryk, K.O., 2016, Molochna produktyvnist kiz zaanenskoi porody latviiskoi selektsii [Milk productivity of Zaanen goats of Latvian breeding]. Rozvedennia i henetyka tvaryn [Animal breeding and genetics], Vol. 52: 109–114. http://irbis-nbuv.gov.ua/cgi-bin/irbis_nbuv/cgiirbis_64.exe?C21COM=2&I21DBN=UJRN&P21DBN=UJRN&IMAGE_FILE_DOWNLOAD=1&Image_file_name=PDF/rgt_2016_52_15.pdf Accessed on 04.05.2023.

[37]Soyeurt, H., Dehareng, F., Mayeres, P., Bertozzi, C., Gengler, N., 2008, Variation of delta (9)-desaturase activity in dairy cattle. J. Dairy Sci., Vol. 91: 3211–3224. https://doi.org/10.3168/jds.2007-0518

[38]Statystychnyi biulleten, 2022, «Vyrobnytstvo produktsii tvarynnytstva za vydamy» [Statistical bulletin, 2022, «Production of livestock products by species»]. Derzhstat Ukrainy [State Statistics Service of Ukraine]. https://ukrstat.gov.ua/operativ/operativ2022/sg/vpt/arh_vpt2022_u.html Accessed on 04.05.2023.

[39]Statystychnyi zbirnyk «Tvarynnytstvo Ukrainy» [Statistical collection "Livestock of Ukraine"]. Derzhstat Ukrainy [State Statistics Service of Ukraine]. https://ukrstat.gov.ua/druk/publicat/Arhiv_u/07/Arch_tvar_zb.htm Accessed on 04.05.2023.

[40]Strzalkowska, N., Jóźwik, A., Bagnicka, E., Krzyzewski, J., Horbańczuk, K., Pyzel, B., Horbańczuk, J.O., 2009, Chemical composition, physical traits and fatty acid profile of goat milk as related to the stage of lactation. Anim. Sci. Pap. Rep., Vol. 27: 311–320. https://www.researchgate.net/profile/Emilia-Bagnicka/publication/228653105_Chemical_composition_physical_traits_and_fatty_acid_profile_of_goat_milk_as_related_to_the_stage_of_lactation/links/0912f50eb00566b46a000000/Chemical-composition-physical-traits-and-fatty-acid-profile-of-goat-milk-as-related-to-the-stage-of-lactation.pdf Accessed on 28.04.2023.

[41]Tripaldi, C., Martillotti, F., Terramoccia, S., 1998, Content of taurine and other free amino acids in milk of goats bred in Italy, Small Ruminant Research, Vol. 30(2): 127–136. https://doi.org/10.1016/S0921-4488(98)00095-9.

[42]Vlaeminck, B., Fievez, V., Cabrita, A.R.J., Fonseca, A.J.M., Dewhurst, R.J., 2006, Factors affecting odd- and branched-chain fatty acids in milk: A review, Animal Feed Science and Technology, Vol. 131(3–4): 389-417. https://doi.org/10.1016/j.anifeedsci.2006.06.017.

[43]Yurchenko, S., Sats, A., Tatar, V., Kaart, T., Mootse, H., Jõudu, I., 2018, Fatty acid profile of milk from Saanen and Swedish Landrace goats. Food Chem. Vol. 254: 326–332. https://doi.org/10.1016/j.foodchem.2018.02.041.

[44]Zazharska N.M., Hramma V.O., 2016, Porivnialna kharakterystyka pokaznykiv yakosti moloka kiz nimetskoi biloi, alpiiskoi ta anhlo-nubiiskoi porid [Comparative characteristics of milk quality indicators of German white, Alpine and Anglo-Nubian goats]. Visnyk ZhNAEU, Veterynariia [Bulletin of ZhNAEU, Veterinary], Vol. 1(53): 214-220. [in Ukrainian] https://sciencehorizon.com.ua/web/uploads/pdf/%E2%84%961(53)_214-220.pdf Accessed on 28.04.2023.

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EFFICIENCY OF BIOLOGICAL ACTIVATED SLUDGE TREATMENT OF WASTEWATER FROM A MEAT PROCESSING PLANT. CASE STUDY

Cecilia NEAGU, Andrei Radu IOVA, Daniela CREȚU, Elena LASCĂR

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăști Blvd, District 1, Bucharest, Romania. E-mails: neagu.cecilia@managusamv.ro; iova.andrei@managusamv.ro; cretu.daniela@managusamv.ro, lascar.elena@managusamv.ro

Corresponding author: neagu.cecilia@managusamv.ro

Abstract

Biological treatment is the technological process by which organic impurities in wastewater are transformed by a culture of microorganisms into harmless degradation products (CO_2, H_2O, other products) and new cell mass (biomass). The microorganism culture is then dispersed in the reaction volume of the sewage treatment plant, forming activated sludge. The aim of this work was to present the efficiency of wastewater treatment from the food industry using the operating principle of a biological activated sludge treatment plant in a meat processing plant. The methods of determining the indicators that highlight the quality of wastewater from the meat processing unit were those according to the STAS in force, and the determinations were carried out in the laboratory of the Călărași Environment Protection Agency. Following the analysis of the 5 wastewater samples taken in the period March-July 2023, it could be remarked that regardless of the volume of wastewater entering the treatment plant and the amount of kg of meat processed per day, the treated water leaving the treatment plant meets the requirements for discharge into the natural outfall according to NTPA - 001, except for the indicator total phosphorus, which at concentrations higher than 35 mg/L in the wastewater before treatment cannot be brought below the maximum permitted value of 1 mg/L for discharge into the natural outfall. The efficiency of the treatment plant, analyzed for 10 indicators is good, ranging from 70.22 - 99.63%. So, biological treatment with activated sludge is an efficient treatment technology in such a unit, inexpensive, clean and environmentally friendly.

Key words**:** *activated sludge, biological treatment, outfall, purified water, quality indicator*

INTRODUCTION

Food industry waters high in protein and fat can lead to the growth of bacteria and microbes in the emissaries they reach [2]. The wastewater treatment plants of medium and high size have a specific flow of sludge treatment and conditioning [1].
Monitoring of parameters in wastewater treatment processes is an essential activity in wastewater treatment plants and is closely related to the monitoring of the environment in general. Its purpose is to track compliance with legislation by monitoring water quality parameters at the outlet of the wastewater treatment plant and to track the operation of treatment processes and their efficiency by monitoring treatment process parameters [6,17]. The principle of wastewater treatment with activated sludge is that the microorganisms in activated sludge are mixed with wastewater containing organic material in the presence of oxygen, followed by flocculation of the microorganisms to form activated sludge (an active microbial mass) [16]. Activated sludge is the basic structural unit of the biological treatment process, it contains all species that in their joint activity can metabolize organic substances to CO_2 and H_2O. Active sludge can be defined by sedimentable floaters at the time of aeration interruption [22]. The colour of the floaters varies from yellow-brown to black and are obtained by the growth of a mixed population of bacteria and other microorganisms in the presence of oxygen and in the presence of biologically treated wastewater [8].
In terms of composition, the mixed population of microorganisms in activated sludge varies with the chemical nature of the substrate, flow rate, pH and temperature [10]. In the wastewater treatment process with activated

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sludge, bacteria play an essential role and therefore the microbiological composition of activated sludge must be known. In a good active sludge 10^8 - 10^{10} bacteria/ml active sludge suspension are found.

The group of bacteria involved in biological treatment processes with activated sludge includes carbon oxidants, nitrogen oxidants, bacteria involved in floaters formation, aerobic bacteria, facultatively anaerobic bacteria [9]. Under optimal conditions bacteria have a high growth rate and/or a high speed of metabolic processes [18].

The kinds of bacteria commonly found in activated sludge are: *Achromobacter, Aerobacter, Alcaligenes, Arthrobacter, Bacillus, Citrobacter, Corynebacterium, Empedobacter, Esherichia, Flavobacterium, Klebsiella, Lophomonas, Micrococcus, Mycobacterium, Neiseria Paracolobacterium, Pseudomonas, Serratia, Sphaerotilus, Streptococcus, Zooglea* [4].

The most common species of fungi (from the active mud) are Sphaerotilus natans and Zooglea sp. [5].

In the biological treatment step, biodegradable organics (BOD_5), nitrogen are removed by nitrification and denitrification processes and phosphorus by biological processes [17].

Wastewater from the food industry is generally an ideal basis for biological treatment - a combination of anaerobic and/or aerobic, depending on local wastewater disposal requirements [19]. Aerobic biological treatment is based on the principles of the activated sludge process with biological removal of nutrients (nitrogen and phosphorus) and separate sludge regeneration [21]. Continuously supplied oxygen activates bacteria so that they can degrade the organic content, which is then converted into CO_2 and excess activated sludge. This method is the most widely used and has been developed over time, so that a large number of activated sludge variants have been achieved.

The presence of nitrogen in any form requires the application of the aerobic nitrification-denitrification biological process so that it is removed to the desired level, but at the same time the formation of this process in the final settlers must be avoided in order to prevent the active sludge from floating [11].

The chemical composition of activated sludge is expressed by the dry matter which represents the totality of organic substances and volatile substances characterising the organic content. The dry matter concentration varies widely between 0.5 - 10 g/L. A brown activated sludge contains more than 75% volatile substances. The calcined residue, what remains after calcination at 600-800°C contains mineral salts and oxides of elements common in wastewater and which at the same time are necessary for growth. [20] The cations Na^+, K^+, Mg^{2+}, Ca^{2+}, Fe^{2+}, Al^{3+}, and anions Cl^-, PO_4^{3-}, NO_3^-, SO_4^{2-} are present. The elements that make up the organic substances of activated sludge are: C, H, O, N. [22]

The chemical composition of sludge is approximately as follows: 60% protein; 5-20% nucleic acids; 4-25% carbohydrates; 1-40% lipids based on the weight of dry sludge [13].

The activated sludge wastewater treatment plant consists of a primary clarifier, an aeration tank and a secondary clarifier. The treatment plant includes an aeration tank called aerotank, in which the wastewater from the primary settler is strongly aerated by means of air blowing devices, and a sedimentation tank - the secondary settler [7].

Wastewater is directed to the general collection basin, where all wastewater from both the cutting sections and domestic wastewater is collected. With the help of pumps, the wastewater is sent to a rotating drum filter, which is designed to retain coarse suspensions (mechanical treatment stage). The screens retain floating coarse particles suspended in the wastewater. The materials retained on the grates are discharged as such, to be landfilled or incinerated. In some cases they can be shredded by cutting to size 0.5-1.5mm in mechanical disintegrators. The wastewater is then directed to the homogenisation tank of about 190 m², where it undergoes a homogenisation process using high-power mixers, from where it is then redirected to the flotation tank. The wastewater is directed to the flotation tank of about 25 m² (chemical treatment stage) [7]. Magnasol and zetag are used as reagents for chemical treatment.

Dosing is carried out with dosing pumps in the mixing tank into which air is bubbled. The flocs of dirt that have risen to the surface of the tank are removed into the excess sludge tank by means of scrapers. The purpose of the flotation basin is to remove from the wastewater oils, fats and, in general, all substances lighter than water, which rise to the surface of the water in quiet areas and at low horizontal water velocities [7].

In the activated sludge tank, three elements are mixed: waste water, containing organic substances that constitute the food for mineralising bacteria (the so-called organic substrate), air, which contains oxygen and is supplied by mechanical, pneumatic, mixed or jet processes, and recirculating activated sludge, which contains the living cellular material necessary to maintain a certain concentration of activated sludge in the aeration tank, corresponding to a certain degree of purification required [7].

The purified water is pumped into the settling tank of about 450 sqm, equipped with a raked bridge, which collects the excess decanted active sludge passing the aeration tank, into an excess sludge tank and with the help of a pump system the decanted sludge is redirected either into the aeration tank for the maintenance of microorganisms and the refreshment of the active sludge or into the excess sludge tank. The sludge circuit, via a set of valves, can be directed either to the aeration tank for the maintenance of microorganisms and the refreshment of active sludge, or to the excess sludge tank with recirculation pumps. The settled water is gravity fed into the final basin of the treatment plant, from where it is directed to the natural outfall in the immediate vicinity [7].

In this context, the purpose of the paper was to present the efficiency of wastewater treatment from the food industry using the operating principle of a biological activated sludge treatment plant in a meat processing plant. The indicators reflecting the quality of wastewater were determined using the methods specified by the STAS in force and the research was carried out in the laboratory of the Călărași Environment Protection Agency.

MATERIALS AND METHODS

The legal basis of the legislation concerning wastewater treatment is Directive 91/271/EEC of 21 May 1991, amended and supplemented by the Commission Directive 98/15/EC of 27 February 1998 [2].

In Romania, this Directive was transposed by the Government Decision No 188/2002, subsequently amended and supplemented by the Government Decision No 352/2005 and is the basis for NTPA 001 and 002 [15].

Sampling was carried out between March and July 2023 according to SR ISO 5667-10.

Part 10: Guideline for wastewater sampling, after which the wastewater was analysed in the Laboratory of Călărași Environment Protection Agency.

The methodology for carrying out the determinations was NTPA - 001/ 2002 Limit values for pollutant loading of industrial and urban wastewater discharged into natural receptors - Regulation approved by GD 188/2002 modified and completed by GD No. 352/2005.

The equivalent standards for each indicator highlighting the quality of wastewater from meat processing are shown in Table 1.

The values of these indicators were compared with the maximum permissible value according to NTPA001 [14].

pH determination was done with the INOLAB 720 pH meter, with an accuracy of 0.01units, at 25^0C.

Suspended solids were determined by filtering a given volume of wastewater through a glass fibre filter, followed by dissolving the existing salts by washing the filter with distilled water. This is followed by drying the solids in the filter at a temperature of 100-105°C. The amount of dry substance in relation to the volume of water initially used is the final result [3].

Table 1. Indicators monitored and standards corresponding to their determination methods

Crt no	Analysed Indicators	The standards
1	**pH**	SR ISO 10523 /2012
2	**Suspended Solids**	SR EN 872/ 2005
3	**COD-Cr**	SR EN ISO 8467:2001
4	**BOD_5**	SR EN 1899-2/2002
5	**P tot**	SR EN ISO 6878/2005
6	**Substances extractable with organic solvents**	SR 7587-96
7	**Biodegradable synthetic detergents**	SR EN 903 /2003
8	**N tot**	SR EN 25663/2000
9	**$N\text{-}NH_4^+$**	SR ISO 7150-1/ 2001
10	**Chlorides (Cl^-)**	SR ISO 9297/2001

Sources: Data from Calarasi Environment Protection Agency [3].

The determination of COD-Cr in the waste water was carried out using the automatic reflux and volumetric titration system. The value of this indicator is extremely important in assessing the degree of wastewater pollution, as it expresses the amount of organic substances contained in the wastewater.

BOD_5 estimates the degree of wastewater pollution, this time the amount of biodegradable organic substances contained in the wastewater. It is a measure of the organic impurification of wastewater and is the amount of oxygen (mg/mass) required for oxidative degradation by microorganisms of the organic substances contained in a litre of water at 20^0C for 5 days (BOD_5). The determination of this indicator in wastewater was carried out using an automated dissolved oxygen consumption reading system [3].

The determination of total phosphorus in wastewater was performed by a colour reaction using the UV-VIS spectrophotometer [3]. The phosphorus contained in wastewater comes mainly from animal waste, but also from detergents or chemical fertilizers [11].

The determination of organic solvent extractable substances in wastewater was done gravimetrically by filtration and oven drying. They are represented by animal fats, hydrocarbons, organic compounds with nitrogen, insecticides, soaps, which are solvent extractable and found in wastewater [12]. The determination of anionic surfactants (detergents) was done by the methylene blue index measurement method [3]. The method to determine total nitrogen in wastewater was IR analysis - oxidative combustion. The gases from the combustion tube, after passing through IR detection for CO_2 analysis, are sampled and introduced into a chemiluminescence detector, used for nitrogen analysis [3]. Determination of ammonia nitrogen in wastewater was performed by volumetric analysis method, by distillation and titration [3].

Chlorides in wastewater were determined by silver nitrate titration using chromate as an indicator (Mohr method) [3].

In order to find out the efficiency of the treatment plant, we calculated the average values of the analysed indicators and then estimated the degree of treatment for each of them. The degree of purification (GE) is the efficiency of the wastewater treatment plant in reducing, in percent, a part of the pollutants in the wastewater, so that the remaining part in the treated water represents the permissible limit value [17]. According to the definition, the degree of purification is determined by the relation:

$$GE = (Ci-Cf)/Ci*100 \qquad (1)$$

where:

Ci – represents the value of the initial concentration of the influent indicator in the wastewater (mg/L);

Cf - represents the value of the final concentration (effluent) of the same indicator after wastewater treatment (mg/L).

RESULTS AND DISCUSSIONS

For an accurate assessment of the impact of wastewater discharge in Călărași municipality on the outfall into which it flows, both the influent wastewater and the effluent from the wastewater treatment plant of the enterprise under study were chemically analyzed. Between March and July 2023, 5 samples of wastewater, influent and effluent were taken and the wastewater treatment capacity of the analysed unit was monitored using the activated sludge biological treatment method [7]. A total volume of 529 m^3 wastewater was treated during this period and the amount of meat processed was 6,370 kg (82 slaughtered animals).

Factors influencing the values of influent indicators were analysed. The values of the effluent concentrations were analysed in relation to the average value (calculated for the 5 days analysed) and the maximum allowable concentration of NTPA 001.

Table 2. Parameters depending on the situation during the sampling

Crt no	Date of waste water sampling	Quantity of treated wastewater (m^3)	Number of slaughtered animals	Quantity of processed meat (Kg)
1.	15th March 2023	102	18	1,320
2.	12th April 2023	93	16	1,210
3.	17th May 2023	201	29	2,320
4.	15th June 2023	84	12	960
5.	20th July 2023	49	7	560

Sources: Internal meat processing plant data [7].

On 15th March 2023, wastewater samples were taken from both the inlet and outlet of the treatment plant. During this period, 102 cubic meters of wastewater were treated and 18 animals were slaughtered (quantity of meat processed 1,320 kg).

Analysing the data in Table 3, we can see:

- a high value at the inlet to the treatment plant of the analysed indicators: suspended matter, chemical oxygen consumption (COD-Cr), biochemical oxygen consumption (BOD_5), total phosphorus, total nitrogen, ammonia nitrogen (NH_4^+) due to the contribution of organic matter from the fat solubilised after the washing of the installations and nutrients from the blood;
- the concentration of the indicators analysed at the outlet of the treatment plant: pH, chemical oxygen consumption (COD-Cr), biochemical oxygen consumption (BOD_5), total phosphorus, ammoniacal nitrogen (NH_4^+), extractable substances with organic solvents, shows a slight increase, insignificant compared to the average value at the outlet of the treatment plant, due to the contribution of organic matter from the fat solubilised after washing and nutrients in the blood;
- the concentration of the analysed indicators at the outlet of the treatment plant: biodegradable synthetic detergents, total nitrogen, suspended matter, chlorides (Cl-) shows a slight decrease, insignificant compared to the average value at the outlet of the treatment plant, probably due to the physico-chemical treatment with the flocculation agent magnasol and the cationic polyelectrolyte zetag - used in wastewater treatment;
- the concentration of the analysed indicators at the outlet of the treatment plant shows low values compared to the maximum allowed concentration values, except for the indicator total phosphorus, which at concentrations higher than 35 mg/L in the wastewater before treatment cannot be brought below the maximum allowed value of 1 mg/L when discharging water into the outfall, according to NTPA - 001/ 2002, Regulation approved by GD 188/2002 amended and supplemented by GD No. 352/2005.

Table 3. The value of the indicators analyzed on 15th March 2023

Crt no	Analysed Indicators (U.M.)	Station input values	Station output values	Average output value	Maximum permitted conc.
1.	pH (pH Units)	6.69	7.48	7.41	6.5 – 8.5
2.	Suspended Solids (mg/L)	1,618	11.350	32.556	60
3.	COD-Cr (mg O_2/L)	3,526.016	53.203	33.662	125
4.	BOD_5 (mg O_2/L)	1,516.410	22.450	14.581	25
5.	P tot (mg/L)	37.326	1.838	1.099	1.0
6.	Substances extractable with organic solvents (mg/L)	79.167	4.333	1.396	20
7.	Biodegradable syntetic detergents (mg/L)	0.958	0.050	0.214	0.5
8.	N tot (mg/L)	46.616	1.541	6.541	10
9.	N-NH4+ (mg/L)	45.236	0.193	0.151	2.0
10.	Chlorides (Cl^-) (mg/L)	590.165	175.748	192.237	500

Source: Determinations in the laboratory of the Environmental Protection Agency Calarasi [3].

It shows an exceeding of the maximum allowed concentration by 83.8%.

Wastewater treatment in the physico-chemical and biological step is effective for phosphorus of organic nature, phosphorus of inorganic nature remains however solubilized in the treated water.

On 12th April 2023 influent and effluent wastewater samples were taken. During this period a quantity of 93 cubic meters of wastewater was treated and the number of animals slaughtered was 16 (quantity of processed meat 1,210 kg).

Table 4. The value of the indicators analyzed on 12th April 2023

Crt no	Analysed Indicators (U.M.)	Station input values	Station output values	Average output value	Maximum permitted conc.
1.	pH (pH Units)	6.73	7.36	7.41	6.5 – 8.5
2.	Suspended Solids (mg/L)	1,026	30.4	32.556	60
3.	COD-Cr (mg O_2/L)	3,473.365	32.819	33.662	125
4.	BOD_5 (mg O_2/L)	1,458.660	16.8	14.581	25
5.	P tot (mg/L)	32.067	0.881	1.099	1.0
6.	Substances extractable with organic solvents (mg/L)	173.167	1.333	1.396	20
7.	Biodegradable syntetic detergents (mg/L)	128	0.189	0.214	0.5
8.	N tot (mg/L)	41.728	6.043	6.541	10
9.	N-NH4+ (mg/L)	39.478	0.128	0.151	2.0
10.	Chlorides (Cl-) (mg/L)	621.987	195.858	192.237	500

Source: Determinations in the laboratory of the Environmental Protection Agency Calarasi [3].

Following the analyses carried out, according to the data in Table 4, the following were found:

➢ a high value at the entry to the treatment plant of the concentration of the analysed indicators, greatly reduced after the treatment process (especially in the case of indicators showing organic material in the influent wastewater: chemical oxygen consumption (COD-Cr), biochemical oxygen consumption (BOD_5), ammonia nitrogen (NH_4^+), suspended solids);

➢a slight increase in the biochemical oxygen consumption (BOD_5) at the outlet of the wastewater treatment plant, probably due to the contribution of organic matter from fat solubilised by the washing of the machinery used in the technological flow;

➢ concentration of analysed indicators at the outlet of the treatment plant: pH, suspended matter, chemical oxygen consumption (COD-Cr), extractable substances with organic solvents, total phosphorus, total nitrogen, ammoniacal nitrogen (NH_4^+), synthetic biodegradable detergents, chlorides (Cl^-) - shows a slight decrease compared to the average value, because the amount of processed meat is lower than the average value;

➢ the concentration of the indicators analysed at the outlet of the treatment plant show values close to the average values and are within the limits of the water discharge into the outfall, according to NTPA - 001/ 2002 Regulation approved by GD 188/2002 modified and completed by GD No. 352/2005, except for the indicator total phosphorus which exceeds the alert threshold value (0.7 of the maximum allowed value of 1 mg/L).

Table 5. The value of the indicators analyzed on 17th May 2023

Crt no	Analysed Indicators (U.M.)	Station input values	Station output values	Average output value	Maximum permitted conc.
1.	pH (pH Units)	6.82	7.39	7.41	6.5 – 8.5
2.	Suspended Solids (mg/L)	1,102.8	33.68	32.556	60
3.	COD-Cr (mg O_2/L)	3,678.9	34.987	33.662	125
4.	BOD_5 (mg O_2/L)	1,545.7 8	14.689	14.581	25
5.	P tot (mg/L)	35.987	0.987	1.099	1,0
6.	Substances extractable with organic solvents (mg/L)	196.9	1.569	1.396	20
7.	Biodegradab le syntetic detergents (mg/L)	1.59	0.234	0.214	0.5
8.	N tot (mg/L)	42.78	6.768	6.541	10
9.	N-NH4+ (mg/L)	41.56	0.156	0.151	2.0
10.	Chlorides (Cl^-) (mg/L)	688.6	203.89	192.237	500

Source: Determinations in the laboratory of Calarasi Environment Protection Agency. [3].

According to the data in Table 5, the following was found: On 17th May 2023 wastewater samples were taken from the inlet and outlet of the treatment plant. During this period a quantity of 201 m^3 waste water was treated and the number of animals slaughtered was 29 (quantity of meat processed 2,320 kg)

- high values at the entrance to the treatment plant of the analysed indicators: suspended matter, chemical oxygen consumption (COD-Cr), synthetic biodegradable detergents, extractable substances with organic solvents, biochemical oxygen consumption (BOD_5), total nitrogen, ammoniacal nitrogen (NH_4^+), chlorides (Cl^-), due to the contribution of organic matter from fat solubilised after washing and nutrients in the blood, which are greatly reduced by the biological treatment process with active sludge;
- high values at the inlet to the treatment plant of the analysed indicators: suspended solids, chemical oxygen consumption (COD-Cr), synthetic biodegradable detergents, extractable substances with organic solvents, biochemical oxygen consumption (BOD_5), total nitrogen, ammoniacal nitrogen (NH_4^+), chlorides (Cl^-), due to the contribution of organic matter from the fat solubilised after washing and nutrients from blood;
- the concentration of the total phosphorus indicator at the exit of the station shows a slight decrease compared to the average value of this indicator; the concentration of the other indicators at the exit of the station showed higher values compared to the average values, this is due to the higher quantity of meat processed that day;
- the concentration of the indicators analysed at the outlet of the treatment plant shows values close to the average value and is in line with the discharge of water into the outfall according to NTPA - 001/ 2002 Regulation approved by GD 188/2002 modified and completed by GD No. 352/2005.

On 15th June 2023 influent and effluent wastewater samples were taken. During this period, 84 cubic meters of wastewater were treated and the number of animals slaughtered was 12 (quantity of processed meat - 960 kg).
Following the analysis, according to the data in Table 6, we can conclude the following:

- high values of influent indicators, considerably reduced as a result of the purification process;
- a slight increase at the outlet of the treatment plant in the indicators analysed: pH, suspended solids, total nitrogen, biodegradable synthetic detergents, chlorides (Cl^-) due to the contribution of organic matter from fat solubilised after washing and nutrients in the blood;
- the concentration of the analysed indicators: chemical oxygen consumption (COD-Cr), biochemical oxygen consumption (BOD_5), extractable substances with organic solvents, total phosphorus, ammoniacal nitrogen (NH_4^+) shows a slight decrease compared to the average value, probably due to the lower quantity of processed meat;
- the concentration of the indicators analysed at the outlet of the treatment plant shows values close to the average values and are within the limits of the water discharge into the outfall according to NTPA - 001/ 2002 Regulation approved by GD 188/2002 modified and completed by GD No. 352/2005, except for the indicator total phosphorus, which exceeds the alert threshold value (0.7 of the maximum allowed value of 1 mg/L).

Table 6. The value of the indicators analyzed on 15th June 2023

Crt no	Analysed Indicators (U.M.)	Station input values	Station output values	Average output value	Maximum permitted conc.
1.	pH (pH Units)	6.67	7.43	7.41	6.5 – 8.5
2.	Suspended Solids (mg/L)	1,043.8	32.80	32.556	60
3.	COD-Cr (mg O_2/L)	3,568.49	31.98	33.662	125
4.	BOD_5 (mg O_2/L)	1,498.67	13.430	14.581	25
5.	P tot (mg/L)	34.876	0.912	1.099	1.0
6.	Substances extractable with organic solvents (mg/L)	183.7	1.340	1.396	20
7.	Biodegradable synthetic detergents (mg/L)	1.457	0.245	0.214	0.5
8.	N tot (mg/L)	42.100	6.679	6.541	10
9.	N-NH4+ (mg/L)	40.457	0.145	0.151	2.0
10.	Chlorides (Cl^-) (mg/L)	645.790	197.890	192.237	500

Source: Determinations in the laboratory of Calarasi Environment Protection Agency[3].

On 20th July 2023, wastewater samples were taken from both the inlet and outlet of the treatment plant. During this period, 49 cubic meters of wastewater were treated and the number of animals slaughtered was 7 (quantity of processed meat 560 kg).

Table 7. The value of the indicators analyzed on 20th July 2023

Cr tno	Analysed Indicators (U.M.)	Station input values	Station output values	Average output value	Maximum permitted conc.
1.	pH (pH Units)	6.56	7.40	7.41	6.5 – 8.5
2.	Suspended Solids (mg/L)	1,032.7	31.89	32.556	60
3.	COD-Cr (mg O_2/L)	3,345.76	30.845	33.662	125
4.	BOD_5 (mg O_2/L)	1,405.22	13.390	14.581	25
5.	P tot (mg/L)	33.46	0.876	1.099	1.0
6.	Substances extractable with organic solvents (mg/L)	178.9	1.34	1.396	20
7.	Biodegradable syntetic detergents (mg/L)	1.345	0.218	0.214	0.5
8.	N tot (mg/L)	41.679	6.675	6.541	10
9.	N-NH4+ (mg/L)	39.876	0.134	0.151	2.0
10.	Chlorides (Cl^-) (mg/L)	681.568	187.8	192.237	500

Source: Determinations in the laboratory of the Environmental Protection Agency Calarasi [3].

Following the analyses carried out, according to the data in Table 7, the following was found:

➢high values of influent indicators, especially those indicating organic matter in the influent;

➢a slight increase at the outlet of the treatment plant of synthetic biodegradable detergents used for washing machines and total nitrogen;

➢ all other indicators analysed at the outlet of the treatment plant: extractable substances with organic solvents, pH, suspended matter, chemical oxygen consumption (COD-Cr), biochemical oxygen consumption BOD_5), total phosphorus, total nitrogen, ammoniacal nitrogen (NH_4^+), chlorides (Cl^-) show a slight decrease compared to the average value, because the amount of meat processed is lower than the average value;

➢ the concentration of the indicators analysed at the outlet of the treatment plant shows values close to the average values and is within the limits of the discharge of water into the outfall according to NTPA - 001/ 2002 Regulation approved by GD 188/2002 modified and completed by GD No. 352/2005, except for the indicator total phosphorus which exceeds the alert threshold value (0.7 of the maximum allowed value of 1 mg/L).

Analyzing the average concentration of the indicators taken in the study, both at the inlet to the treatment plant and at the outlet and calculating the degree of treatment (efficiency of the biological treatment plant with active sludge):

Table 8. The mean concentration of indicators analyzed

Crt no	Analysed Indicators	U.M.	Average conc. Influent	Average conc. effluent	GE (%)
1	pH	pH Units	6.69	7.41	-
2	Suspended Solids	mg/L	1,164.66	32.556	97.20%
3	COD-Cr	mg O_2/L	3,518.506	33.662	99.04%
4	BOD_5	mg O_2/L	1,484.948	14.581	99.02%
5	P tot	mg/L	34.743	1.099	96.84%
6	Substances extractable with organic solvents	mg/L	162.367	1.396	99.14%
7	Biodegradable syntetic detergents	mg/L	1.326	0.214	83.86%
8	N tot	mg/L	42.981	6.541	84.78%
9	N-NH4+	mg/L	41.321	0.151	99.63%
10	Chlorides (Cl^-)	mg/L	645.622	192.237	70.22%

Source: own calculation.

It should be noted that the yield of all the indicators determined in Table 8 is within the maximum concentration allowed by the legislation in force. The quantity of wastewater varies within very wide limits, depending on the number of animals cut on the day. The wastewater from the meat processing plant, however, is much more concentrated than the wastewater and contains almost only organic substances, both in suspension and in solution.

The pH of the influent water, slightly acidic - 6.69, was brought to an average value of 7.41 after the treatment process - this means neutral water discharged into the outfall.

We can see from Table 8. that throughout the period under analysis, from the determination of the yield of each indicator, according to the specified formula (1), the efficiency of the treatment plant in terms of the degree of purification of the main indicators is noted, which was between 70.22% - in the case of chlorides and over 99% - in the case of COD-Cr, BOD_5 and substances extractable with organic solvents. The high content of chlorides is due to the salt used in the technological process. The high concentration of chlorides has, by increasing the ionic strength, a role in the extraction and presence of proteins in wastewater.

A percentage of 83.86% represents the purification efficiency of biodegradable synthetic detergents used for sanitizing premises, and the purification efficiency of total nitrogen is determined at a percentage of 84.78%. (Nitrogen - is present in high concentrations in influent wastewater, representing an indication of the presence of proteins in the water).

The degree of purification of 84.78% - corresponding to total nitrogen, and 96.84% - corresponding to total phosphorus, may mean that there are still nutrients in the waters in question that can cause a weak eutrophication process in the outfall into which they are discharged.

We can see the efficiency of the treatment plant by the way the analyzed indicators are reduced to very low concentrations at the outlet of the treatment plant according to NTPA - 001.

CONCLUSIONS

The quality indicators of the wastewater discharged into the outfall, regardless of the volume of treated water, are within the limits imposed by the regulations in force, i.e. NTPA 001, with the exception of total phosphorus, particularly in March 2023, when it exceeded the maximum permitted value by 83.8%. At concentrations higher than 35 mg/l in wastewater before treatment, total phosphorus cannot be brought below the maximum permitted value of 1 mg/l when discharging water into the outfall.

The efficiency of the treatment plant, analysed for the 10 indicators is good, ranging from 70.22-99.63%.

Advantages of the biological treatment process with activated sludge: it is a clean process, leading to a non-putrescible effluent; odours emitted are reduced; the degree of nitrification is controllable; treatment efficiency can be high for BOD_5 - 99.02% and for settleable suspensions - 97.2%; low investment cost.

Disadvantages of biological treatment with activated sludge: requires highly qualified personnel and careful supervision; must be continuously managed and controlled; high operating costs; large amount of sludge formed - difficult to handle and stabilise; process is sensitive to influent composition and concentration; small amounts of nutrients (phosphorus or nitrogen) may remain in the effluent, which may cause a weak eutrophication process in the outfall water.

Biological treatment remains an efficient, economical and least polluting method of removing organic substances from wastewater.

REFERENCES

[1]Ammary, B.Y., 2004), Nutrients requirements in biological industrial wastewater treatment, African J. Biotehnology.3(4), pp. 236-238

[2]Directive91/271/EEC,http://eurlex.europa.eu/LexUriServ/ LexUriServ.do?uri= CELEX:32000L0059:EN:HTML, Accessed on Sept. 10, 2023.

[3]Environment Protection Agency, Calarasi. Report on the state of the environment factors in Călăraşi in 2023. www.apmcl.ro, Accessed on Sept. 10, 2023.

[4]Ghinea, L., 2002, Biology and soil microbiology - course, Agroprint Publishing House, Timișoara, pp.22.

[5]Ifrim, I., 2007, Biotechnologies of wastewater treatment, Pim Publishig House, Iaşi, pp.37.

[6]Iova, R. A., Neagu, C., Crețu, D., 2021, Case tudy Regarding the Variation of the Qualitative Parameters of Wastewater – Chemistry magazine, Vol. 72(2), 1-8, https://doi.org/10.37358/RC.21.2.8414

[7]Internal meat processing plant data.

[8]Manolache, L., 2003, Poison in the water, The Scientific and Encyclopaedic Publishing, Bucharest, 47, Rev. Chim., 72(2), 2021, 1-8 8 https://doi.org/10.37358/RC.21.2.8414

[9]Neagu, C. V., 2006, Mineralization of nitrogen in Călăraşi county depending on the type of soil and

regime of fertilization, PhD. Thesis, The University of Agricultural Sciences and Veterinary Medicine of Banat, Timişoara, pp. 35.

[10]Neagu, C.A., 2013, Sources of eutrophication of the waters in Calarasi county, Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development", Vol. 13(1): 257-262.

[11]Neagu, C.V., 2014, Degree of Water Eutrophication in the Terminal Basin of the Danube. Case Study – Bulletin of the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca – Agriculture 71 (2), 274-281.

[12]Neagu, C.V., 2016, Quality of treated water in Călăraşi Municipality, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development", Vol.16 (4) 235-238.

[13]Negrea, A., Pode, V., Negrea, P., Iovi, A., Lupa, L., Ciopec, M., Moșoarcă, G., 2007, Studies on the elimination process by precipitation-coagulation of phosphate ion. Process modelling, Rev. Chim., 58(10), 999. https://ww`w.revistadechimie.ro/pdf/NEGREA.pdf, Accessed on Sept. 10, 2023.

[14]NTPA 001/2005, GD 188/ 20.03.2002 for the approval of some norms on the discharge conditions in the aquatic area of wastewater, modified and completed by GD 352/11.05.2005 (M.O. nr. 398)

[15]NTPA 002/2005, GD 188/ 20.03.2002 for the approval of some norms on the discharge conditions in the aquatic area of wastewater, modified and completed by GD 352/11.05.2005 (M.O. nr. 398)

[16]Oprean, L., 2012, Water-basic resource of sustainable development, Vol. I, The Romanian Academy Publishing House, Bucharest, pp. 42.

[17]Panaitescu, M., 2011, Techniques for wastewater treatment, Guideline to establish treatment station, Nautica Publishing House, Constanța, pp. 37

[18]Panaitescu, C., Stoica, M. E., 2015, Enhancing of COD Treatment in the Physico-chemical Stage of Refinery Wastewater Treatment Plants, Rev. Chim., 66(5), 731. https://revistadechimie.ro/pdf/PANAITESCU%20C.pdf%205%2015.pdf, Accessed on Sept. 10, 2023.

[19]Petre, M., Teodorescu, A., 2009, Biotechnology of Environment Protection, Vol 1., 2nd Ed. rev., Bucuresti, pp. 28

[20]Popa, D., 2011, Water – fundamental resource of sustainable development. Unconventional methods and techniques for water treatment and purification; Water resources protection within the concept of sustainable development, the Academy Publishing House, pp.32.

[21]Robescu, D., Gheorghe, B., 2000, Wastewater treatment, Bren Publishing House, Bucharest, pp. 29.

[22]Simonescu, C., M., 2009, Biological treatment of wastewater, Matrix Rom Publishing House, Bucharest.

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DYNAMICS OF FOOD LOSS AND WASTE CAUSES ALONG THE AGRIFOOD CHAIN IN ROMANIA

Daniel NIJLOVEANU*, Victor TIȚA*, Nicolae BOLD*, Gina FÎNTÎNERU, Dragos SMEDESCU**, Irina-Adriana CHIURCIU**, Cosmina SMEDESCU**, Nicoleta GHEORGHE PĂTRĂCHIOIU***

University of Agronomic Sciences and Veterinary Medicine of Bucharest, *Faculty of Management and Rural Development – Slatina Branch, 150 Strehareti Street, Slatina, Romania, **Faculty of Management and Rural Development-Bucharest, 59 Marasti Boulevard, District 1, 011464, Bucharest, Romania, E-mails: nijloveanu_daniel@yahoo.com, victortita@yahoo.com, bold_nicolae@yahoo.com, gina.fintineru@usamv.ro, dragos.smedescu@managusamv.ro, irina.chiurciu@yahoo.ro, cosminasmedescu@gmail.com, nico.nicoleta06@yaho.com

Corresponding author: bold_nicolae@yahoo.com

Abstract

The investigation of the causes and consequences of food loss and waste has been extensively explored in the literature, given its significant impact on both the local community and the national economy. This paper suggests various comprehensive approaches concerning food loss and waste (FLW) in Romania, considering the broader European context of the FLW phenomenon based on a bibliographic study, a statistical approach of the causes dynamics analysis and a system-based approach leading to an integrated view of the phenomenon. In order to accomplish this purpose, we have used statistical material originated from national and European statistical institutions and we have processed it using direct observation and interpolation. Our objective was to identify various factors contributing to food loss and waste throughout the agrifood chain and analyse their impact on the FLW phenomenon. The findings revealed that the primary factors contributing to food waste are associated with economic aspects. This study serves as a foundational step for subsequent research endeavours.

Key words: *food waste, food loss,system, agrifood chain, Romania*

INTRODUCTION

Food waste in Romania is a complex problem [3], influenced by several factors and which leads to widespread effects [14]. The main causes include excessive food production, supply chain issues [5], consumer behavior [2], expiration date and food labeling, restaurants and the food industry, poverty and inequitable food distribution, awareness and education [9] and government policies [19]. The actions [1] made to prevent and combat food loss and food waste [4] have been made extensively worldwide and in Romania [17], related to the agrifood chain and also on an individual basis generation of food waste [8]. In the same time, a series of alternative measures [10] are thought related to food loss and waste (FLW) at a national and global scale [15] using several methods such as reusage [16], game theory [11] or technology-based approaches.

This paper shows a summary related to the food waste causes and their dynamics in Romania, comprising a short bibliographical study and a statistical analysis regarding the food waste phenomenon in order to determine the amount of influence of several factors on the food waste amount and their potential harmful impact [13] on agrifood chain processes [18]. In this context, a variety of materials and methods, including direct observations, correlation analyses, and statistical procedures, were employed to derive significant findings pertaining to the evolution of food waste in Romania.

MATERIALS AND METHODS

In order to determine the aspects that influence the food waste in Romania, we have followed several results from previous research papers and determined the dynamics of the food loss and waste causes in Romania. In this regard, the process of this assessment involves several steps:

(a) The identification of the key factors contributing to food loss and waste through a thorough analysis of existing literature and an in-depth review of relevant bibliographic sources.

(b) The conduct of statistical observations and the run of a comprehensive overview of the principal statistical indicators associated with these identified factors.

(c) The assessment of the impact of these statistical indicators (treated as independent variables) on the statistical indicators for food waste (regarded as dependent variables) is conducted through a statistical correlation analysis.

(d) The evaluation of the significance and the exploration of the statistical, economic, and social implications of the established relationships.

The bibliographic study will use a research database (Dimensions.ai) and a term mapping software (VOS Viewer), which will process the database search results. The statistical analysis was made using the data extraction and interpolation from the existent datasets (e.g., Tempo online data base of the National Institute of Statistics and Eurostat). The assessment of how these indicators affect the quantity of food waste will be accomplished by calculating the Pearson correlation coefficient for each indicator, treating them as independent variables, and the food waste indicator as the dependent variable. A multiple correlation was not made between the multitude of statistical indicators and food waste quantity due to small amounts of data within the series. The examination of these influences and their statistical, economic, and societal implications will be conducted through the interpretation of statistical parameters derived from the obtained correlations. This interpretation will primarily rely on the utilization of t-tests applied to these correlations and the outcomes they yield. Finally, the modelling part of the research will determine the dynamics of the FLW causes based on a causal loop diagram and a primary stock-and-flow diagram for the FLW phenomenon modelled via System Dynamic (SD) method.

RESULTS AND DISCUSSIONS

The bibliographic study

Agriculture and the food industry can produce large quantities of food and managing it can be difficult, leading to waste. Issues within the supply chain, spanning from storage to distribution, can contribute significantly to food waste. Additionally, consumer behavior, such as over-purchasing and discarding uneaten food, represents another significant contributing factor.

Table 1. The list of the terms resulted from the bibliographic study for “food waste” sorted by the number of occurrences

No.	Term	Number of occurrences	Relevance score
1.	study	1,093	0.4741
2.	waste	946	0.4326
3.	production	614	0.4521
4.	product	578	0.5925
5.	food	554	0.4836
6.	impact	542	0.3088
7.	country	525	0.5371
8.	process	483	0.4367
9.	use	464	0.3945
10.	review	440	0.3892

Source: own data processed from Dimensions.ai datasets

The bibliographic study exploring food loss and waste in Romania focused on key phrases including "food waste" as the first term and "food loss and waste" as the second term, combined with specific regional terms like "Romania." The outcomes of this search underscored that the predominant research in this domain is centered around economic-based topics. The data processing stage of the search results considered two primary indicators provided by the VOS Viewer software, i.e., the number of occurrences of the term in the search results and the relevance score, which delimited the most used terms that were more specific to the

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search term and not used in common subjects. According to the software documentation, this score is used to exclude generic terms and to increase specificity of the mapping process. The lower threshold for the term “food waste” was set to 100 number of occurrences and to 50 for the term “food loss and waste”, due to a low number of results for the same threshold as the first term. Table 1 presents a list of the terms that were found based on the number of occurrences of the term in the search results for the threshold of 100 occurrences. The prevalent terms in research concerning food loss and waste in Romania are predominantly associated with systems and production systems. Specifically, these terms are interconnected with the agrifood chain, encompassing aspects such as “production”, “product”, “food”, “process” and “waste”. This pattern underscores that the primary focus of the research is directed towards understanding the economic causes and impact of food loss and waste. The most relevant terms used for the first key phrase were related to economic stages of the agrifood chain also (food industry, consumer, circular economy) and also to biological events (pandemic, covid). Table 2 presents the results for the same term filtered by the relevance score.

Table 2. The list of the terms resulted from the bibliographic study for “food waste” sorted by the relevance score

No.	Term	Number of occurrences	Relevance score
1.	pandemic	137	9.3120
2.	covid	168	8.1642
3.	food industry	111	2.1019
4.	sample	178	2.0567
5.	day	132	1.8778
6.	consumer	282	1.6373
7.	author	111	1.3108
8.	person	171	1.2806
9.	circular economy	226	1.2309
10.	chapter	152	1.0199

Source: own data processed from Dimensions.ai datasets

Table 3 presents a list of the terms that were found based on the number of occurrences of the second term in the search results for the threshold of 50. Table 3 presents the results for the same term filtered by the relevance score. The results from the second terms shows little difference from the first term results, with a slight tendency towards sustainability and management in case of frequency of terms and more geographical (regional and global) approaches in case of relevance (FAO, India, China, European Union, region, group), leading to a primary conclusion that the research is also made based on comparisons with several key stakeholders related to the FLW phenomenon, as well as the concern related to agriculture terms (agriculture organization, volume, field).

Table 3. The list of the terms resulted from the bibliographic study for “food loss and waste” sorted by the number of occurrences

No.	Term	Number of occurrences	Relevance score
1.	food	310	0.2047
2.	country	205	0.4064
3.	approach	187	0.3209
4.	book	180	0.5208
5.	research	177	0.2918
6.	management	160	0.3149
7.	issue	159	0.2661
8.	sustainability	141	0.2712
9.	economy	129	0.8917
10.	industry	126	0.3397

Source: own data processed from Dimensions.ai datasets

Table 4. The list of the terms resulted from the bibliographic study for “food loss and waste” sorted by the relevance scores

No.	Term	Number of occurrences	Relevance score
1.	FAO	51	5.4594
2.	agriculture organization	50	5.4172
3.	India	54	4.2763
4.	China	59	4.0284
5.	European Union	68	3.2397
6.	group	78	2.9435
7.	region	95	1.8386
8.	economy	129	0.8917
9.	volume	59	0.6297
10.	field	80	0.5395

Source: own data processed from Dimensions.ai datasets

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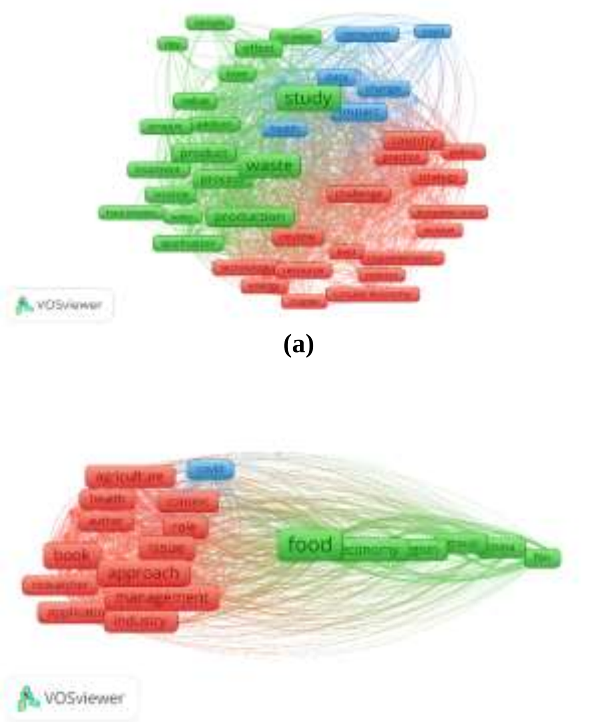
The determination of the terms mapping was made based on the two values for the occurrence threshold (50 and 100). For each value, a map was generated based on the number of the occurrences. The obtained maps are shown in Fig. 1.

The both maps (a) and (b) from Figure 1 show three main clusters related to FLW phenomenon:

-economic cluster, shown in green, comprised of terms such as “study”, “effect”, “time”, “value”, “production”, “source”, “food”, “economy”, “region” for both search terms;

-systems and agrifood chain cluster, shown in red, comprised of terms such as “country”, “industry”, “practice”, “policy”, “strategy”, “circular economy”, “industry”, “management”, “approach” for both search terms;

-public health cluster, shown in blue, comprised of terms such as “health”, “consumer”, “impact”, “covid” for both search terms.



(a)

(b)

Fig. 1. The search term maps obtained for (a) 100 occurrences for “food waste”; (b) 50 occurrences for “food loss and waste”

Source: own data processed from Dimensions.ai datasets

This configuration leads to the conclusion that the research of the food loss and waste phenomenon in Romania is mainly related to aspects referring to agrifood chain and its situation within the economy systems with mentions to health issues generated by recent events (COVID-19 pandemic).

The statistical analysis

According to the previous step, the main factors have been into consideration:

-*economic factors*: GDP per capita, inflation rate (IR), crop production;

-*social factors*: students enrolled in education, students enrolled in tertiary education, consumption expenditure per household, poverty threshold;

-*environmental factors*: land use, plastic packaging waste per capita.

The presentation of the factors is shown in the next part of the paper.

Fig. 2 presents the evolution of GDP per capita in the period 1995-2022.

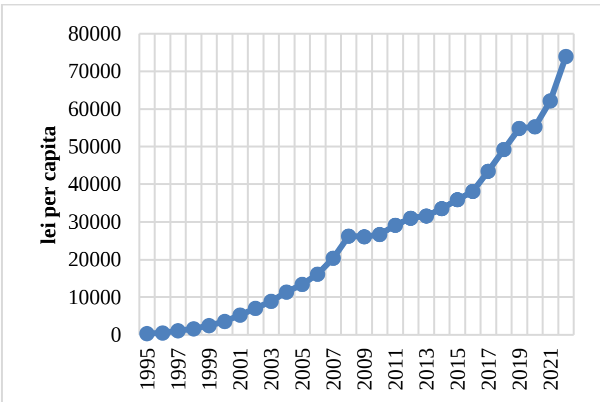


Fig. 2. GDP per capita evolution in Romania between 1995 and 2022

Source: TEMPO database, National Institute of Statistics Romania [12].

The main indication of the GDP evolution shows that a steep increase is stated between 1995 and 2022, at an average value of Lei 35,000 per capita.

Fig. 3 presents the evolution of the inflation rate (IR) in Romania in the period 1991-2022, which reflects a major decrease between 1991 and 2000 and a stabilization between 2000 and 2022.

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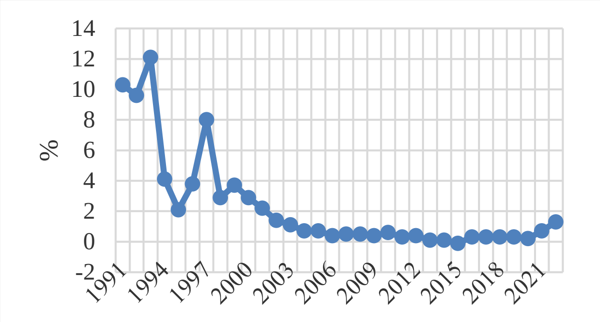

Fig. 3. The inflation rate (IR) evolution during 1991-2022 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

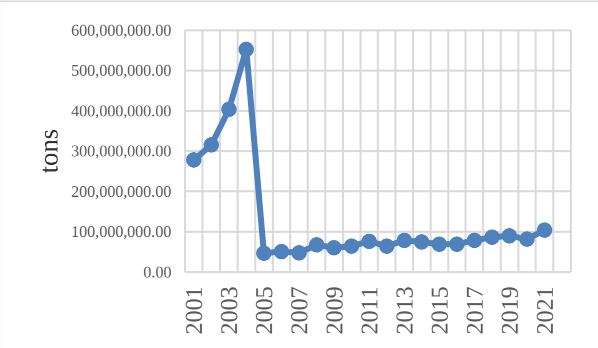

Fig. 4. Crop production between 2001 and 2022 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

Fig. 4 presents the evolution of crop production (measured in tons) in the period 2001-2022 in Romania.
The graphic shows a major and abrupt decrease in 2005, followed by an slight increasing trend.

Fig. 5 presents the evolution of the number of students enrolled in all levels of education (primary, secondary, tertiary) in the period 1990-2022 in Romania. The graphic based on the statistical data reflects that student enrollment registered a trend with minor fluctuations.
Figure 6 illustrates the trend in the enrollment of students at the tertiary level of education in Romania from 1990 to 2022. The graphic emphasizes that the proportion of students enrolled in tertiary education comprises nearly 15% of the total student enrollment. Furthermore, it indicates that after reaching a peak in 2005, the number of tertiary-level students has experienced a significant decline.

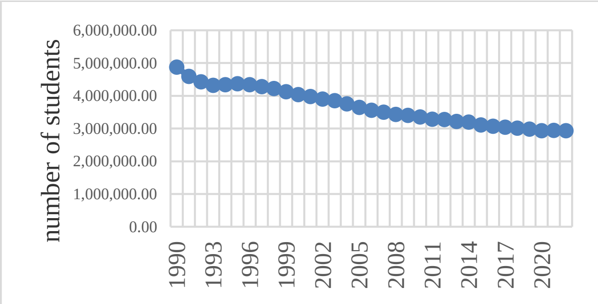

Fig. 5. Students enrolled in all levels of education between 1990 and 2022 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

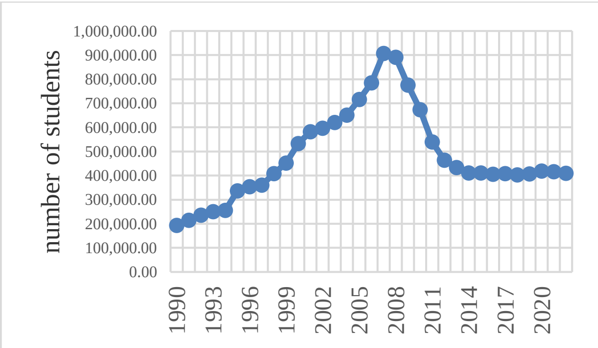

Fig. 6. Students enrolled in tertiary education between 1990 and 2021 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

Fig. 7 presents the evolution of household consumption between 1995 and 2022 in Romania. The value of the annual average consumption level is situated in 2022 at above Lei 50,000 per household and the general tendency in the studied period was an ascending one.

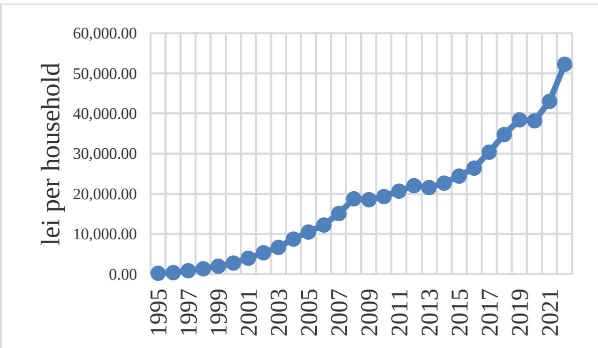

Fig. 7. Household consumption between 1995 and 2022 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

Fig. 8 presents the evolution of the surface of land used for agriculture which between 1990 and 2022 recorded a slight decrease in Romania.

Fig. 9 shows an increasing trend in the evolution of quantity of plastic waste sourcing from packaging per capita in the period 2008-2019 in Romania.

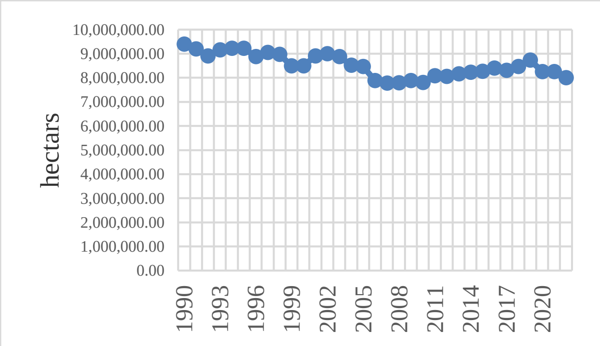

Fig. 8. Land use for agriculture between 1990 and 2022 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

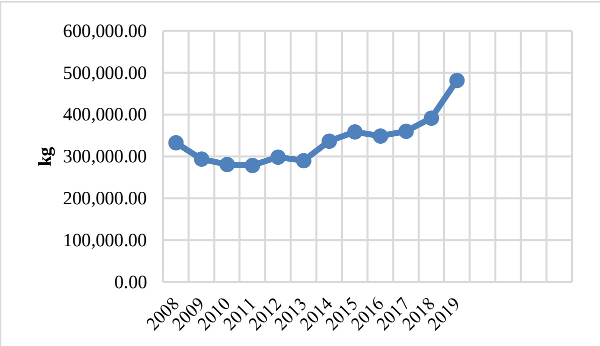

Fig. 9. Plastic packaging waste between 2008 and 2019 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

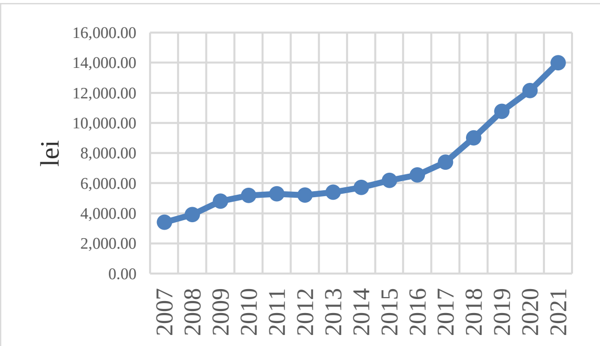

Fig. 10. Poverty threshold between 2007 and 2021 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

In the interval 2007-2021, the poverty threshold registered an increasing trend, showing that the population has difficulties related to poverty (Figure 10).

Fig. 11 presents the evolution of the total quantity of the food waste in three main areas (households, food manufacturing and agriculture) in the period 2004-2020 in Romania.

The data for total food waste was aggregated as the sum of the quantities of FLW categories based on the source. We can observe that after 2008, the quantity of food waste generated from the agricultural processes has deeply decreased, after 2010 the main food waste generator being the household components.

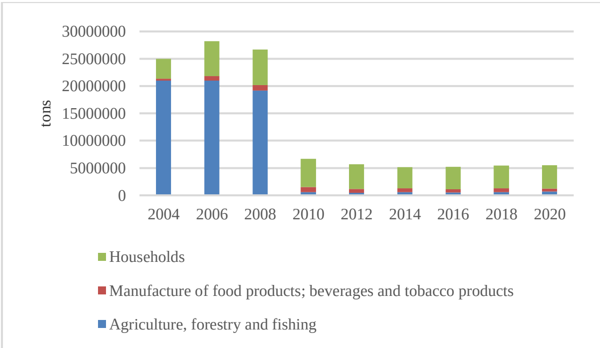

Fig. 11. Total food waste between 2004-2020 in Romania
Source: Eurostat [6].

Correlations between variables

Each indicator was established as an independent variable in the determination of a correlation between two variables.

For each indicator, the dependent variable was established to be the total amount of food waste, shown in

Fig. 11, with missing values from 1990 to 2004 and odd years between 2004 and 2020 being determined using the interpolation method. Then, a determination of a Pearson correlation coefficient (PCC) was made between each pair of the independent variables and the dependent one and the statistical significance was verified using a t-Test (two-sample assuming equal variances). The number of observation (Obs.) for each pair of variables was established as the number of common years presented in the statistical series of data.

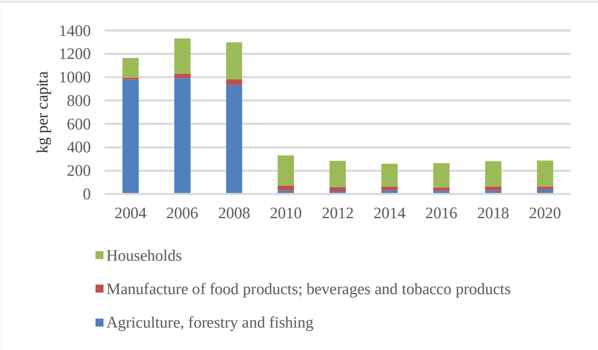

Fig. 12. Food waste per capita between 2004 and 2020 in Romania
Source: Eurostat [6].

Fig. 12 presents the evolution of the quantity of the food waste per capita in the period 2004-2020 in Romania. These values remain at an average level of 200 kg per capita after 2010, with the same situation repeating from the total quantity context.

Table 5. The correlation coefficients (PCC) between the independent variable considered each studied indicator and the dependent variable considered "total amount for food waste" in Europe

No.	Indicator	PCC	p-value	Obs.
1.	GDP	-0.36	0.000000000000000000001	11
2.	HICP	-0.51	0.000053309400000000000	11
3.	Crop production	-0.48	0.000000000000000000593	11
4.	Students enrolled	0.36	0.000000000000000000006	6
5.	Students enrolled tertiary	-0.29	0.000000000000000326481	8
6.	Household consumption	-0.57	0.000000000000000001194	11
7.	Land use	0.54	0.000000000000000022399	9
8.	Plastic waste	-0.53	0.000000000000000000003	11

Source: own determination

Table 6. The correlation coefficients (PCC) between the independent variable considered each studied indicator and the dependent variable considered "total amount for food waste" in Romania

No.	Indicator	PCC	p-value	Obs.
1	GDP	-0.88	0.0000000003740	26
2	IR	0.51	0.0000000000006	30
3	Crop production	0.56	0.0002930000000	20
4	Students enrolled	0.83	0.0000000001030	31
5	Students enrolled tertiary	0.01	0.0000000000003	31
6	Household consumption	-0.88	0.0000000003710	26
7	Land use	0.57	0.0000006160000	31
8	Poverty threshold	-0.05	0.0003530000000	12
9	Plastic packaging waste	-0.48	0.0001550000000	14

Source: own determination.

For the discrete variables (i.e., the ones which presented values for several years), the approximation of a continuity throughout the years was made using an interpolation method. The values for the explained methodology are presented in Table 5 for Europe (from a previous research) and in Table 6 for Romania.

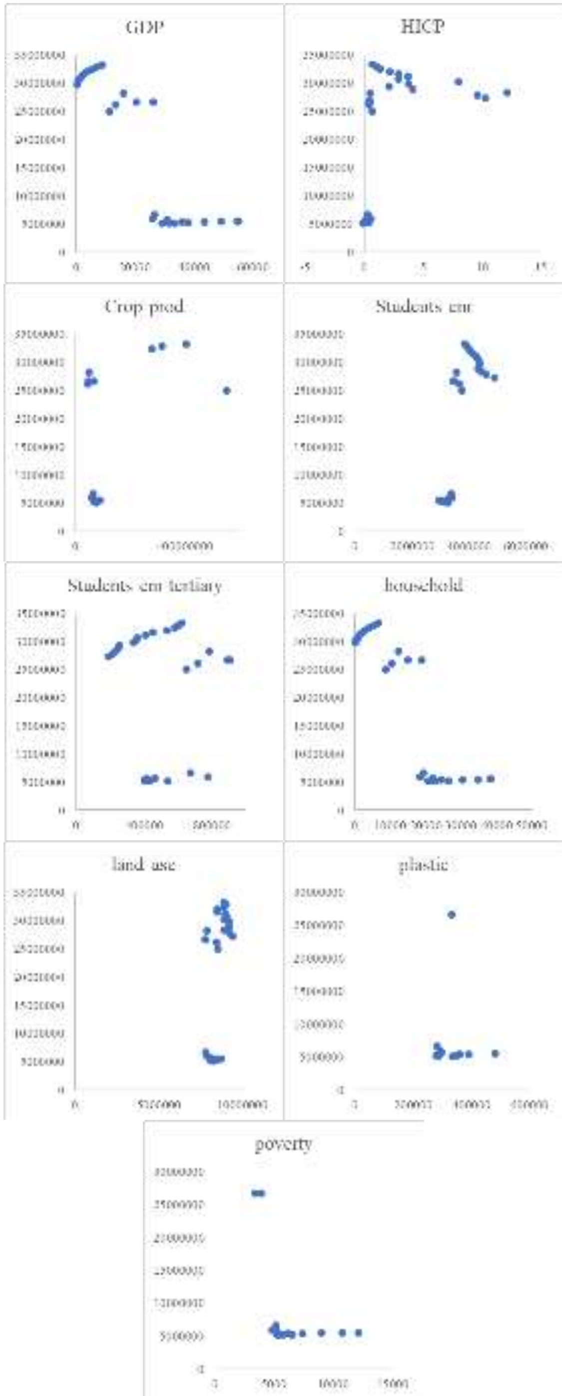

Fig. 13. The graphical representation of the correlation determinations
Source: own determination.

As we can observe, all the correlation determinations were statistically significant (p-value being lower than 0.05), with inverse correlation determined for GDP, household consumption, poverty threshold and plastic packaging waste and direct correlation for the IR, crop production, the total number of enrolled students and the number of enrolled students in the tertiary level and the land use for agriculture. The graphical representation of all the correlation determinations is shown in Fig. 13. The values of the PCC (Pearson Correlation Coefficient) show a medium or low intensity of correlation between the independent variables and the dependent one, as the cloud shape of the data points emphasize in the graphical representation of the correlation determinations. From the independent variables, the ones with the most influence found on food waste are the GDP per capita (inverse), IR (direct), crop production (direct), students enrolled (direct), household consumption (inverse), land use (direct) and plastic packaging waste (inverse).

Factors determination

Related to the previous research, several categories of factors have been determined, as follows:

(a)*behavioural factors*, related to human individual behavioural patterns and reactions;

(b)*demographic factors*, related to societal behavioural patterns and trends;

(c)*biological factors*, related to the food composition and natural processes;

(d)*policy-based factors*, related to rules and regulations, as well as campaigns related to food behaviour;

(e)*economic factors*, related to agrifood chain, from food production to food consumption.

Related to the placement of factors within the agrifood chain, classified in the latter category, we can define the next checkpoints: food production, processing, packaging, logistics, distribution and consuming.

The model will be presented based on the linear structure of these checkpoints, taking into consideration the categories of factors and their major influence on the food loss and waste phenomenon.

A list of the factors taken into consideration for the model structure and taxonomically classified is presented in Table 7.

For the mentioned parameters In Table 7, there were also added several variables that complete the model and connect several parameters and which will be presented in the next subsection.

Model design and structure

The present model is created based on the parameters presented in Table 7. One of the results is the obtaining of a causal loop diagram, shown in Figure 14, where the parameters were connected in order to establish a causal influence related to food waste. To further detail the model, a stock-and-flow diagram will be projected, in order to determine the quantitative aspects of the food waste phenomenon, based on the agrifood chain phases.

Table 7. The list of factors taken into consideration for the model structure

No.	Category	Factor	
1	Behavioural	Buying patterns	
		Habits	
		Attitudes	
		Subject norms	
		Educational background	
2	Demographic	Age	
		Number of members in household	
		Region	
3	Biological	Food perishability	
		External biological agents (e.g., COVID-19 pandemic, food toxins, bacteria, viruses)	
4	Policy	Social policies related to food waste	
		Economic policies related to income	
5	Economic	Producer	Productivity
			Management type
		Processing	Number of processing phases
			Quality standards
		Packaging	Package parameters
		Logistics	Logistic parameters
			Storage
		Distribution	Promotions
			Sales volume
			Low prices
		Consuming	GDP per capita
			Income

Source: own determination.

A primary form of this diagram is shown in Fig. 15, taking into consideration only the main quantities of lost and wasted food and their flow within the system. The causal loop diagram presented Fig. 14 was created using the Vensim (causal loop) and AnyLogic (stock and flow) software and presents the most important parameters delimited in Table 7. The list of factors taken into consideration for the model structure in respect to the agrifood chain phases.

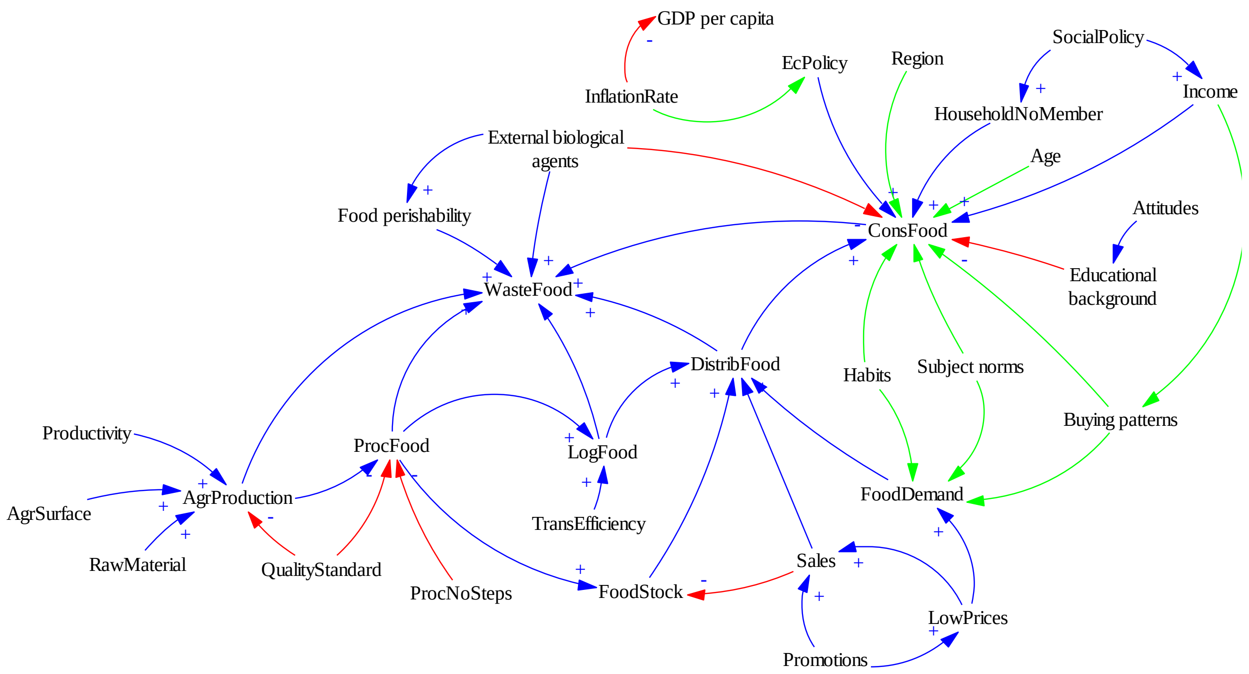

Fig. 14. The causal loop diagram for the considered food waste model
Source: Own determination.

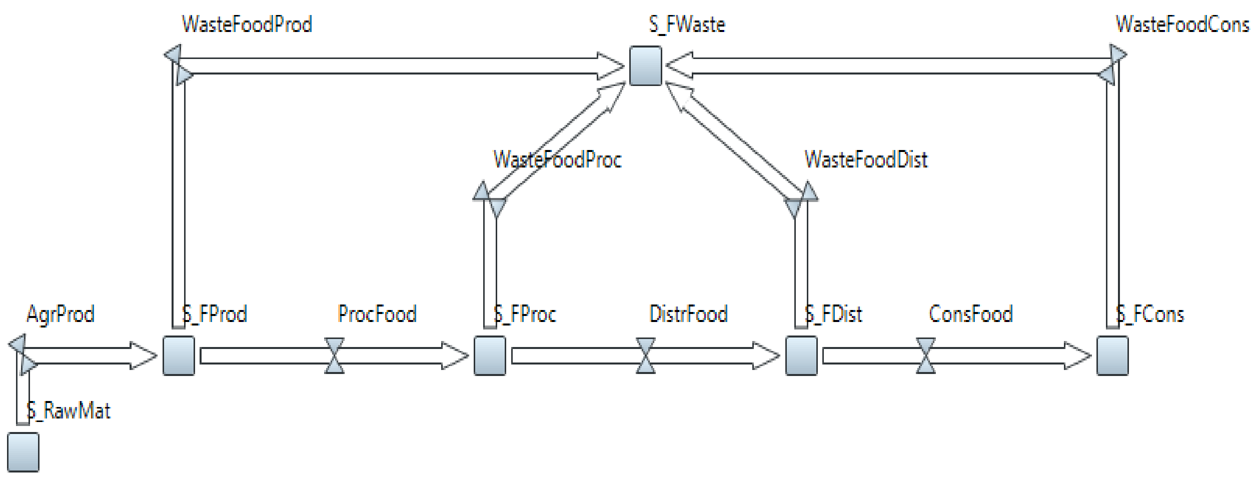

Fig. 15. Primary structure of the stock and flow diagram for the considered food waste model
Source: own determination

The blue arrows indicate a positive influence, the red ones a negative influence and the green ones indicate a mixed influence, based on the context of the model. In future researches, the green arrows will be detailed and transformed in either positive or negative dependencies.

This model illustrates the complex agri-food chain and its interactions related to food waste. The chain starts with agricultural production (AgrProduction) and raw materials and goes through food processing (ProcFood), distribution (LogFood) and retail sales (DistribFood) to consumers (ConsFood). Food waste (WasteFood) is influenced by many factors, including processing and distribution efficiency, food stocks, food demand and consumer behavior. In turn, food waste affects inventory, costs and waste awareness. Farmers, as producers of raw materials, have a significant impact on the entire agri-food chain.

By analyzing feedbacks and interactions, this model highlights the need for effective resource management, consumer education and collaboration between all levels of the agri-food chain to reduce food waste and bring social, economic and ecological benefits.

CONCLUSIONS

Food waste in Romania has complex origins and involves multiple aspects, including consumer behavior, business practices, supply chain management and quality standards. Expiration dates and incorrect food labeling can cause people to throw away food that could have been safe to eat. In the food industry and restaurants, large portions and irregular menus can lead to waste. Inequality in food distribution and the level of awareness and education may also play a role.

Changes in food waste dynamics can be influenced by socioeconomic developments, education and awareness, and government policies.

Addressing food waste requires efforts at government, industry and individual levels [7] to promote more efficient management of food resources and reduce waste.

Future work will be established for the refinement of the data using more specific datasets and the usage of the results in further analysis of the effects, impacts and solutions for the food waste phenomenon.

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REFERENCES

[1]Cattaneo, A., Sánchez, M. V., Torero, M., Vos, R., 2021, Reducing food loss and waste: Five challenges for policy and research. Food Policy, 98, 101974.

[2]Chereji, A. I., Chiurciu, I. A., Popa, A., Chereji, I., Iorga, A. M., 2023, Consumer Behaviour Regarding Food Waste in Romania, Rural versus Urban. Agronomy, 13(2), 571.

[3]Chirescu, A. D., Cloșcă, A., 2023, Food security: past, present and future. The case of Romania. Romanian Review of Statistics- Supplement no. 95., 94-103.

[4]Gheorghescu, I.C., Balan, I.M., 2018, Food waste and food loss in Romania. Agricultural Management, Series I, 20(3), 356-361.

[5]Dumitru, O. M., Iorga, C. S., Mustatea, G., 2021, . Food Waste along the Food Chain in Romania: An Impact Analysis. Foods, 10(10), 2280.

[6]Eurostat, 2023, Generation of waste by waste category, hazardousness and NACE Rev. 2 activity, https://ec.europa.eu/eurostat/databrowser/view/env_wasgen/default/table?lang=en, Accessed on the 16th of October 2023.

[7]Gherman, E. D., Martin, A. R., Bălan, I. M., Trasca, T. I., 2023, Increasing food security by reducing food overconsumption. Agricultural Management, Series I, 24(3), 94.

[8]Ilea, M., Chiciudean, G., Chiciudean, D., 2014, Analysis regarding food waste and consumption in Romania. Annals of Oradea University, Fascicula: Ecotoxicology, Zootehnics and Food Industry Technologies, 13(A), 293-296.

[9]Ishangulyyev, R., Kim, S., Lee, S. H., 2019, Understanding food loss and waste—Why are we losing and wasting food? Foods, 8(8), 297.

[10]Hoehn, D., Vázquez-Rowe, I., Kahhat, R., Margallo, M., Laso, J., Fernández-Ríos, A., ... Aldaco, R., 2023, A critical review on food loss and waste quantification approaches: Is there a need to develop alternatives beyond the currently widespread pathways? Resources, Conservation and Recycling, 188, 106671.

[11]Li, Y., Zhao, Y., Fu, J., Xu, L., 2021, Reducing food loss and waste in a two-echelon food supply chain: A quantum game approach. Journal of Cleaner Production, 285, 125261.

[12]National Institute of Statistics, Tempo online data base, 2023, http://statistici.insse.ro:8077/tempo-online/, Accessed on the 16th of October 2023.

[13]Paraschivu, M., Cotuna, O., Matei, G., Sarateanu, V., 2022, Are food waste and food loss a real threat for food security? Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.22(1), 479-484.

[14]Pocol, C. B., Amuza, A., Moldovan, M. G., Stanca, L., Dabija, D. C., 2023, Consequences of Recent Crises on the FLW Consumer Behaviour: A National Wide Representative Research—The Case of Romania. Foods, 12(10), 1973.

[15]Puiu, S., Florea, N. M., 2022, Food Waste in Romania from an Individual and a National Perspective. In Case Studies on Sustainability in the Food Industry: Dealing With a Rapidly Growing Population (pp. 203-228). Cham: Springer International Publishing.

[16]Quintero-Herrera, S., Zwolinski, P., Evrard, D., Cano-Gómez, J. J., Rivas-García, P., 2023, Turning food loss and waste into animal feed: A Mexican spatial inventory of potential generation of agro-industrial wastes for livestock feed. Sustainable Production and Consumption, 41, 36-48.
[17]Stanciu, S., Pila, M., 2023, Food waste in Romania-statistics and facts. Economic and Social Development: Book of Proceedings, 147-153.
[18]Tarhini, M., Turcea, V.C., Zapucioiu, L.F., Ion, R.A., 2022, Food waste status and reduction through the circular economy, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.22(4), 731-742.
[19]von Braun, J., Sorondo, M. S., Steiner, R., 2023, Reduction of Food Loss and Waste: The Challenges and Conclusions for Actions. In Science and Innovations for Food Systems Transformation (pp. 569-578). Cham: Springer International Publishing.

DETERMINANTS AND EXTENT OF CROP DIVERSIFICATION AMONG SMALL AND MEDIUM SCALE FARMERS IN CAMEROON

Emmanuel Oben NJOCK, Majory MELIKO, Raoul Fani Choumbou DJOMO

University of Buea, Department of Agricultural Economics and Agribusiness, P.O. Box 63, South West Region, Cameroon, Emails: njockoben@gmail.com, melikiomo@yahoo.com, djomo.choumbou@ubuea.cm

Corresponding author: njockoben@gmail.com

Abstract

The importance of crop diversification and its scope is underscored by the contribution that agriculture makes to the development of other economically productive industries. This study was conducted to evaluate the reasons behind crop diversification, its degree, and the variables affecting it among small and medium-sized farmers in Cameroon. Through a multi-stage sampling process, 457 small-scale farmers and 163 medium-scale farmers in total were sampled. The degree of crop diversity was evaluated using descriptive statistics, and the factors affecting crop diversification among small and medium farmers were identified using the Tobit regression model. The analysis revealed that crop diversification was high for both small and medium scale farmers, with a mean Herfindahl index of 0.44 and 0.38 respectively. As a result of the rising need for food production to address the problem of hunger, poverty, and malnutrition levels in the nation, the results also showed that the production of cassava and cocoyam, as well as the household size, had a positive and substantial effect on crop diversification. Credit usage and household size were found to have a favorable and significant impact on crop diversification for medium-scale farmers, suggesting that family labor and access to credit encourage farmers to diversify their crops and enhance their well-being. Emphasis on training and credit accessibility should be encouraged to increase cassava and cocoyam output.

Key words: *crop diversification, small and medium scale farmers, Herfindahl index*

INTRODUCTION

In the past decades, crop diversification is presented as an important solution to many problems in agricultural development [7]. These issues include high levels of specialization in farming systems that limit their ability to achieve economies of scale, agronomic issues like production stagnation or disease resistance, and insect concerns. [32]. Another key problem is the limited quality and quantity of input use, stemming from the small farm sizes and inadequate capital for investments to expand agricultural production. Rudimentary implements are still being used for all levels of agricultural production and the consumption of fertilizer per hectare is still far below 200 kg [22].

Studies from developing nations [25, 11, 20, 27, 17, 16] have investigated factors influencing crop diversification with explored factors affecting crop diversification with little or no emphasis on the difference between small and medium scale farmers. For some authors, Crop diversification can be impacted by both internal variables (such as farmer traits and farm structure) and external ones (such as territorial features such as regional and geographical patterns) [25].

The diversification of crop production systems is an essential factor for national strategy of rural development in Cameroon [26]. This has created a vacuum. It is based on the backdrop that this study intends to fill the research gap by analyzing factors influencing crop diversification among small and medium farmers. This study hypothesizes that there is significant difference in crop diversification between small and medium scale farmers.

In agriculture, farmers practice crop diversification to mitigate the rick related to monoculture farming and to minimize the climatic and natural uncertainties [33] by maximizing the use of land and other resources [30]. Small farms, in other words, are less subject to output losses and more resistant to environmental variations by diversifying their crops [21]. It is possible to mitigate the hazards associated with low agricultural output income, food insecurity, and nutritional insecurity [24]. Diversification of agricultural holdings consists in cultivating more than one variety of crops in the form of diverse output [29]. Diversification is intended to boost agricultural income at the farm level, even though risks associated with management systems are permanent. Diversification is meant to ensure national self-sufficiency and is carried out at the regional level [33].

Diversification can be an effective strategy for farmers' financial security and greater integration into local markets. Some analysts feel that improving linkages between agriculture and other sectors of the economy can stimulate agricultural diversification and so contribute significantly to long-term rural development [23]. The foundation of sustainable agriculture is the use of technology to increase output while attempting to have as little of an adverse environmental impact as possible. Therefore, diversification helps farmers to take part in putting the idea of "Sustainable Agricultural and Rural Development" into practice [13].

Agriculture sector diversification is a significant source of employment. According to the European Parliament's Resolution on How the Common Agricultural Policy Can Improve Job Creation in Rural Areas, held on October 27, 2016, the European Parliament advocate the use of agricultural diversification as solution for employment in rural areas, through entrepreneurship, innovation and products specialization for particular given areas. Additionally, small farms that diversify their crops would benefit from increased economic efficiency, which would help stabilize their relative income [34].

Traditionally grown less profitable crops are phased out in favor of more profitable ones as part of crop diversification. Rain-fed regions use crop diversification and an increase in the number of crops to reduce the risk of crop failures brought on by drought or insufficient precipitation. Crop diversification can be a useful strategy for farmers to manage several sorts of risk, including price risk (the farmer can utilize what he knows about the mean and variations of the prices for each crop to select a mixture of crops that have a low correlation of profitability) [30].

The contribution of diversity on agricultural output and opportunity cost is explained in this paper. As a result, the particular goals are to evaluate crop diversification's degree and identify the endogeneous variables affecting Cameroonian small- and medium-scale farmers' crop diversification.

MATERIALS AND METHODS

The Study Area

The study was carried out in Cameroon, which covers a total land area of 475,442sq km and located in the Central part of Africa within latitudes 2 and 13 North and longitude 9 and 16 East of the equator. The country has ten regions: Centre; Littoral; Adamawa; Far-North; North; South; East; West; North-West, and South-West [12, 10]. A major amount (about 60%) of the country's economically active population is employed in the agricultural sector, which also contributes to 30% of the nation's gross domestic product (GDP) and provides around 15% of the government's revenue [6]. Moreover, agricultural is the main activity inducing most of the spread effects on other sectors of the economy [18]. Diversification of crops in Cameroon is dominated by local ecological factors and local preferences for specific foods, which sometimes reflect the ethnic affiliation and history of the people [9].

Sample size and Sampling procedure

The study adopted the multistage random sampling technique. The first stage involved the purposive random selection of three (3) regions (South-West, West and far-north) based on the fact that these regions are agricultural based and having high number of small and medium farmers. Four (4) villages were chosen at random from each region in the second stage, for a total of twelve (12) villages. Following this, respondents were chosen from each of the chosen villages after being divided into small farmers and middle farmers. Structured questionnaires were used as instrument for collecting data from individual farmers.

For the selection of sample, list of all registered farmers were obtained from the Sub Divisional delegates. The sample sizes of 457 small scale and 163 medium scale farmers were obtained using [36] formula. The formula is expressed as follows:

$$n = \frac{N}{1+N(e^2)} \text{..(1)}$$

where:

n = sample size; N = real or estimated size of the population; e = level of significance (5% or 0.05). For the purpose of distribution of samples according to strata [31] Kumaisons (1997) formula was adopted thus:

$$n_h = \frac{nN_h}{N} \text{...(2)}$$

where:

n = sample size; N_h= population size in each stratum; n_h = number of questionnaire needed for each stratum.

Method of Data Collection

The questionnaire was given to agricultural farming families chosen for primary data in each village that was chosen. A structured questionnaire and interview techniques were used to gather this main data from the 620 respondents in the study region. In the study region, information was gathered on the degree of crop diversification among small and medium farmers as well as on internal factors that affect this practice.

Techniques of Data Analysis

Descriptive and inferential statistics were used to analyze the data that were gathered for this study. A Tobit regression model was used to identify the internal determinants driving crop diversification among small and medium scale farmers, and descriptive analysis was utilized to quantify the degree of agricultural diversity among these farmers. Finally, a t-test was employed to assess the claim that there is no discernible difference between small- and medium-scale farmers in terms of crop diversity.

Theoretical Foundation and Method of Estimation

Tobit Regression model

The determinants of crop diversification were investigated using a Tobit regression model. The choice of this model lie on the fact that crop diversification index has both the lower and upper bounds (from 0 to 1). Moreover, this model has the main advantage of using the maximum likelihood estimation (MLE) procedures to estimate errors in the presence of non-normal distribution, which is the most efficient estimator for asymptotically distributed dependent variable [31, 35]. According to [14] Gujarati (2010), using the ordinary least squares (OLS) method in this case would cause major violations of the assumptions of the OLS model (normality of distributions, homoscedasticity of errors, and exogeneity of independent variables) and lead to inconsistent parameter estimates.

The Tobit model used for this study is defined as:

$$Y_i^* = \lambda_0 + \lambda_1 V_{1i} + \lambda_2 V_{2i} + ... + \lambda_8 V_{8i} + \lambda_9 V_{9i} + \rho_i$$
$$\text{...(3)}$$

where:

$Y_i = 0$ if $Y_i^* < 0$

$Y_i = Y_i^*$ if $0 \le Y_i^* \le 1$

$Y_i = 1$ if $Y_i^* \ge 1$

With, Y_i^* = crop diversification index, λ_0 = intercept, the value of TE_i when others variables are null. λ_i = are the parameters to be estimated, V_1 = cassava output, V_2 = maize output, V_3 = cocoyam output, V_4 =cassava price, V_5 = maize price, V_6 =cocoyam price, V_7 = experience, V_8 = household size, V_9 = Credit use, ρ_i is an error term which is assumed to be independent and identically distributed.

Crop Diversification Index (CDI)

The Crop Diversification Index (CDI) was developed to gauge crop diversification

levels. It was calculated by deducting the Herfindahl index (HI) from one and had a direct correlation with agricultural diversity, with a zero value indicating specialization and a trend towards one indicating a greater degree of crop diversification.
The CDI index was calculated as follows:

$$P_i = \frac{A_i}{\sum_i^n A_i} \qquad .... (4)$$

where:
P_i = proportion of i^{th} crop
A_i = area under i^{th} crop
$\sum_i^n A_i$ =total crop area, $i = 1,2, \ldots n$ (number of crops)
Herfindahl index has the formula:

$$\text{Herfindahl index } (\boldsymbol{HI}) = (\textstyle\sum_i^n \boldsymbol{P_i})^2 \quad ....(5)$$

Crop diversification index (CDI) has the formula:

$$\text{CDI} = 1\text{-}(\boldsymbol{HI}) = \mathbf{1} - (\textstyle\sum_i^n \boldsymbol{P_i})^2 ....(6)$$

When CDI shows a value of zero (0), it means that the farmer is least diversified while a value of one (1) indicates the most highly diversified

RESULTS AND DISCUSSIONS

Extent of crop diversification

Herfindahl index (HI) results from Table 1 revealed that all farmers were involved in crop diversification (HI<1). This suggests that the research area has a high level of diversification. The HI specifically varies between 0.25 and 0.5 for medium-scale farmers, with a mean and standard deviation of 0.38 and 0.044, respectively, whereas it varies between 0.34 and 0.83 for small-scale farmers, with a mean and standard deviation of 0.44 and 0.063, respectively. These findings imply that medium scale farmers had higher level of crop diversification. A high level of crop diversification confirmed the results of [8] who found almost a same level of diversification (0.46) in Delta State of Nigeria. This situation might be explained by the uncertainty of farmers to resistant to environmental changes [21], the reduction of the risks associated with low agricultural income, food and nutrition insecurity, or the need to generate more employment. However, this finding is in contradiction with the result of [28], who reported a low level of crop diversification for small and medium scale farmers in Benue State, Nigeria.
The difference level of crop diversification between small scale and medium farmers is likely reflecting their bigger farm size [4], as well as their facility to get access to credit.

Table 1. Crop diversification Index (CDI)

Herfindahl index (HI)	**Small Scale**		**Medium Scale**	
	Frequency	Percentage	Frequency	Percentage
<0.35	1	0.2	39	23.92
0.35-0.40	186	41	78	47.85
0.41-0.46	55	12	32	19.63
0.47-0.52	179	39	13	8
0.53-0.58	2	0.4	1	0.6
0.59-0.64	32	7		
0.65-0.70	2	0.4		
Total	457		163	
Maximum	0.83		0.50	
Minimum	0.34		0.25	
Mean	0.44		0.38	
Standard deviation	0.063		0.044	
CDI Index = (1-HI)	**0.56**		**0.62**	

Source: Field survey, 2022.

On the specificities, 23.92% of medium scale farmers have less than 0.35 HI, 47.85% of medium scale farmers have between 0.35 to 0.4 HI, 19.63% have between 0.41 to 0.46 HI, 8% have between 0.47 to 0.52 HI, and 0.6% have between 0.53 to 0.58 HI.

For small scale farmers, 0.2% less than 0.35 HI, 41% have between 0.35 to 0.4 HI, 12% have between 0.41 to 0.46 HI, 39% have between 0.47 to 0.52 HI, 0.4% have between 0.53 to 0.58 HI, 7% have between 0.59 to 0.64 HI, and 0.4% have between 0.65 to 0.70 HI.

Determinants of crop diversification

To determine the internal factors influencing small and medium farmers' crop diversification in Cameroon, Tobit regression model was estimated. The findings were presented in Table 2.

The sigma revealed the fitness of the model at 1% ($p < 0.01$) level of significance. The likelihood ratio chi-square of 0.062 and 0.083 with a p-value of 0.0001 and 0.0001 respectively for small and medium scale farmers, tells us that our models as a whole are statistically significant. That is to say that it fits significantly better than a model with no predictors. Three out of the nine variables were shown to have a substantial impact on small-scale farmers' crop diversification, according to the model's findings. These factors were household size, cocoyam and cassava output. The crop diversification of medium-scale farmers, however, was found to be significantly impacted by household size and loan utilization.

Cassava and cocoyam production for small-scale farmers was positive and statistically significant at the 5% level of probability, according to the results. This suggests that as cocoyam and cassava productivity rises, crop diversification rises as well. The positive effect of cassava and cocoyam production on crop diversification confirms the results of [19] who showed that the increase in crop production, due to population increase leads to higher crops diversification to respond adequately to the issue of national urgency related to the increasing of hunger, poverty and malnutrition levels. Thus, diversification and agricultural crop production system is the key for the smallholder farmers to respond to increasing demand for food products [1, 8]. Furthermore, this result also confirms the fact that farmers increase their output by intensive use of land and the adoption of specific land management method to avoid the negative effect of land use intensity on their productivity [2].

The coefficient of household size was found to be positive and statistically significant at 1% level of probability. This implies that crop diversification increases when the household size increases.

Table 2. Determinants of crop diversification

Variables	Small Scale		Medium Scale	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	0.432	13.07	0.45	5.83
Cassava output	0.0000105	2.45**	7.89e-06	1.04
Maize output	-0.00005	-1.61	-0.00005	-1.04
Cocoyam output	0.000062	1.79*	-0.000027	-0.66
Cassava price	0.000015	0.17	-0.0002	-0.92
Maize price	6.93e-06	0.04	0.00024	0.57
Cocoyam price	0.0000954	1.37	0.000124	0.76
Experience	-0.00033	-1.00	-.003266	-0.28
Household size	0.0032	2.97***	.003266	1.64*
Credit used	-1.85e-08	-0.78	1.02e-07	2.55**
Sigma	0.062	30.24***	0.083	16.02***
LR chi2(8)	22.31		16.54	
Prob > chi2	0.0079		0.056	
Log likelihood	619.769		121.27722	

***, **and * significant at 1, 5 and 10% respectively.
Source: Field survey, 2022.

That is to say that those farmers diversify their crop production to express their consumption needs.

More the household size is large more the need for crop diversification is high to ensure diverse dietary standard and nutritional status of the household [7, 15].

However, this result is in disagreement with the findings of [19] who found no significant relationship between household size and crop diversification in Zambia.

For medium scale farmers, credit used was found to have significant effect on crop diversification. The coefficient of credit used showed that an increase of credit boosts crop diversification. The results imply that famers that have better access to credit have every opportunity to practice crop diversification as an innovation or technology to improve their wellbeing.

The results are in agreement with the findings of [17] in Delta State of Nigeria, [3] in Jordan and [5] in the central region of Ghana. Also, the coefficient of household size showed that an increase of household size will increase the crop diversification as well.

Two samples t-test of crop diversification

A two-sample Student's *t*-test assuming unequal variances using a pooled estimate of the variance was performed to test the hypothesis that the means Herfindahl index for small scale and medium scale farmers were equal.

We reject the null hypothesis based on the data in Table 3 because the t-values (9.44) and (11.17) for equal and unequal variances, respectively, are significant at 1%. We therefore draw the conclusion that there is a significant difference between small- and medium-scale farmers' crop diversification and reject the premise that there is no discernible difference between CDI of small- and medium-scale farmers.

Table 3. Two samples t-test for difference in Herfindahl Index

		Test of Levene on equality of variances		**t-Test-t for egality of means**				
		F	Sig.	t	ddl	Sig.	Difference mean	Difference stand-dev
HI	Hypothesis of equal variances	20.038	0.000	9.443	618	0.000	.05082	0.00538
	Hypothesis of unequal variances			11.173	411.32	0.000	.05082	0.00455

Source: Author's computation.

CONCLUSIONS

This study hypothesized and validated that there is significant difference in the extent of crop diversification among small and medium scales farmers. Also, internal factors such as cassava and cocoyam output, and household size significantly affect small scale farmers crop diversification while credit used, and household size significantly affect medium scale farmers crop diversification. Therefore, policies that would encourage experienced and educated farmers, especially from sizable households to continue in cassava and cocoyam farming. Emphasis on household members' training on skillful farm practices and credit accessibility should be encouraged to increase cassava and cocoyam output given their contribution in crop diversification.

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REFERENCES

[1]Adjimoti, G. O., Kwadzo, G. T. M., 2018, Crop diversification and household food security status: evidence from rural Benin. Agric & Food Secur (2018) 7:82. https://doi.org/10. 1186 /s40066-018-0233-x.

[2]Alawode, O. O., Kabiru, B. A., Akanbi, O. A., 2020, Land Use Intensity, Crop Diversification and Productivity of Farmers in Akinyele Local Government Area of Oyo State, Nigeria. International Journal of Innovative Environmental Studies Research, 8(3):20-32.
[3]Al-Zyoud, F. A., 2014, Adoption range of integrated pest management (IPM) techniques by greenhouse vegetable growers in Jordan. Jordan Journal of Agricultural Sciences, 10(3): 504–525.
[4]Ashfaq, M., Hassan, S., Naseer, Z.M., Baig, A., Asma, J., 2008, Factors Affecting Farm Diversification in Rice-Wheat. Pakistan Journal of Agricultural Sciences, 45(3), 45-47.
[5]Baffoe-Asare, R., Danquah, J. A., Annor-Frenpong, F., 2013, Socioeconomic factors influencing adoption of codapec and cocoa high-tech technologies among small holder farmers in Central Region of Ghana. American Journal of Experimental Agriculture, 3(2): 277–292.
[6]BIT (Bureau International du Travail), 2004, Une approche équitable pour les travailleurs migrants dans une économie mondialisée, Genève, Rapport VI. Conférence internationale du Travail, 92e session, 229 pp.
[7]Brajesh, J., Tripathi, A., Mohanty, B., 2009, Drivers of Agricultural Diversification in India, Haryana and the Greenbelt Farms of India. Institute of Economic Growth University of Delhi Enclave North Campus Delhi – 110 007, India. Working Paper Series No. E/303/2009.
[8]Dembele, B., 2018, Income, Crop Diversification Strategies and Agricultural Practices in Crop and Livestock Production Systems in Southern Mali.
[9]Dizian, R., 1978, Cameroon. Under the aegis of the International Association of Agricultural Economists, 4: 120-125.
[10]Djomo, C. R. F., Ukpe, U. H., Oben, E. N, Dzever, D. D., Obekpa, O. H., Nde, A. T., Sani, M., Annih, M. G., Dontsop, N. P. M., 2021, Assessing the Performance and Participation among Young Male and Female Entrepreneurs in Agribusiness: A Case Study of the Rice and Maize Subsectors in Cameroon. Sustainability 2021, 13, 2690.
[11]Dries, L., Pascucci, S., Gardebroek, C., 2012, Diversification in Italian Farm Systems: Are Farmers Using Interlinked Strategies? NewMedit, 4, 7–15.
[12]Farris, P.W., Neil, T.B., Pfeifer, E.P., Reibstein, D.J., 2010, Marketing Metrics: The Definitive Guide to Measuring Marketing Performance; Pearson Education: Upper Saddle River, NJ, USA.
[13]Figurek, A., Rokvic, G., Vasko, Ž., 2012, Diversification of the rural economy as the function of the sustainability of rural areas. Agric. For., *58*, 51–61.
[14]Gujarati, D., Porter, D., 2010, Essentials of econometrics, 4th ed. McGraw-Hill, Boston.
[15]Herforth, A.W., 2010, Promotion of traditional African vegetables in Kenya and Tanzania: a case study of an intervention representing. Cornell University; fle:///Users/amandinesagnieres/Downloads/Herforth.Anna.pdf.
[16]Ibrahim, H., Rahman, S.A., Envulus, E.E., Oyewole, S.O., 2009, Income and crop diversification among farming households in a rural area of north central Nigeria. Journal of Tropical Agriculture, Food, Environment and Extension, 8 (2):84-89.
[17]Inoni, O. E., Gani, B. S., Sabo, E., 2021, Drivers of Crop Diversification: Evidence from Smallholder Farmers in Delta State Nigeria. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 69(1): 59–70.
[18]INS (Institut National de la Statistique), 2005, Les comptes nationaux du Cameroun, Yaoundé: Cameroun.
[19]Kiru, S., 2014, Determinants and extent of crop diversification among smallholder farmers in Southern Zambia. Master of Science Thesis submitted to the faculty of development, University of Malawi. 87pp
[20]Kumar, C.R., 2020, Crop Diversification and Its Determinants: A Comparative Study between Cuttack and Kandhamal Districts of Odisha, India. J. Glob. Resour. 6. 51.
[21]Kurdys-Kujawska, A., Strzelecka, A., Szczepanska-Przekota, A., Zawadzka, D. Dochody Rolnicze, 2019, Determinanty-Zróznicowanie-Stabilizacja. (Agricultural income. Determinants-Differentiation-Stabilization); Wydawnictwo Politechniki Koszalinskiej: Koszalin, Poland.
[22]Lenis, S.O.L., Ayoola, G.B., Oyeleke, R.O., 2009, Enhancing the competitiveness of agricultural commodity chains in Nigeria: Identifying opportunities with cassava, rice and maize using a policy analysis matrix (PAM) framework.
[23]Locola, I., Angevin, F., Bockstaller, C., Catarino, R., Curran, M., Messean, A., Schader, C., Stilmant, D., Van Stappen, F., Vanhove, P., Ahnemann, H., Berthomier, J., Colombo, C., Guccione, G. D., Merot, E., Palumbo, M., Virzi, N., Canali, S., 2020, An actor oriented multi-criteria assessment framework to support a transition towards sustainable agricultural systems based on crop diversification. Sustainability, 12:1-30.
[24]Mango, N., Makate, C., Mapemba, L., Sopo, M., 2018, The role of crop diversification in improving household food security in central Malawi. Agric. Food Secur, 7, 7.
[25]Mazzocchi, C., Orsi, L., Ferrazzi, G., Corsi, S., 2020, The Dimensions of Agricultural Diversification: A Spatial Analysis of Italy Municipalities. Rural Sociol. 85, 316–345.
[26]Ministere de l'Agriculture et du Development Rural (MINADER), 2014, Les Politiques Agricoles à Travers Le Monde. Site Du Ministere de l'Agriculture, de l'Agroalimentaire et de la Foret.
[27]Mulwa, C.K., Mulwa, C., Marenya, P., Bahadur, D., Kassie, M., 2017, Climate Risk Management Response to climate risks among smallholder farmers in Malawi: A multivariate probit assessment of the role of information, household demographics, and farm

characteristics. Climate Risk Management, 16, 208–221.

[28]Msoo, A. A., Aye, G.C., 2014, Diversification and farm household welfare in Makurdi, Benue State, Nigeria, Development Studies Research. An Open Access Journal, 1:1, 168-175.

[29]Mzyece, A., Zereyesus, Y.A., Shanoyan, A., 2018, Does crop diversification involve a trade-off between technical efficiency and income stability for farmers in Zambia? In proceedings of the selected paper prepared for presentation at the agricultural and applied economics association annual meeting, Washington, DC, USA, 5-7 August.

[30]Ojo, M.A., Ojo, A.O., Odine, A.I., Ogaji, A., 2014, Determinants of Crop Diversification among Small-Scale Food Crop Farmers in North Central, Nigeria. PAT, 10 (2): 1-11.

[31]Okello, D. M., Bonabana-Wabbi, J., Basil, M., 2019, Farm level allocative efficiency of riceproduction in Gulu and Amuru districts, Northern Uganda. Agricultural and Food Economics, 7:19 https://doi.org/10.1186/s40100-019-0140-x

[32]Ridier, A., Roussy, C., Chaib, K., 2021, Adoption of crop diversifcation by specialized grain farmers in south-western France: evidence from a choice-modelling experiment. Review of Agricultural, Food and Environmental Studies, Springer, 2021, 102 (3), pp.265-283. f10.1007/s41130-021-00144-0f. fhal-03628983.

[33]Saraswati, P.A., Basavaraja, H.L., Kunnal, B., Mahajanashetti, S.B., Bhat, A. R., 2011, Crop Diversification in Karnataka: An Economic Analysis.

[34]Vanden Berg, M.M., Hengesdijk, H., Wolf, J., Ittersum, M.K.V., Guangho, W., Roetter, R. P., 2007, The impact of increasing farm size and mechanization on rural income and rice production in Zhejiang province, China. Agric. Syst., *94*, 841–850.

[35]Wooldridge, J., 2002, Econometric analysis of cross section and panel data. The MIT Press, London.

[36]Yamani, T., 1973, Statistics: An Introduction Analysis. 3rd Edition, Harper and Row, New York.

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DIFFERENCES IN AGRICULTURAL RETURNS IN SESAME PRODUCTION: AN EMPIRICAL EVIDENCE OF EFFICIENCY IN FACTOR INPUT ALLOCATION IN RINGIM LOCAL GOVERNMENT AREA, JIGAWA STATE, NIGERIA

Tohib Oyeyode OBALOLA, Abdullahi Abbas YAKUBU

Usmanu Danfodiyo University, Department of Agricultural Economics, Sokoto, Nigeria, E-mails: oyeyodeobalola@yahoo.com; aayakubu13@gmail.com

Corresponding author: oyeyodeobalola@yahoo.com; obalola.oyeyode@udusok.edu.ng

Abstract

The study looked into the use of input in sesame production with the view on seeing the returns to its production in Ringim Local Government Area, Jigawa State, Nigeria. Data were obtained from 100 randomly selected farmers using the multistage sampling technique. Descriptive statistics, net farm income and regression model were used in data analysis. The result showed that the mean age of the respondents was 38 years with secondary education been most popularly attained. The respondents had a household size of 3 persons cultivating a farm size of 3.5ha with experience of 8 years on average in sesame production. The results also reveal net farm income and return on naira invested of ₦ 46,190.59 and 1.54 respectively, an indication of a profitable enterprise. The semi-log functional form gave the best fit based on the normal econometric criteria with coefficient of multiple determination of 0.312 implying that about 31 percent of the variation in yield of sesame was explained by the specified explanatory variables. It also revealed that there was under utilization of all the production inputs under consideration. It is therefore encouraged that more of the limiting factors (farm size, quantity of seed and quantity of organic manure) observed be put into cultivation.

Key words: *sesame, profitability, efficiency, resource use*

INTRODUCTION

Prior to independence, sesame was a major foreign exchange source to Nigeria. The annual exports of sesame from Nigeria are valued at about US$35 million from an estimated world trade of US$600 million in 2005 [1]. However, after the discovery of petroleum in the late 50s and its exploitation and export in the early 70s, the economic scenario changed in favor of crude oil as the chief revenue source for the nation [4, 12].

In 2022, according to the National Bureau of Statistics (NBS), the sesame seeds export value accounted for ₦139. 85 billion, representing 23.34 % of Nigeria's total agricultural exports [16].

In 2021, Nigeria came on the 5th position among the top exporters of Sesamum seeds in the world after India ($425M), Sudan ($402M), Niger ($344M), Ethiopia ($291M), and Nigeria ($256M) [14].

Sesame is grown essentially for sale and therefore it can be regarded as an economic enterprise organized exclusively for the pursuit of economic returns [8]. Sesame output was extremely poor, according to Jigawa State Agricultural and Rural Development Authority, ranging from 168 to 314 kg/ha [7]. However, if resources are employed effectively, enhanced sesame cultivars can generate over 1,000 kg/ha [9]. Sesame output in Jigawa State decreases on a figure of about 38,000 metric tons (MT) to about 10,000 MT from 2000 to 2004 [15].

The differences between observed yields and frontier yields are substantial despite the intensive study on sesame, a significant source of foreign exchange before independence, and various initiatives to increase sesame production in recent decades. Farmers' yields ranged from 168 to 1,066 kg/ha, and this might be enhanced by more effectively utilizing the agricultural inputs [5]. A study of sesame yields between Ringim and its neighboring local government areas reveals a significant difference in output, with respective values for Ringim, Taura, and Garki of 47,847 kg, 1,436,919 kg, and 1,821,739 kg in 2011 [6].

In view of the afore mentioned, efficiency in resource and technology use by farmers becomes a top goal for research. In order to increase production and efficiency in resource usage among sesame growers, it is crucial to enhance the aforementioned scenario. It is in the light of the forgoing that the research addressed the following objectives:

(i)Describe the socio-economic characteristics of the farmers

(ii)Determine the costs and returns to sesame production

(iii)Determine the resource use efficiency of sesame farmers

MATERIALS AND METHODS

Study area

Ringim Local Government Area is located on latitudes 12^0 17'N and longitudes 9^0 28'E. It has a total land mass of 1,057 km^2 and population of 192,024 [10].

Its common borders with Gabasawa Local Government Area, Taura Local Government, Garki and Taura Local Government, and Dutse, Jahun, and Ajingi Local Government are on the west, east, north, and south, respectively. The region has a flat, plain landscape with several distinct land features. The mean daily maximum and minimum temperatures are 35°C and 19°C, respectively, with 700 mm of rainfall on average a year [7]. Over 90% of the labor force depends on agriculture for a living, making it the mainstay of the State's economy as well as the economy of the Ringim local government. The bulk of the population also works in marketing in addition to farming. Sesame, cowpea, and groundnut are the state's three most important economic crops.

Sampling Procedure and Sample Size

Multi- stage sampling techniques was employed in the selection of the respondents for the study. Ringim Local Government Area has five districts namely; Ringim, Yandutse, Sankara, Dabi and Chai-Chai districts. The first stage involves the purposive selection of three (3) important sesame producing districts. In the second stage, two (2) villages were randomly selected from each of the three (3) selected districts. This gave a total number of six (6) villages for the study. The third stage involved a proportionate random sampling of 100 respondents from the sampling frame of 345 sesame farmers.

Method of data collection

Data were collected from primary source. This was obtained through the use of structured questionnaire that were administered to the selected 100 sesame farmers in Ringim Local Government Area.

Methods of Data Analysis

Descriptive and inferential statistics were used in analyzing the data. Descriptive statistics such as frequency, means and percentages were used to describe the socio-economic characteristics of sesame farmers in the area and also to identify the constraints to sesame production. Multiple regression analysis was used in the determination of efficiency of resource utilization by the sesame farmers in the study area.

Net Farm Income

The difference between gross income and all production costs is known as net farm income. According to [2, 11], it is expressed as:

$$NFI = GFI - TC \quad (1)$$

where:

NFI = Net Farm Income (₦);

GFI = Gross Farm Income (₦);

TC = Total Cost (₦)

Since

$$TC = TVC + TFC \quad (2)$$

Therefore, equation (1) can be re-written as:

$$NFI = GFI - TVC - TFC \quad (3)$$

where:

TVC = Total Variable Costs of production (₦);

TFC = Total Fixed Costs of production (₦);

Other variables are as previously defined.

Production function model

Ensuing [13], the model used was specified implicitly as:

$$Y = f\ (X_1, X_2, X_3, X_4, X_5, X_6, e) \quad (4)$$

where:
Y= Output of sesame of the i[th] farmer (kg)
X_1 = Farm size (ha)
X_2 = Quantity of seeds (kg)
X_3 = Labour (Man-Days)
X_4= Quantity of organic manure (kg)
X_5 = Quantity of fertilizer (kg)
X_6 = Pesticides (ltrs)

However, four functional forms were fitted to the data. The functional forms in their explicit forms were as follows:

Linear

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + e \quad (5)$$

Double log (Cobb-Douglas)

$$InY = \text{In}\beta_0 + \beta_1 InX_1 + \beta_2 InX_2 + \beta_3 InX_3 + \beta_4 InX_4 + \beta_5 InX_5 + \beta_6 InX_6 + e \quad (6)$$

Exponential

$$InY = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + e \quad (7)$$

Semi – logarithmic

$$Y = \text{In}\beta_0 + \beta_1 InX_1 + \beta_2 InX_2 + \beta_3 InX_3 + \beta_4 InX_4 + \beta_5 InX_5 + \beta_6 InX_6 + e \quad (8)$$

β_o - β_6 = regression coefficients
In = natural logarithm
Other variables are as earlier defined

Resource Use Efficiency

To access the resource use by the farmers, the allocative index was calculated. To do this, each input's marginal value product (MVP) is equated to its price or marginal factor cost (MFC). According to [13], it is expressed directly as:

$$MVP = P_{xi} = MFC_{xi} \quad (9)$$
$$MVP_{xi} = MPP_{xi} \, . P_y \quad (10)$$
$$MPP_{xi} = \frac{dy}{dx_i} \quad (11)$$

Where,
MVP_{xi} = Marginal value product of the i[th] input;
P_{xi} = Unit price of the i[th] input;
MFC_{xi} = Marginal factor cost of the i[th] input;
P_y = Unit price of output;
MPP_{xi} = Marginal physical product of the i[th] input;
X_i = Mean quantity of input;
Y = Mean weight of output

However, the following conditions are obtainable;
MVP_{xi} >MFC_{xi} = Underutilization of resource X_i;
MVP_{xi} < MFC_{xi} = Overutilization of resource X_i;
MVP_{xi} = MFC_{xi} = Optimum utilization of resource X_i [13].

For the semi-logarithmic function, the elasticity with respect to the production input was computed using the formula:

$$E = \frac{\beta}{\bar{Y}} \quad (12)$$

where:
β = Coefficient of i[th] input
$\bar{Y}$ = Geometric mean of output

RESULTS AND DISCUSSIONS

The socioeconomic characteristics on sesame farmers showed that the farmers were young and still in their prime working years, with a mean age of 38 years. This backs up the argument made by [3]. The majority of farmers (72.34%) are married. The proportion of farmers with secondary education was higher. The farmers (23.40%) without a formal education came next. However, 22.34% of farmers had completed primary school, and 18.06% had completed tertiary education. A 3.5ha farm was cultivated by an average household of 3 farmers.

Table 1. Socioeconomic characteristics of the sesame farmers

Variable	Frequency	Percentage
Age (years)		
21-30	24	25.53
31-40	30	31.91
41-50	28	29.79
51 and Above	12	12.77
MEAN = 38		
Marital status		
Married	68	72.34
Single	16	17.02
Divorced	10	10.64
Education		
No formal education	22	23.40
Primary education	21	22.34
Secondary education	34	36.20
Tertiary education	17	18.06
Household size (number)		
1-5	53	56.38
6-10	26	27.66
11-15	12	12.77
16-20	3	3.19
MEAN = 3		
Farm size (hectare)		
1-2	41	43.62
3-4	23	24.45
5-6	19	20.21
7 and above	11	11.70
MEAN = 3.5		
Farming experience (years)		
1-5	33	35.11
6-10	30	31.91
11-15	18	19.15
16-20	10	10.64
21 and above	3	3.19
MEAN = 8		

Source: Field Survey, 2019.

The farmers had an average of 8 years of experience producing sesame. This was quite low and possibly explains the farmers' declining sesame production (Table 1).

Production costs and returns

The Net farm income (NFI) and return on naira invested was used to determine the profitability of the enterprise.

The total cost of production which comprises both the total variable cost and total fixed cost were considered.

The total variable cost per hectare was ₦ 23,763.60 and this account for 79.10% of the total cost.

From the total variable cost component, it was recorded that labour cost covers 60.45% of the total cost of production.

Accordingly, this was followed by cost incurred on fertilizer and seeds.

Similarly, the values of the fixed cost constitute only 20.9% of the total cost of production indicating small scale operation of the enterprise.

On the part of the fixed cost, depreciation gulped 10.91% of the total cost while rent on land amount to 9.99%.

Table 2. Average Costs and Returns to Sesame Production in Ringim Local Government Area

Production variables	(₦/ha)	Percentage
A. Variable cost		
Seed	750	2.50
Labour	18,159.93	60.45
Fertilizer	3,544.88	11.80
Pesticides	247.50	0.82
Transportation	532.33	1.77
Empty sacks	528.96	1.76
Total variable cost (TVC)	**23,763.60**	
B. Fixed cost		
Depreciation	3,278.34	10.91
Rent on land	3,000	9.99
Total fixed cost (TFC)	**6,278.34**	
Total cost of production (A+B)	**30,041.94**	**100.00**
C. Returns		
Revenue	**76,232.53**	
Gross margin (GM)	**52,468.93**	
Net farm income (NFI)	**46,190.59**	
Return on naira invested (NFI/TC)	**1.54**	

Source: Field Survey, 2019.

On the revenue, the average output and price from the study were 357.34kg and ₦ 213.33/kg respectively and amount to a revenue of ₦ 76,232.53/ha. However, the NFI was ₦ 46,190.59 (Table 2).

Return on naira invested was 1.54. This implies that sesame production is profitable in the area since return to naira invested was positive.

This finding is in line with that of [17] who reported, that sesame production is profitable in the study area (Table 2).

Production function analysis

According to conventional econometric standards, the semi-log functional form provided the best match. The coefficient of multiple determinations R^2 was 0.312, indicating that the explanatory variables specified were responsible for explaining around 31 percent of the variation in sesame yield. The coefficients of farm size, quantity of seeds and organic manure utilized were all found to be significant at the 10% and 1% levels, respectively.

The positive farm size coefficient indicates that, while maintaining other variables constant, an increase in farm size would result in an increase in production level. Ideally, *ceteris paribus*, increased land use would surely require more inputs, and as a result, under proper management, the output is anticipated to increase. The coefficients for the quantity of seed and organic manure used are also positive and significant at 1%. The output would therefore increase if these variables are used more frequently (Table 3).

Table 3. Results of the ordinary least square regression analysis for estimated sesame production

Variables	**Linear**		**Exponential**		**Double-log**		**Semi-log**	
Constant	1,684.606	0.503	3.564***	26.772	1.685*	1.888	-28,079.516	-1.234
Farm size (Ha)	1,013.547	1.349	0.290	0.959	0.236	1.493	7,664.906*	1.905
Quantity of Seed (Kg)	0.446***	3.147	1.67E-5***	2.960	0.309***	3.088	8,115.840***	3.178
Labour (Mandays)	0.008	0.172	158E-6	0.834	0.039	0.265	-2,195.265	-0.580
Quantity of Organic Manure (Kg)	12.722***	3.968	0.000***	3.643	0.383***	3.518	7,071.285***	3.442
Quantity of Fertilizer (Kg)	-3.158	-0.502	-910E-6	-0.036	0.031	0.178	-2,023.039	-0.449
Quantity of Agrochemical (Ltr)	-36.482	-0.217	-0.003	-0.517	0.006	0.409	3,424.875	0.815
R^2	0.332		0.289		0.287		0.312	
F- Value	6.039***		4.937***		4.894***		5.521***	

Source: Field Survey, 2019.
Note: *** significant at 1%, * Significant at 10%

Resource use efficiency

By calculating the ratio of the marginal value product (MVP) to the marginal factor cost (MFC), it was possible to analyze how effectively the resources were being used, as well as whether they were being used inefficiently, excessively, or both.

In order to get the elasticity for the computation of the allocative efficiency index, the coefficient from the semi-logarithmic output was divided by the geometric mean of the output. However, the result from Table 4 shows that all the resources were inefficiently utilized.

The allocative efficiency index with respect to farm size, quantity of seeds and quantity of organic manure were 1.52, 6.46 and 17.06 respectively and are greater than unity. This implies that these resources are underutilized. The under-utilization of farm size could be attributed to land fragmentation and the land tenure system. Since land appears to be a limiting factor, there is need to encourage farmers in the study area to bring more land under cultivation. Hence, the farmers are operating in stage 1 of the classical production function. More of the inputs should be employed in order to make the farmers efficient with their resource use (Table 4).

Table 4. Marginal analysis of input utilization of sesame producers

Resources	Elasticity(b)	P_y (N)	MVP	MFC	Allocative Efficiency Index (MVP/MFC)	Decision
Farm size (X_1)	21.45	213.33	4,575.93	3,000.00	1.52	Under utilized
Quantity of seeds (X_2)	22.71	213.33	4,844.72	750.00	6.46	Under utilized
Quantity of organic manure (X_4)	19.79	213.33	4,221.80	247.50	17.06	Under utilized

Source: Field Survey, 2019.
Unit price of output (P_y) = ₦213.33/kg
Mean of output = 357.34kg

CONCLUSIONS

From the study, it was shown that sesame farmers were functioning in stage I of the classical production function because they were underutilizing their production inputs. The enterprise's limiting factors were farm size, seeds, and manure. The farmer should boost input employment levels to function in stage II, the rational stage of production, in order to optimize output.

REFERENCES

[1]Ali, A., Salawu, A.J., Sani, R.M., 2015, Factors Influencing Sesame (*Sesamum indicum* L) Marketing in Jigawa State, Nigeria. Journal of Agricultural Extension, 19(2): 126-133. https://dx.doi.org/10.4314/jae.v19i2.11.
[2]Ayinde, O.E., Agboola, B.O., Obalola, T.O., 2023, Comparative Analysis of the Economic Performance of Shika Brown, Isa Brown and Harco Black Layers: An Experimental Approach. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 23(1): 49-56.
[3]Ayinde, O.E., Obalola, T.O., 2017, Effect of Socioeconomic Characteristics and Income Status on Onion Farmers Risk Attitude in Sokoto State, Nigeria. Agricultura Tropica Et Subtropica, 50(3): 141–146.
[4]Faborode, M.O., 2016, Optimal utilization of natural resources through research and development and technology adaptation. 4th RMRDC International Conference on Natural Resources Development and Utilization. Feb 8-9, 2016. Raw Material Research and Development Council (RMRDC), Federal Ministry of Science and Technology, Abuja, Nigeria.
[5]Jigawa Agricultural and Rural Development Authority (JARDA), 2010, Annual Crop Production Report. Agric. Services Unit.
[6]Jigawa Agricultural and Rural Development Authority (JARDA), 2011, Annual Report 2011.
[7]Jigawa Agricultural and Rural Development Authority (JARDA), 2005, Sesame Production Prospects and Marketing, 2005 Wet -Season Industrial Crops Production Programme. Jigawa State, Nigeria.
[8]Katanga, Y.N., Ginsau, N.I., Musa, S., 2021, Socioeconomic Analysis of Sesame Marketing in Hadejia L.G.A. of Jigawa State, Nigeria. Ife Journal of Agriculture, 33(1): 36-45.
[9]National Cereal Research Institute (NCRI) 2004, Report of the Base Line Survey on Beniseed Production and Utilization in Nasarawa State. Project commissioned by the Nasarawa State Government pp 23.
[10]National Population Commission (NPC) 2006, Population Figure: http://www.jstor.org. Accessed on 25/7/2023.
[11]Obalola, T.O., Agboola, B.O., Odum, E.B.E., 2017, Profitability and Constraints to Irrigated Onion Production in Wamakko and Kware Local Government Areas, Sokoto State, Nigeria. Journal of Global Agriculture and Ecology, 7(3): 106-110.
[12]Obalola, T.O., Likita, T., Aboaba, K.O., Olabode, E.J., 2020, Drivers of cassava and rice consumption in Nigeria: A vector error correction model approach. Agro Economist - An International Journal, 7(1): 01-11. https://dx.doi.org/10.30954/2394-8159.01.2020.1
[13]Obalola, T.O., Tanko, L., 2016, Comparative Economic Analysis of Irrigated and Rainfed Spinach (*Amaranthus cruentus*) Production in Minna Metropolis, Niger State, Nigeria. Journal of Agriculture, Food and Development, 16(1): 91- 98.
[14]OEC.world,
https://oec.world/en/profile/hs/sesamum-

seeds#:~:text=Sesamum%20seeds%20are%20the%20world's,%2C%20and%20Nigeria%20(%24256M), Accessed on July 31, 2023.

[15]Raw Materials Research and Development Council (RMRDC) 2004, Report of Survey of Agro-Raw Materials in Nigeria: Beniseed Publisher Raw Material Research and Development Council, Garki Abuja.

[16]The Nation, 2023, Nigeria records marginal gains in sesame exports, https://thenationonlineng.net/nigeria-records-marginal-gains-in-sesame-exports/, Accessed on July 31, 2023.

[17]Umar, H.S., Okoye, C.U., Mamman, B.D., 2010, Resource use efficiency in sesame (*Sesamum indicum* L.) production under organic and inorganic fertilizers application in Keana Local Government Area of Nasarawa State, Nigeria. Journal of Agriculture and Biological Sciences, 6 (4): 466-467.

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RESEARCHES ON BEHAVIOR OF TWO MAIZE HYBRIDS GROWN IN CONVENTIONAL SYSTEM IN CLIMATE CONDITIONS OF THE ROMANIAN PLAIN

Nicoleta OLTENACU[1], Mariana BURCEA[1], Cătălin Viorel OLTENACU[2], Mirela (FULGA) PÎRVU[3,4], Mihai GÎDEA[1]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, 11464, Bucharest,Romania, Phone/Fax: 00 40 744 6474 10.E-mails: nicoleta_oltenacu@yahoo.com; burcea_mariana2003@yahoo.com; gideam@yahoo.com
[2]Research Development Station for Fruit Culture Băneasa, 4 Ion Ionescu de la Brad Blvd, District 1,013813, Bucharest, Romania,tel.021 233 0613. E-mail: oltenacu_viorel@yahoo.com
[3]Ministry of Investments and European Projects, 1-1B Bucharest-Ploiesti Road, Victoria Office, 7 Menuetului Entrance, District 1, 013713, Bucharest, Romania, Phone:.0372.838.633. E-mail: mirela_fulga29@yahoo.com.
[4]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, 11464, Bucharest, Romania, Phone/Fax: 00 40 744 6474 10; Doctoral School: Engineering and Management Plant and Animal Resources; Field: Agronomy. E-mail: mirela_fulga29@yahoo.com.

Corresponding author: nicoleta_oltenacu@yahoo.com

Abstract

Maize, one of the most popular cereal, originates from the Central America and is very versatile, being used in various fields. It is used in food, as feed and in industry. The purpose of the paper regards the choice of hybrids which is one of the most important factors influencing the productivity and quality of the maize. The area where the crop is located influences the choice of the most suitable hybrid, as it must be selected according to the average temperature during the growing period and the type of soil. In this study, the experiments were carried out in the climate and soil conditions of Moara Domneasca Research Station. To find the right hybrid, several hybrids were selected to grow and later to compare their harvest and choose the optimal variant. To obtain the highest production of maize, the chosen hybrid should be also as resistant as possible to extreme weather conditions, such as periods of drought grown in the Romanian Plain, on a specific soil and fertilized with different doses of chemical fertilizers. The economic efficiency of the applied fertilization system was also analyzed. As a conclusion, the two hybrids tested reacted positively to chemical fertilization. The SC4140 hybrid behaved better in the non-fertilized version, achieving higher yields than the P9903 hybrid.

Key words: *fertilization doses, maize hybrid, production performance, economic efficiency*

INTRODUCTION

In Romania, maize occupies the largest grown area due to its high productivity and high yields per unit area [28]. The area grown with maize varies between 2.5-3.1 million ha depending on the level of precipitation in the cold season or as a result of the compromise of the autumn crops during the winter [29]. Maize is one of the most versatile crop plants, an enormous diversity of hybrids provides the basis for growing maize in different locations and conditions around the world [4, 27]. The yield components and the grain yield are influenced by several factors, either they are environment or technological.

The consumption of nutrients differs depending on the destination of the crop and silage or grain corn. Chemical fertilization is an agrotechnical measure essential in cropping systems and it guarantees yield boosts [10, 15, 25]. Basic nutrients N and P react very different at maize crop, depending on soil type and climate conditions Nitrogen is the element which determines the biggest increase in maize yield [11, 25]. The yields

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for wheat and corn crops increased along with the increase in the rotation duration and in the dose of nitrogen fertilization; the increase was statistically relevant [8, 19, 26]. As a result, the association of rotation with fertilization leads to an increase in organic biomass, with amplified action of the factors in maize [14].

As a very important biological factor in the increase of production, the quality of the seeds from the agricultural point of view is given by their genetic and somatic value [16].

Maize (*Zea mays* L.) is a crop with a high production capacity, which is determined by the yield components participating to the yield formation [1, 18].

The yielding capacity is given for each maize hybrid by its genetics, but it is also influenced by the growth conditions, respectively by the environmental factors, mainly soil and climatic conditions, as well as by the crop technology used by the maize grower [5]. Yield potential can be diminished as a consequence of insufficient water supply to meet crop water demand [17]. But severe drought stress is affecting in a very significant way the yielding capacity of the maize plants, even leading in extreme conditions to the loss of the yielding capacity [8, 9]. Drought is the main yield constraint especially in South Romania, the most important Romanian growing area for maize [20]. Rainfed crop management systems need to be optimized to provide more resilient options in order to cope with the decrease in mean precipitation and more frequent extreme drought periods [13]. Therefore, it is of great importance for farmers but also for scientists to better understand the maize plant responses to drought under different technological conditions [2]. Farmers growing maize must consider crop technology as a tool for a maximum use of resources and for diminishing the effects of limitative environmental factors [16]. Preceding crop is among the important crop technology measures with a significant influence upon the yield and its components [14].

The exclusive use of chemical fertilizers does not reduce the importance of manure [7]. The largest gains at harvest are obtained from the combined action of chemical fertilizers with manure [12, 26].

In the last 30 years, the area cultivated with grain maize has increased by 8.58%, from 2,466,735 ha (26.23% of the total agricultural area) in 1990 to 2,678,504 ha (30.65% of the country's agricultural sector), in 2019. In three decades, the area reserved for growing has never fallen below 2 million hectares [6].

Instead, in 10 years (1992, 1992, 1995, 1996, 1997, 1998, 1999, 2000, 2003, 2004), the area was greater than 3 million hectares, the absolute record being recorded in 1992, when there were cultivated 3.3 million ha with grain corn [24, 21]. The area cultivated with corn has kept a relatively constant level approx. 2,500-2,600 thousand ha with a small decrease in 2010, when the surface reached only 2,098 thousand ha [25, 26]. The maintenance of the areas grown with maize can be explained by the market demand for this crop, by the high productions obtained with this cereal, especially in favorable conditions of precipitation or irrigation, and by its quality as a good precursor to the other crops [13, 23].

Figure 1 shows visible increase both of the area and the production of maize in Romania in the period 2007-2020. This was due to the improvement of the technical endowment, the subsidies granted by the state, the high demand, the continuously increasing price.

The largest grown area was in 2012 (2,730.2 thousand ha) with an average production of 2,180 kg/ha and a total production of 5,953.4 thousand tons.

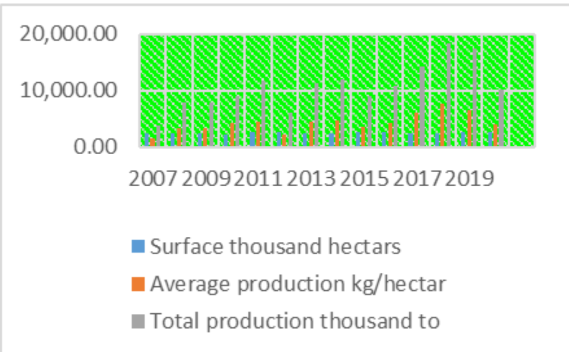

Fig. 1. Evolution of maize surfaces and productions in Romania in the period 2007-2020.
Source: NIS [22].

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The highest total production was recorded in 2018, namely 18,353 thousand tons [3, 21]. Compared to the area grown in 2020, of 2,537 thousand ha, in 2021, the areas grown with maize in Romania increased to 2,493 thousand ha [21].

Recorded productions also increased, 2021 being a very good year for agriculture. The increases varied from 10,097 thousand tons in 2020 to 14,445 thousand tons in 2021.

In this context, the purpose of the paper is to test two maize hybrids SC4140 and P9903 for their production capacity under the soil and climate conditions and four levels of fertilization at the S.D.C.D.A. Moara Domnească Didactic Station of Agriculture Research and Development, situated in the South Romanian Plain.

MATERIALS AND METHODS

The research was carried out in the experimental field of S.D.C.D.A. Moara Domnească Didactic Station of Agriculture Research and Development on a preluvosol type soil, with a loamy-clay texture, a medium humus content in A (2.77-2.16%).

From the analytical data of the representative profiles of this soil unit, the following physico-chemical characteristics result: the texture is loamy-clay throughout the profile, with a variation of the clay fraction between 39.20% in A and 39.84% in Bt, which means a weak textural differentiation, Idr (textural differentiation index), having values up to 1.2; the main hydrophysical indices have medium to high values (CH Around 9% in A and up to almost 10% in B; CO over 13% in A and over 14% in B; CC 26-25% in A and 24-21% in B; humus content is medium in A (2.77-2.16%) and remains relatively high in A/B (around 1.2%); the sum of exchangeable bases has high values, generally over 21 me/100 g of soil, on the entire profile; the exchangeable hydrogen has low and very low values (2-5 me); the degree of saturation in bases usually have high values (79-89%); the reaction is weakly acid-neutral (in A, pH=6.2-6.6 and in B, pH=6.0-6.5); nitrogen indices are medium in A (above 2) and low in B (below 2), which shows a medium and weak nitrogen supply, respectively; at a depth of 20 cm from the surface (the active start of roots), the soil is moderately supplied in mobile phosphorus (17 ppm PAL) and well supplied in mobile potassium (184 ppm K_{AL}) [12].

Sowing was carried out between 15-18thApril 2022 and harvesting was carried out between 20-25thAugust 2022. For 2021, sowing was carried out between 5thApril and harvesting on 30thAugust. The preceding crop for the maize plots was soybean, a legume that fixes nitrogen in the soil, giving the corn an important and natural "supplement" for fertilization [14].

In autumn, the surface was scarified, in October and then, in November, the land was discussed in two passes. In spring, before sowing, a work was carried out with the combine.

Sowing was carried out on 15thApril and together with the sowing work, DAP 18:46:0 was also applied. From sowing to harvesting, the only work was weeding. The herbicide Adengo was applied before emergence (dose of 0.4 l/ha) and then, in the 8-10 leaf phase on 12thMay, Laudis was administered (dose of 2.2 l/ha). The total amount of precipitation was 288 liters per square meter, the rains being accumulated between February and August 2022.

The harvest took place on 25thAugust. Density at sowing: 66,000 grains/ha. The culture did not benefit from irrigation. The experiment was bifactorial based on the method of blocks with subdivided plots, with three repetitions, where factor A - the hybrid with two grades a1 SC4140 and a2 P9903, and factor B - doses of mineral fertilizers with the following grades: b1-N_0P_0 ; b2-$N_{50}P_{50}$; b3-$N_{100}P_{50}$; b4-$N_{150}P_{100}$.

RESULTS AND DISCUSSIONS

Effect of chemical fertilization on the production obtained in maize growing is shown in Table 1.

According to the data presented in Table 1, productions increased as the dose of fertilizers increased, from 3,590 kg/ha to 6,940 kg/ha (average productions of the 2 years).

Table 1. Productions made on grown surfaces with hybrid SC4140

Fertilization Variant	Production kg/ha 2021	Production kg/ha 2022	Average production kg/ha	Production increase compared to control kg/ha	Production increase between variants Kg/ha
N_0P_0	3,250	3,930	3,590	Mt	Mt
$N_{50}P_{50}$	4,270	4,380	4,310	720	720
$N_{100}P_{50}$	5,580	5,900	5,740	2,150	1,430
$N_{150}P_{100}$	6,900	6,980	6,940	3,350	1,200

Source: own processing.

Production gains have increased significantly compared to the non-fertilized version, reaching values of over 3,000 kg/ha. The increase in production between the version fertilized with 50 kg a.s. and the one fertilized with 100 kg. to. N has grown significantly 1,430 kg. Fertilization with another 50 kg a.s. N. It did not determine increases of less than 1,200 kg, which means that the increase in doses does not imply an increase in gains.

Table 2. Productions obtained from the cultivated surfaces with P9903 hybrid in 2022 versus 2021

Fertilization Variant	Production kg/ha 2021	Production kg/ha 2022	Average Production kg/ha	Production increase compared to Control Kg/ha	Production increase between variants Kg/ha
N_0P_0	2,950	3,200	3,075	Control	Control
$N_{50}P_{50}$	3,300	3,550	3,425	350	350
$N_{100}P_{50}$	5,500	5,300	5,400	2,325	1,975
$N_{150}P_{100}$	6,850	6,700	6,775	3,700	1,375

Source: Own processing.

Table 2 shows the productions achieved on the areas grown with the P9903 hybrid.
It has positively reacted to the doses of fertilizers administered, reaching increases of 3,700 kg in the version fertilized with 150 kg N/ha a.s. Both the productions and the increases obtained were very significant.
The yield increase between the variants increased very significantly in the variant fertilized with 100 kg a.s.N, 1,975 kg/ha.
The version fertilized with 150 kg N a.s. recorded substantial but smaller increases compared to previous versions.
To analyze the influence of fertilizer doses on plant development, biometric measurements were performed.
The results presented in Table 3 were obtained by calculating the average of the measurements performed on a number of 10 plants from each experimental variant.

Table 3. Biometrical measurements

Variant	Height of plant m	No of leaves/ plant	Height of cob insertion/ fr. no.
N_0P_0	1.77	11	0.64 cm/5
$N_{50}P_{50}$	1.81	11	0.61 cm/6
$N_{100}P_{50}$	1.89	11	0.62 cm/5
$N_{150}P_{100}$	1.78	11	0.63 cm/5

Source: own processing.

From Table 3, it appears that the variant in which the plants recorded the greatest increase in height was the one fertilized with the N150P100 formula. It can be concluded that high doses of nitrogen cause obvious vegetative growth. The number of leaves per plant was on average 11, the insertion height of the cob being between 0.61-0.64 cm.

The economic efficiency of the grow system analyzed

The technological measures applied were also analyzed from the point of view of economic

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efficiency The financial result was influenced by the price of cereals on the market.

Table 4. Sale price of cereals

	Sale price (lei/kg)			
	2019	**2020**	**2021**	**2022**
Maize	0.62 ↑	0.76 ↑	1.0 ↑	1.5 ↑

Source: www.agrointeligenta.ro [2].

The sale price of maize has had an upward trend in recent years as shown in Table 4. This was influenced by the small productions achieved especially in 2020, an extremely difficult agricultural year due to the drought, but also in 2022, when the same climatic conditions led to a low harvest. As a result, increased demand and reduced supply led to higher prices.

Table 5. Costs made with fertilizers - lei

Variant	Costs of fertilizers lei/ha		
	2021	2022	Average
N_0P_0	-	-	-
$N_{50}P_{50}$	820	1,020	920
$N_{100}P_{50}$	1,380	1,548	1,464
$N_{150}P_{100}$	1,940	2,276	2,108

Source: Research Station data.

From the data presented in Table 5, it appears that the total expenses per ha were 1,320 lei in 2021 and 1,500 lei/ha in 2022. Maize is a crop that requires weeding and therefore higher expenditure on pesticides.

The price of DAP in 2021 was 4.2 lei/kg and 5.0 lei/kg in 2022. The price of ammonium nitrate was 5.2 lei/kg in 2022 and 4.0 lei/kg in 2021. To ensure the doses established for each variant, the following amounts were calculated and administered:

Variants:

-N_0P_0 - not fertilized

-$N_{50}P_{50}$- DAP 18:46:0- 100 kg pc/ha+ ammonium nitrate 100 kg pc/ha (33%N)

-$N_{100}P_{50}$- DAP 18:46:0- 100 kg pc/ha+ Ammonium nitrate 240 kg pc/ha (33%N)

-$N_{150}P_{100}$- DAP 18:46:0- 200 kg pc/ha+ Ammonium nitrate 330 kg pc/ha(33%N).

The values of costs with these doses of fertilizers are shown in Table 5.

Among the direct expenses, administered fertilizers had the largest share, the increase in doses also causing their increase.

The price of fertilizers also influenced the level of expenses incurred by farmers for the establishment and maintenance of crops (Table 6).

From Table 6, it appears that the expenses incurred per hectare were influenced by the amount of fertilizers administered. Thus, for the non-fertilized version, the expenses were 1,410 lei/ha, reaching 3,518 lei/ha for the one fertilized with 150 kg N a.s. The quantity and price of fertilizers drove these increases. The income obtained were influenced by the productions achieved but also by the price of the cereals at the time of utilization. Incomes per hectare were lower in 2021 because the selling price was only 1 leu/kg.

In the following year, the price increased to 1.5 lei/kg, thus increasing the income per ha. The lowest income was recorded in the non-fertilized version, an average of 4,573 lei/ha, the highest was obtained in the version where doses of N s.a. were administered. of 150 kg/ha, 8,685 lei/kg (Table 6).

Analyzing the table, we notice that the good price in 2022, 1.5 lei/kg and the higher productions but also the precipitation that fell at the critical moment for the plant influenced the financial result.

Thus, the profit increased from 4,395 lei/ha in the non-fertilized version to 6,694 lei/ha in the version fertilized with the maximum dose.

In 2021, although the productions were close, the sales price influenced the financial result, which was much lower.

We performed the economic efficiency calculation using the average production values for the two years and an average selling price of 1.3 lei/kg.

The data presented in Table 7 show that the productions increased proportionally with the increase in the doses of administered fertilizers, the yield increase also increased from 720 kg/ha to the variant in which it was fertilized with the dose of 50 kg N s.a. to 3,350 kg/ha in the fertilized version with a dose of 150 kg N a.s /ha.

Table 6. Economic analysis of grow with SC4140 - hybrid (lei/ha)

Variant	**Production kg/ha**		**Income /ha lei/ha**			**Costs /ha lei/ha**			**Profit lei/ha**	
	2021	**2022**	**2021**	**2022**	**Media**	**2021**	**2022**	**Media**	**2021**	**2022**
N_0P_0	3,250	3,930	3,250	5,895	4,573	1,320	1,500	1,410	1,930	4,395
$N_{50}P_{50}$	4,270	4,350	4,270	6,575	5,422.5	2,140	2,520	2,330	2,130	4,055
$N_{100}P_{50}$	5,580	5,900	5,580	8,850	7,215	2,700	3,048	2,874	2,880	5,802
$N_{150}P_{100}$	6,900	6,980	6,900	10,470	8,685	3,260	3,776	3,518	3,640	6,694

Source: Own processing based on the data from the Research Station.

Table 7. Economic efficiency of crop culture SC4140 hybrid

Variant	Prod kg/ha	Prod. increase Kg/ha	Fertilizer costs lei	Profit for production increase lei/ha
N_0P_0	3,590	Control	Control	Control
$N_{50}P_{50}$	4,310	720	920	936
$N_{100}P_{50}$	5,740	2,150	1,464	2,795
$N_{150}P_{100}$	6,940	3,350	2,108	4,355

Source: Own processing based on the data from the Research Station.

Fertilizer costs increased as applied rates increased. The profit recorded on the increase in production increased proportionally with the increase in the doses of fertilizers used as a result of the increase in production, from 936 lei/ha to 4,355 lei/ha. As a result, the administration of increased doses of fertilizers causes significant increases in production, the expense of these high doses being economically justified. Above these doses, the plants no longer registered significant increases in production, which no longer economically justifies spending on higher doses of administered fertilizers.

The incomes obtained were influenced by the productions achieved but also by the price of the cereals at the time of utilization. Revenues per hectare were lower in 2021 because the selling price was only 1 leu/kg. In the following year, the price increased to 1.5 lei/kg, thus increasing the income per ha. The lowest income was recorded for the non-fertilized version, an average of 3,875 lei/ha, the highest, for the version with doses of N s.a.of 150 kg/ha, 8,450 lei/kg (Table 8).

Table 8. Financial results for P9903 hybrid

Variant	**Production kg/ha**		**Income lei/ha**		**Costs lei/ha**		**Profit lei/ha**	
	2021	2022	2021	2022	2021	2022	2021	2022
N_0P_0	2,950	3,200	2,950	4,800	1,760	1,940	1,190	2,860
$N_{50}P_{50}$	3,300	3,550	3,300	5,325	2,580	2,960	720	2,365
$N_{100}P_{50}$	5,500	5,300	5,500	7,950	3,140	3,488	2,360	4,462
$N_{150}P_{100}$	6,850	6,700	6,850	10,050	3,700	4,216	3,150	5,834

Source: Own processing based on the data from the Research Station.

The profit made per hectare was influenced by the yields obtained, by the price of cereals on the market at the time of harvesting, but also by the expenses for the establishment of the crop.

The non-fertilized or low-dose fertilized variants did not achieve high yields, as a result, incomes were lower in 2021 but higher in 2022 favored by the increased price of grain on the market.

The profit increased for the variants fertilized with higher doses of fertilizers as a result of the increase in the harvest, higher prices in 2022 and the increases in production recorded (Table 9).

The production increases significantly as the dose of fertilizers administered increases, reaching from 3,075 kg/ha in the unfertilized version to 6,775 kg/ha in the version fertilized with 150 kg N a.s.

The increase in harvest was 3,700 kg/ha, the profit achieved was also high, 4,810 lei/ha.

Table 9. Economic efficiency of P9903 crop system

Variant	Prod. kg/ha media	Prod. increase Kg/ha	Costs with fertilizers Lei	Profit for production increase lei/ha
N_0P_0	3,075	-	-	-
$N_{50}P_{50}$	3,425	350	920	455
$N_{100}P_{50}$	5,400	2,325	1,464	3,022
$N_{150}P_{100}$	6,775	3,700	2,108	4,810

Source: Own processing based on the data from the Research Station.

In conclusion, as the data in Table 9 shows, the expenses with fertilizers were lower than the profit achieved, which means that from an economic point of view the additional expenses with the administered doses are justified.

CONCLUSIONS

The application of mineral fertilizers determines higher yields and significant increases in production. The unbalanced application of chemical fertilizers can produce imbalances in the plant and the crop increases recorded are increasingly lower as the amount administered increases beyond the useful limit for the plants, which causes higher expenses that are not found in the increases achieved.

Another goal of this analysis was to follow the reaction of hybrids to fertilization and choose for the future the one that brought us the best results without generating large expenses.

The two hybrids tested reacted positively to chemical fertilization, the gains obtained being significant and close for both hybrids.

The SC4140 hybrid behaved better in the non-fertilized version, achieving higher yields than the P9903 hybrid.

The costs of the additional amounts of fertilizers administered were approx.500 lei for each option, expenses that were economically justified by the increases obtained and the revenues recorded. The incomes achieved were about 3,000 lei/ha for the unfertilized version of both hybrids and more than 10,000 lei/ha for the versions fertilized with 150 kg N s.a./ha.

Expenses were about the same for the two hybrids, slightly higher for P9903, the difference being driven by the higher price of seed material. Profit influenced by slightly lower seed costs was higher in hybrid SC4140.

Both hybrids can be grown with good results, taking into account the climatic conditions of the year, the type of soil and the price of the genetic material. In the climatic conditions of the years 2021 and 2022, doses of up to 150 kg N/ha s.a. they generated crops that justified the costs of fertilization. The application of higher doses did not lead to significant increases in production to justify the additional expense.

REFERENCES

[1]Agapie, A.L., Sala, F., 2022, The variation of protein content in maize grains in relation to the fertilization level, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(4), 31-37.

[2]Agrointeligenta.ro, Bursa cerealelor, Astazi oretul porumbului l[-a depasit pe cel al graului, https://www.agrointeligenta.ro/ https://agrointel.ro/249477/bursa-cerealelor-astazi-pretul-porumbului-l-a-depasit-pe-cel-al-graului/, Accessed on Feb. 1, 2023.

[3]Bâtcă, A., 2011, How Romanian agriculture performed from 2010, Ceres Publishing House, Bucharest, p. 14.

[4]Bășa, A. Gh., Ion, V., Dumbravă, M., Temocico, G., Epure, L.I., Ştefan, D., 2016, Grain Yield and Yield Components at Maize under Different Preceding Crops and Nitrogen Fertilization Conditions, Agriculture and Agricultural Science Procedia, Vol.10, 104-111, https://doi.org/10.1016/j.aaspro.2016.09.025, https://www.sciencedirect.com/science/article/pii/S2210784316302182, Accessed on Sept. 10, 2023.

[5]Bărbos, A., Moldovan, Gr., Micu, O., 2016, The influence of genotype, treatment and storage period on ageing process of hybrid corn seeds. Agriculture Science and Practice Journal, 70-75, Academicpres, Cluj-Napoca.

[6]Berca, M., 2019, Modern transformation of agriculture, Ceres Publishing House, Bucharest, p. 321.

[7]Berca, M., Buzatu, C.S., 2011, Maize answer modelling at nutrition with nitrogen and phosphorous within the Romanian space, Scientific Papers Series Agronomy, University of Agricultural Sciences and Veterinary Medicine of Iasi, Vol. 54 (1), 102-105.

https://www.uaiasi.ro/revagrois/PDF/2011/paper/2011-54(1)-23-en.pdf, 102-105, Accessed on Sept. 10, 2023.
[8]Blaise, L., 2012, Rotation of crops, M.A.S.E. Publishing, Bucharest, p. 57 and p.78.
[9]Bologa, G. C., 2014, Sustainable rural development in Romania, Pro Universitaria Publishing House, Bucharest, p. 38.
[10]Burcea, M., 2018, Anthropic impact studies on the agrochemical quality condition of the soil, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 18(1), 109-113.
[11]Burcea, M., Oltenacu, N., 2019, The bonitation method for assessing the fertility of the chernozem, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 19(3), 107-111.
[12]Ciontu, C., Săndoiu, D. I., Penescu, A., Gâdea, M, Schiopu, T., Obriscă, M., Dincă, L., 2012,The essential role of crop rotation and nitrogen fertilization in wheat and maize in the sustainable agriculture system of reddish preluvosoil, AgroLife Scientific Journal 1(1), 68-77,
https://agrolifejournal.usamv.ro/index.php/agrolife/article/view/10, Accessed on Sept. 10, 2023.
[13]Cociu, A., Cizmaș, G.D., 2015, Maize yield and its stability as affected by tillage and crop residue management in the eastern Romanian Danube Plain. Scientific Papers. Series "AgroLife Journal", Vol. 4(1), 46-51.
[14]David, Gh., Borcean A., 2011, Cereals and legumes for grains, Eurobit Publishing House, Timişoara, p. 13.
[15]Dobre, M., 2019, Agrotechnics, Universitaria, Publishing House, Bucharest, pp. 29-31.
[16]Dumbrava, M., Basa, A.G., Ion, V., Dobrin, I., 2015, Analysis of the yield components at maize under the specific conditions from South Romanian. Book of Proceedings, Sixth International Scientific Agricultural Symposium „Agrosym 2015", pp. 291-295.
[17]Grassini, P., Yang, H., Cassman, K.G., 2009, Limits to Maize Productivity in Western Corn-Belt: A Simulation Analysis for Fully Irrigated and Rainfed Conditions. Agricultural and Forest Meteorology, 149, pp. 1254-1265.
[18]Ion, V., Dicu, G., State, D., Fintineru, G., Epure, L.I., Basa, A.G., Toader, M., 2013, Yield components of different hybrids of maize (*Zea mays* L.) cultivated in South Romania under drought conditions. Scientific Papers. Series A. Agronomy, Vol. LVI, pp. 276-283.
[19]Ionescu, G., Staicu, I.R., 2008, Agrotechnics (Vol. I), Agro-Silvică Publishing Houser, Bucharest, p. 22.
[20]Mihai, M., 2019, Romania Encyclopedia, South-East development region, Bucharest, p. 48.
[21]Ministry of Agriculture and Rural Development, MARD, Statistics, https://www.madr.ro/, https://www.madr.ro/statistica.html, Accessed on Sept. 9, 2023.
[22]National Institute of Statistics, NIS, Vegetal production for the main crops in 2022, https://insse.ro/cms/,
https://insse.ro/cms/sites/default/files/com_presa/com_pdf/prod_veg_r22.pdf, Accessed on Sept. 9, 2023.
[23]Oltenacu, C. V., Burcea, M., Oltenacu, N., Dima, F. M., 2022, The evolution of cultivated areas and the productions obtained at four agricultural crops cultivated in a conventional and ecological system in the period 2016-2020 in Călăraşi county. AgroLife Scientific
Journal, 11(2).https://doi.org/10.17930/AGL2022216.
[24]Popescu, A., 2018, Maize and wheat - top agricultural products produced, exported and imported by Romania. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 18(3), 339-352.
https://managementjournal.usamv.ro/pdf/vol.18_3/volume_18_3_2018.pdf, Accessed on Sept. 10, 2023.
[25]Sala, F., Boldea, M., 2011, On the optimization of the doses of chemical fertilizers for crops. AIP Conference Proceedings, 1389, 1297.
[26]Săndoiu, D.I., Dumitrescu, N.C., Ştefanic, Gh., Obrişcă, M., Gheorghiţă, N., Ciontu, C., Săndoiu, I.F., 2007, Influence of crops rotation and fertilization with nitrogen on autumn maize productions and grains and fertilization of brown-red soil. In vol. Improvement, preservation and use of damaged soils by anthropic interventions, Ion Ionescu de la Brad Publishing House, Iaşi, pp. 20-40.
[27]Shah, T.R., Prasad, K., Kumar, P., 2016, Maize - A potential source of human nutrition and health: A review. Cogent Food & Agriculture, 2(1), 1166995.
[28]Stancu, M. R., 2010, Romania's agriculture compared to EU exigencias, ASE Publishing House, Bucharest, p. 12.
[29]Toader, M., Roman G.M., 2008, General Agriculture, Part I – Universitaria Publishing House, Bucharest, pp. 62 -63.

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INFLUENCE OF INDEBTEDNESS ON PROFITABILITY OF AGRICULTURAL ENTERPRISES IN THE REPUBLIC OF SERBIA

Vasili Vasilije OSTOJIĆ, Bojan SAVIĆ, Zorica SREDOJEVIĆ

University of Belgrade, Faculty of Agriculture, Nemanjina 6, 11080 Zemun, Serbia, Phones/Fax: +381 11 441-3215; +381 11 441-3211; +381 11 441-3297; E-mails: vasilije.ostojic@agrif.bg.ac.rs; bsavic@agrif.bg.ac.rs; zokas@agrif.bg.ac.rs

Corresponding author: vasilije.ostojic@agrif.bg.ac.rs

Abstract

Different capital structures and their impact on firm performance are one of the most studied topics in the finance literature. This study is an attempt to assess the impact of financial structure on profitability of agricultural enterprises in the Republic of Serbia, with the aim of evaluating the importance and nature of the contribution of the total, short-term and long-term aspects of debt to the success of the company. The financial performance of the selected sample of 38 medium and large agricultural enterprises in the Republic of Serbia was analysed in the period from 2018 to 2021. The findings of this paper indicate that total debt and short-term debt significantly determine the return on equity, while the effect of long-term debt is insignificant. The nature of the impact of all three aspects of financial structure is negative. The inclusion of size and growth of sales in the regression models showed that only annual sales growth significantly positively determines profitability.

Key words: *business success, indebtedness, regression analysis, determinants of profitability, agricultural enterprises*

INTRODUCTION

Indebtedness and the size of the company are the two most frequently examined determinants of company success. Different capital structures and their implications on profitability are some of the most represented and discussed topics in financial literature [2]. The previous is also one of the key issues that determines the long-term development of a company, which simultaneously depends on internal (property structure, level of return on total invested funds, level of cash flow and profitability) and external factors such as the amount of taxes and interest paid, the level of competition and information asymmetry [9]. The relatively low accumulation capacity and slow cash turnover in agricultural enterprises emphasise the importance of proper planning and management of the various sources of funding [11]. Therefore, the object of research of this paper is the impact of the financial structure on the profitability of agricultural enterprises of the Republic of Serbia, with the aim of evaluating the importance and the nature of the contribution of different aspects of debt (total, short-term and long-term) to the success of the company. Since the existing research on the profitability determinants of agricultural enterprises in the Republic of Serbia indicates that there is no relationship between the measures of financial structure and success, this study attempts to disaggregate and analyse the impact of debt by the maturity date [6]. It is emphasized that authors have so far investigated the state of different aspects of indebtedness of agricultural enterprises in the Republic of Serbia [3, 8], however, the focus of the aforementioned studies was not the analysis of its relationship with business success. The breakdown and examination of the impact of individual aspects of debt has so far been carried out in an analysis that included the operations from companies regardless of the sector of economic activity [4]. Selected financial ratios were calculated based on data from publicly available balance sheets and income statements of medium and large agricultural companies for the period from 2018 to 2021 and used as variables in the regression models.

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MATERIALS AND METHODS

The sample used for this study included 38 medium and large agricultural enterprises (all large Serbian agricultural companies and about 35% of medium enterprises in the sector), whose predominant activity is classified as sector A - Agriculture, forestry and fishery, according to the Law on Classification of Activities [5] (138 sample units). According to the Serbian Accounting Law [1], companies can be micro, small, medium and large legal entities based on the following criteria (Table 1).

Table 1. Criteria for the classification into enterprise size classes in the Republic of Serbia

Company size	Average number of employees	Business income (euro)	Value of total assets (euro)
Micro	10	700,000	350,000
Small	50	8,000,000	4,000,000
Medium	250	40,000,000	20,000,000

Source: Systematization of authors based on [1].

If the company exceeds the threshold value for a certain size according to two of the three criteria, it is classified in the next group. Similarly, large legal entities are all companies and entrepreneurs that exceed at least two threshold values for the medium-sized group. The mean monthly number of employees includes those working abroad [1]. Large and medium-sized companies are subject to the greatest responsibility in relation to various financial and non-financial reporting requirements, and therefore their reports are assumed to be more reliable, which has led to the exclusion of micro and small companies from the sample of this research. The analysis covers the operations of the companies in the period from 2018 to 2021. By calculating ratio indicators based on financial data from publicly available financial reports published by the Serbian Business Registers Agency, the state of indebtedness and profitability of the sampled agricultural enterprises was determined.

In order to examine the impact of different aspects of the financial structure on profitability, three regression models were formed with three variables (predictors) each, with ROE (return on equity - the share of net profit in the shareholders' equity in a given year multiplied by 100) as the dependent variable, which is a frequently used measure in previous studies in which the business success of agricultural enterprises was considered [3, 8, 12]. It is also emphasized that ROA (return on assets) is also often present as an indicator of profitability in similar studies, which, in addition also considers assets acquired from borrowed sources [7, 8, 10]. The models include one indebtedness indicator each, namely model 1 - financial leverage (LEV) - ratio of total debt to equity, model 2 - share of short-term debt (SHORT) and model 3 - share of long-term debt (LONG) in total assets. Following the example of the previous research in which the impact of various aspects of indebtedness was considered [4], sales growth and firm size were also included in the regression models as control variables. Sales growth (SALES) is defined as the average annual growth rate of sales revenue, while the logarithm of the value of the company's business assets (SIZE) was chosen as a measure of company size.

Accordingly, the following general form regression models were defined:

Model 1: $ROE = \beta_0 + \beta_1 LEV_{it} + \beta_2 SALE_{it} + \beta_3 SIZE_{it} + \varepsilon_{it}$

Model 2: $ROE = \beta_0 + \beta_1 SHORT_{it} + \beta_2 SALE_{it} + \beta_3 SIZE_{it} + \varepsilon_{it}$

Model 3: $ROE = \beta_0 + \beta_1 LONG_{it} + \beta_2 SALE_{it} + \beta_3 SIZE_{it} + \varepsilon_{it}$

where: β_0 is the free term, β_1-β_3 are regression coefficients, ε is the random error, for company *i* in year *t*.

RESULTS AND DISCUSSIONS

The profitability of the sampled agricultural enterprises varied significantly. The average and median rates of return on equity differed slightly (3.36% and 3.24% respectively), while the highest and lowest recorded values were 13.07% and -11.54% (Table 2).

In 18 out of 152 cases, negative profitability was determined, while the largest number of companies (in about 54% of cases) recorded a rate from 0% to 5%. The values of the indicators of the financial structure indicate a relatively low level of indebtedness.

Table 2. Descriptive statistics of variables in regression models

Variable	N	Mean	Median	Std. Dev.	Min.	Max.
ROE	138	3.36	3.24	4.3458	-11.54	13.07
LEV	138	0.63	0.44	0.6634	0.02	3.02
SHORT	138	0.23	0.20	0.1574	0.01	0.74
LONG	138	0.08	0.06	0.0925	0.00	0.42
SIZE	138	20.30	21.35	3.1457	13.62	25.65
SALES	138	6.98	4.72	19.7254	-40.89	63.92

Source: Own calculation.

More than 75% of the considered companies are predominantly financed from their own funds compared to borrowed sources, while short-term is more present than long-term debt. The natural logarithm of the company size records an average value of 20.3 (median 21.35), which corresponds to the value of business assets of about 5.6 million euros. The sales growth rates determined in the period under review are distributed roughly evenly around the neutral rate, with an average of 6.98% (median 4.72%).

The effect of debt on the profitability of agricultural enterprises

The calculated indicator values indicate the existence of at least a weak relationship between all independent and the dependent variable, which is the basic assumption for the application of multiple regression (Table 3).

Table 3. Pearson's (above) and Spearman's (bellow) coefficients

Variable	ROE	LEV	SHORT	LONG	SIZE	SALES
ROE		-.190*	-.195*	-.105	-.134	.193*
LEV	-.175*		.862**	.515**	.127	-.016
SHORT	-.150	.918**		.193*	.089	-.012
LONG	-.098	.638**	.353**		.158	.069
SIZE	-.206*	.015	-.076	.188*		-.047
SALES	.273**	.022	-.007	.050	.008	

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
Source: Own calculation.

The strong link between the total debt to capital ratio (LEV) and the share of short-term debt is a consequence of the previously mentioned low long-term indebtedness of agricultural enterprises. It is also concluded that the models are free from multicollinearity, since the values of Tolerance and VIF (Variance Inflation Factor) statistics are greater than 0.1 and less than 10.0, respectively for all independent variables (Table 4).

Table 4. Tolerance and VIF (Variance Inflation Factor)

Variable	Model 1		Model 2		Model 3	
	Toler.	VIF	Toler.	VIF	Toler.	VIF
LEV	.984	1.016				
SHORT			.992	1.008		
LONG					.969	1.032
SIZE	.982	1.018	.990	1.010	.972	1.029
SALES	.998	1.002	.998	1.002	.992	1.008

Source: Own calculation.

The results of the regression analysis and the formed regression models point to a statistically significant negative relationship between financial leverage and profitability, and between the level of short-term debt and profitability (Table 5).

Table 5. Regression Models

Models	LEV	SHORT	LONG	SIZE	SALES	Adj. R^2	F
Model 1	-.174** (-1.137)			-.103 (-.143)	.185** (.041)	0.062	4.021*
Model 2		-.183** (-5.058)		-.109 (-.151)	.186* (.041)	0.066	4.215*
Model 3			-.101 (-4.754)	-.109 (-.150)	.195** (.043)	0.042	2.997**

*,**,*** Significant at the 1%, 5%, and 10% respectively.
Source: Own calculation.

The insignificant effect of long-term debt on the success of agricultural enterprises is also found, which is due to its low share in borrowed sources. Nor does firm size significantly influence return on equity. Limitations of the aforementioned conclusion are the exclusive representation of medium and large-sized entities in the research sample. Finally, the observed relationship between the annual sales growth rate and the profitability measure is positive and statistically significant in all three models (at the 5% risk level).

CONCLUSIONS

The results of this study indicate that total debt and short-term debt have a significant negative impact on the profitability of the analysed agricultural enterprises. Proper management and planning of debt is therefore necessary, especially for short-term items, which represent a larger share of borrowed funds. The relatively low representation of long-term debt is primarily related to the unfavourable credit conditions for the agricultural sector in the Republic of Serbia. Overcoming the mentioned limitation requires harmonizing the repayment terms, interest rates and other lending conditions with the specifics (primarily a smaller number of capital turnovers during the year) and the recorded results in the agricultural production. Regression analysis confirmed the importance of sales growth as a determinant of business success. The conclusion about the insignificant contribution of the size of the company is limited by the fact that the research sample exclusively analysed the operations of medium and large entities.

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REFERENCES

[1]Accounting Law, Official Gazette of the Republic of Serbia, No 73/2019-11, 44/2021-4 (other laws).
[2]Avcı, E., 2016, Capital structure and firm performance: An application on manufacturing industry. Marmara Üniversitesi İktisadi ve İdari Bilimler Dergisi, 38(1):15-30
[3]Denis, K., 2021, Financial stability of enterprises in Serbian agriculture, fishing and forestry sector, Ekonomika poljoprivrede 2021, vol. 68(3), 745-758. https://scindeks.ceon.rs/article.aspx?artid=0352-34622103745K, Accessed on May 17, 2023
[4]Janković, M., Jovanović, D., 2016, Influence of leverage on profitability of companies in the Republic of Serbia. In Contemporary Issues in Economics, Business and Management–EBM 2016: Conference Proceedings, 233-242.
[5]Law on Classification of Activities, Official Gazette of the Republic of Serbia, No 104/2009.
[6]Milašinović, M., Mitrović, A., 2021, Internal determinants of profitability for agricultural companies in Serbia (2020), Agroekonomika / Agrieconomica, 49(88), 1-9, https://agris.fao.org/agris-search/search.do?recordID=RS2021000119, Accessed on May 17, 2023.
[7]Milić, D.M., Tekić, D.D., Novaković, T.J., Zekić, V.N., Popov, M.R., Mihajlov, Z.G., 2022, The impact of profitability and productivity on the risk of bankruptcy for agricultural and food companies in Vojvodina, Journal of Agricultural Sciences (Belgrade) Vol. 6791), 47-61. https://doiserbia.nb.rs/img/doi/1450-8109/2022/1450-81092201047M.pdf, Accessed on May 17, 2023.
[8]Mirović, V., Kalaš, B., Mijić, K., 2019, Analysis of variations in profitability and indebtedness of agricultural companies in AP Vojvodina, Facta Universitatis, Series Economics and Organization, Vol.16(2), 161-169, https://doi.org/10.22190/FUEO1902161M
[9]Stekla, J., Grycova, M., 2016, The Relationship between Profitability and Capital Structure of the Agricultural Holdings in the Czech Republic. Agricultural Economics, 62(9):421-428.
[10]Stoicea, P., Toma, E., Iorga, A.M., Dobre, C., Ignat, R.I., 2022, Implications of turnover on the profitability of medium-sized farms in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.22(4), 713-722, https://managementjournal.usamv.ro/pdf/vol.22_4/Art76.pdf, Accessed on May 17, 2023.
[11]Tomašević, S., 2020, Determinants of profitability of agricultural enterprises in the Republic of Serbia (doctoral thesis), University Singidunum, Belgrade.
[12]Vukoje, V., Miljatović, A., Tekić, D., 2022, Factors influencing farm profitability in the Republic of Serbia, Economics of Agriculture, Vo.69(4), DOI: https://doi.org/10.5937/ekoPolj2204031V, a.bg.ac.rs/index.php/EA/article/view/2029, Accessed on May 17, 2023.

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THE INTEGRATION OF ROMANIA INTO THE EUROPEAN UNION MARKET OF SUNFLOWER SEEDS

Radu Lucian PANZARU[1], Dragoş Mihai MEDELETE[1], Gavril ȘTEFAN[2], Mihaela BALAN[1]

[1]University of Craiova, Faculty of Agronomy, 19 Liberty Street, 200421, Craiova, Romania, Phone: +40 741 180 976, Fax: + 40 251 418 475, E-mails: rlp1967craiova@gmail.com, dragosmedelete@gmail.com
[2] University of Life Sciences of Iași, Faculty of Agriculture, 3 Mihail Sadoveanu Street, 700490, Iaşi, Romania, Phone: +40 232 219 175, Fax: +40 232 219 175, E-mail: stef_gav@yahoo.com

Corresponding author: dragosmedelete@gmail.com

Abstract

Sunflower is the most important oil crop practiced in Romania, in terms of the constituent indicators of the primary supply, but also by the fact that sunflower seeds have a surplus trade balance at national level. Culture has a high productive potential, it comes to exploit the existing opportunities on the market, in terms of existing opportunities nationally and internationally. Over time, Romania has been a dynamizing factor of scientific research in the field, highlighting the concerns of researchers from National Institute of Agricultural Research and Development (INCDA) Fundulea for the creation of a quality genetic material. It should be noted that the favorability of sunflower cultivation is quite pronounced at EU level, both due to the pedoclimatic conditions and due to the existing traditions in certain areas (less tradition in the extreme Southern part of the EU), for the practice of other crops providing raw materials for obtaining oil or consumption habits of the population (olive - in the Mediterranean area). The topic of this paper was approachd based on the existing global and continental context for the period 2007-2019. The results showed that in this period 2007-2019, Romania cultivated (on average) 3.81 and 5.39 of the world and European area respectively (966.84 thousand ha compared to 25,325.47 and 16,298.01 thousand ha respectively), achieved 4.62 and 6.79% of the total production (1,919.96 thousand tons compared to 41,548.57 and 28,296.81 thousand tons). The importance on the international market is highlighted by the fact that Romania held 22.52 and 26.97% of the world and continental volume of exports (1,070.99 thousand tons compared to 4,755.42 and 3,971.52 thousand tons), and for imports, the shares were 3.96 and 6.05% (183.47 thousand tons compared to 4,629.84 and 3,220.90 thousand tons respectively). Romania is not an important player in the market of this product at European and global level, especially since sunflower seeds can reduce the deficit of the external trade balance, given the appropriate use of the specific national potential.

Key words**:** *sunflower, export, import, price, total production, yield, cultivated area*

INTRODUCTION

The sunflower culture is distinguished by a fairly significant spread worldwide. Due to the relatively high ecological plasticity of the sunflower, it is grown in large number of countries [4]. The widespread practice of sunflower cultivation worldwide is also influenced by its adaptation to less favorable climate and soil conditions. Drought tolerance and adaptation to a wide variety of soils allows the cultivation of sunflower in many regions of the world [21]. However, the sunflower is a plant sensitive to water stress. Water stress manifests itself as a major limiting factor for sunflower production in arid and semi-arid regions of the world [8]. The sunflower, although it is known as a drought-resistant plant, it greatly reduces its yield on soils without water or in conditions of low atmospheric humidity [15].

As a favorable factor for the practice of sunflower cultivation, the agricultural policy practiced at the level of a region can also be manifested. Thus, in the European Union in 2013, the common agricultural policy included as a priority the increase of vegetable protein production by subsidizing legume crops (including non-genetically modified soybeans), fodder crops (alfalfa, clover) and oilseeds (sunflower, rapeseed) [14].

Globally, it can be appreciated that sunflower is an important source of oilseeds. Among oilseeds, soybeans are the main product influencing world oilseed production, followed by mustard, rapeseed, cotton, peanuts and sunflower [16]. Sunflower (*Helianthus annuus L.)* is one of the main oil crops, with a production of 40-50 million tons per year [13].

Production results are influenced by a number of technological factors. Thus, one of the key factors in increasing the yield of sunflower and other crops is the use of high-quality seeds, with high biological content and high cultural value, free from diseases and pests [18].

Sunflower is a major oil crop for Romania, it is notable for its versatile importance, manifested in terms of industry, feed, agrotechnical-technological, for export and as a source of profit. According to various studies, sunflower is a nationally important crop. In Romania, the share of cereals in the total sowing area was higher than 65% in 2012. Of the total area of cereals, wheat and corn accounted for 35% and 50%, respectively. Other important crops are sunflower, barley, potatoes and oats [1]. This situation makes our country an important producer worldwide. Thus, in 2016, Romania ranked 5th in the world top of growers [2].

The industrial importance of sunflower seeds is underlined by its use for obtaining mainly edible oil. Edible oil is of good quality [17]. It should be noted that sunflower oil currently accounts for 11% of edible oil worldwide [12]. The processing yield of sunflower seeds is influenced by a number of factors. Thus, the oil content is influenced by the character of the year, the time of sowing, the hybrids used and the interaction of these factors [10]. The quality of the oil is influenced by the ratio between saturated and unsaturated fatty acids [9]. In addition to human consumption of the oil, it can also be used in the manufacture of preserves, soap and the impregnation of certain textiles. The seeds can also be used to obtain biofuel. Food crops, such as sunflowers, are a promising alternative to renewable energy, but their use for biodiesel production could be a threat to the amount of food available for human consumption, especially in developed countries [21]. As a result, sunflower has been recognized as a promising crop for biofuel production [6].

Ethyl alcohol, furfural, etc. can be extracted from the seed husks. or they can also give rise to by-products (cakes, grits).

The agrotechnical-technological importance is highlighted, at least, by the inclusion of the crop in appropriate crops and rotations or by the use of particular soil types. Sunflower has an important role in the crop rotation system [7]. Compared to other crops, sunflower has been shown to be moderately tolerant at salt [5]. The importance as an export item is obvious. Sunflower seeds contribute to the completion of the export of oilseeds, in the context in which it is shown that oilseeds are the subject of international trade being a good deal for exporters [11]. The importance of sunflower seeds is closely linked to its export potential [4]. It is interesting to analyze the way Romania integrates on the community market (U. E.), after the accession to the U.E., aspect with consequences on the subsidization of the producers from the Romanian agriculture, but also through the prism of the import-export operations carried out on the market of this product.

In this context, the research aimed to analyze Romania's sunflower cultivated area, production, trade, price in te period 2007-2019, pointing out the main trends in its position in the European and world market.

MATERIALS AND METHODS

The conception and realization of the study started from the research carried out through the documentation, accessing different databases (FAO and the National Institute of Statistics) [3, 20]. In addition to the documentation, the following were also used: comparison, in time and space, correlation, as well as the percentage method. The indicators used are represented by: harvested area (thousand ha), total production (thousand t), average production (kg / ha), selling price ($ / t), imports (thousand t) and exports (thousand t), achieving -then correlations between some of them. A dynamic series of 13 terms is presented, in order to remove, as far as possible, the short-term influences of some factors (the climatic factor) on the analyzed phenomena.

The level of indicators is presented for the component states of the European Union, as well as at general community level. Thus, for area, total production and average production, information can be found for: Austria, Bulgaria, Belgium, Czech Republic, Croatia, France, Germany, Greece, Italy, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Hungary (in the related tables are presented the general levels of indicators - EU 28 and for the first seven producers, the rest of the countries being included in the category "other countries", except for the average production). The price level is presented for 14 states [21]. With regard to imports and exports, the general Community level (EU 28), the main market players (Bulgaria, France, the Netherlands, Romania, Slovakia Hungary - for exports; France, Germany, Italy, the Netherlands, Portugal, Romania, Spain - on imports) and the category "other countries" (Austria, Belgium, Cyprus, Czech Republic, Croatia, Denmark, Estonia, Finland, Greece, Ireland, Latvia, Lithuania, Luxembourg, Malta, United Kingdom, Poland, Slovakia, Slovenia and Sweden).

To highlight the correlation between: (I) surface (x) and total production (y), (II) surface (x) and average yield (y); (III) average yield (x) and total production (y), (IV) total production (x) and export (y), (V) total production (x) and import (y), (VI) export (x) and import (y) at national and UE level. The equation used for the correlation coefficient was:

$$r = \frac{\sum (x_i - \overline{X})(y_i - \overline{Y})}{\sqrt{\left(\sum (x_i - \overline{X})^2\right)\left(\sum (y_i - \overline{Y})^2\right)}},$$

where:

$\bar{X}$ and $\bar{Y}$ - are the averages for samples, average (matrix 1) and average (matrix 2).

In the analysis, the values of the correlation coefficient (r) and of the determination coefficient (R^2 - for the linear function) will be presented, but only at general community level and for Romania.

RESULTS AND DISCUSSIONS

The situation corresponding to the harvested area is presented in Table 1.

Table 1. Harvested area (thousand ha) *

The country	Year												
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU 28	3,298.96	3,784.80	3,912.34	3,768.29	4,336.44	4,286.36	4,578.37	4,251.64	4,181.97	4,122.43	4,295.97	4,025.65	4,338.74
Bulgaria	602.40	721.69	683.72	729.89	747.13	780.76	878.64	843.64	810.84	817.51	898.84	788.66	815.56
France	519.50	629.74	724.84	694.92	740.72	679.96	770.85	657.29	618.78	536.96	586.23	552.07	603.92
Italy	126.26	114.48	123.80	100.50	118.07	111.68	127.63	111.35	114.45	110.72	114.45	103.87	118.52
Romania	748.54	808.79	761.09	786.06	993.26	1,064.75	1,072.06	998.04	1,009.14	1,038.41	999.16	1,006.99	1,282.70
Slovakia	64.75	74.93	82.94	82.87	88.70	90.12	84.13	76.59	75,40	83.79	87.35	68.80	48.55
Spain	600.87	730.82	851.12	697.90	862.87	753.02	849.10	783.44	738.85	717.67	724.63	691.28	701.77
Hungary	512.87	549.80	535.09	501.51	579.55	615.10	596.89	593.73	611.64	629.68	694.54	616.95	564.11
Other states	123.77	154.55	149.74	174,65	206.15	190.97	199.07	187.56	202.87	187.69	190.77	197.03	203.61

Source: * http://www.fao.org/faostat/fr/#data/QC(10.03.2023) [3].

At EU level, the cultivated area was between 3,298.96 thousand ha, in 2007, and 4,578.37 thousand ha, in 2013. Between 2007 and 2009, there is an upward evolution of the indicator, after which the area fluctuates between 2010 and 2019 (decreases and inherent increases). Romania stands out as the main cultivator (areas that have consistently exceeded the threshold of 748 thousand ha - less than 1,000 thousand ha for the years 2007, 2008, 2009, 2010, 2011, 2014 and 2017 and over 1,000 thousand ha in the case of other years). With a relatively similar situation, there are Bulgaria and Spain (which, however, did not exceed the threshold of 1,000 thousand ha), followed by France (between 519 and 771 thousand ha), Hungary (from 501.51 to 694.54 thousand ha in 2010 respectively). 2017), Italy (with areas between 100 and 128 thousand ha) and Slovakia (which did not exceed the threshold of 91 thousand ha, but did not fall below 48 thousand ha). The other states cultivated (in total) between 123.77 and 206.15 thousand ha (2007 and 2011).

Total production shows an uneven evolution (Table 2). We are talking about limits of 4,883.61 thousand t and 10,385.77 thousand t, respectively, at the level of 2007 and 2017 respectively. It is observed, consecutive years with similar trends as follows: 2009 and 2010 - decreases, 2013 and 2014 respectively 2016 and 2017 - increases. Romania obtained below 1,000 thousand t only in 2007 (546.92 thousand t), levels between 1,000 and 2,000 thousand t for the years 2008, 2009, 2010, 2011, 2012 and 2015, productions between 2,000 and 3,000 thousand t for the years 2013, 2014, 2016 and 2017, but also over 3,000 thousand t (2018 and 2019).

Table 2. Total production (thousand t)*

The country	Year												
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU 28	4,883.61	7,215.16	7,062.42	7,021.54	8,499.24	7,116.57	9,152.45	9,242.54	7,846.38	8,708.35	10,385.77	10,003.03	10,281.25
Bulgaria	564.45	1,300.71	1,317.98	1,536.32	1,439.70	1,387.78	1,974.43	2,010.67	1,699.23	1,873.68	2,056.99	1,943.98	1,937.21
France	1,311.27	1,598.27	1,720.15	1,640.83	1,880.70	1,572.95	1,577.69	1,584.19	1,186.91	1,172.41	1,598.97	1,239.08	1,298.14
Greece	19.09	21.47	46.13	116.04	147.66	137.31	172.07	192.23	199.42	186.30	202.90	231.02	298.96
Italy	278.73	260.93	280.20	212.90	274.41	185.49	285.23	250.38	248.01	268.33	243.67	250.46	294.73
Romania	546.92	1,169.94	1,098.05	1,262.93	1,789.33	1,398.20	2,142.09	2,189.31	1,785.77	2,032.34	2,912.74	3,062.69	3,569.15
Spain	733.15	872.69	869.54	887.00	1,090.17	642.02	1,029.40	952.99	769.20	772.18	841.74	960.79	782.29
Slovakia	132.66	192.35	187.24	150.33	200.99	197.23	195.74	200.69	174.29	246.50	218.84	203.83	129.67
Hungary	1,060.46	1,468.10	1,256.18	969.72	1,374.78	1,316.55	1,484.37	1,597.25	1,556.97	1,875.41	2,022.33	1,830.28	1,706.85
Other states	236.88	330.79	286.95	245.47	301.50	279.04	291.43	264.83	226.58	281.20	287.59	280.90	264.25

Source: * http://www.fao.org/faostat/fr/#data/QC(10.03.2023) [3].

The level of the indicator has evolved unevenly, with periods of increase and decrease following one another. Bulgaria presents a situation relatively close to that of Romania (production of less than 1,000 thousand t only in 2007, and the threshold of 2,000 thousand t was exceeded only in 2014 and 2017). Hungary consistently exceeded the threshold of 1,000 thousand t (except for the year 2010 - 969.72 thousand t and respectively the year 2017 - 2,022.33 thousand t). France, another major producer on the Community market, is characterized by total production between 1,000 and 2,000 thousand t. Spain, generally has levels below 1,000 thousand t (except for the years 2011 and 2013 - 1,090.17 and 1,029.40 thousand t respectively). Italy is characterized by total variable productions between 200 and 300 thousand t (except for 2012 - 185.49 thousand t). Slovakia contributed to the establishment of the Community level of the indicator with productions from 129.67 to 246.50 thousand t (2019 and 2016 respectively), while it should be noted the situation of Greece which started from 19.09 thousand t in 2007 and came to exceed 100 thousand t (between 2010 and 2016), respectively 200 thousand t (interval 2017 - 2019). The rest of the sunflower cultivating states obtained annual levels of total production, between 200 and 300 thousand t, except for the years 2008 and 2011 (330.79 and 301.50 thousand t respectively). The evolution of the average production (kg / ha) is shown through Table 3. The indicator is distinguished by its classification in two intervals: between 1,000 and 2,000 kg / ha (2007-2013 and 2015), between 2,000 and 2,500 kg / ha (2014, 2016, 2017, 2018 and 2019, respectively). The evolution over time is upward from 2007 (1,480 kg / ha) to 2011 (1,960 kg / ha), followed by a decrease for 2012 (1,660 kg / ha), increases in 2013 and 2014, followed by decreases in 2015, increases between 2016 and 2018 and at the end there is a decrease for 2019. In Romania, there are the years 2007 (731 kg / ha) and 2018 (3,041 kg / ha), as well as periods with average yields varying between 1,000 and 2,000 kg / ha (years 2008-2013, 2015 and 2016), but also time sequences for which the indicator exceeded 2,000 kg / ha (2014, 2017 and 2019).

Table 3. Average production (kg / ha)*

The country	Year												
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU 28	1,480	1,906	1,805	1,863	1,960	1,660	1,999	2,174	1,877	2,112	2,418	2,485	2,370
Austria	2,251	2,974	2,745	2,617	2,830	2,271	2,352	2,811	1,997	3,294	2,334	2,836	3,037
Bulgaria	937	1,802	1,928	2,105	1,927	1,778	2,247	2,383	2,096	2,292	2,289	2,465	2,375
Czech Republic	2,129	2,493	2,382	2,111	2,483	2,312	2,200	2,274	2,047	2,852	2,461	2,356	2,435
Croatia	2,634	3,103	3,000	2,339	2,828	2,684	3,200	2,853	2,727	2,747	3,119	2,984	2,962
France	2,524	2,538	2,373	2,361	2,539	2,313	2,047	2,410	1,918	2,183	2,728	2,244	2,150
Germany	2,655	1,964	2,411	1,892	1,985	2,379	2,105	2,300	1,919	2,138	2,200	1,821	2,044
Greece	1,589	1,717	1,968	2,170	2,136	2,237	2,380	2,517	2,122	2,438	2,705	2,800	2,968
Italy	2,208	2,279	2,263	2,118	2,324	1,661	2,235	2,249	2,167	2,424	2,129	2,411	2,487
Poland	1,746	1,785	1,811	1,505	1,866	1,761	1,752	1,709	1,645	1,747	1,925	1,630	1,965
Portugal	800	665	537	544	561	534	639	1,056	1,242	1,441	1,546	1,688	1,660
Romania	731	1,447	1,443	1,607	1,802	1,313	1,998	2,194	1,770	1,957	2,915	3,041	2,783
Slovakia	2,049	2,567	2,257	1,814	2,266	2,189	2,327	2,620	2,311	2,942	2,505	2,963	2,671
Slovenia	1,736	1,617	1,454	2,345	2,610	2,365	1,854	2,091	2,513	2,490	1,753	2,724	2,424
Spain	1,220	1,194	1,022	1,271	1,263	853	1,212	1,216	1,041	1,076	1,162	1,390	1,115
Hungary	2,068	2,670	2,348	1,934	2,372	2,140	2,487	2,690	2,546	2,978	2,912	2,967	3,026

Source: * http://www.fao.org/faostat/fr/#data/QC (10.03.2023) [3].

In the case of sunflower cultivating states, the following aspects are manifested: average yields between 2,000 and 3,000 kg / ha for Austria (except for the years 2015 - 1,997 kg / ha, 2019 - 3,037 kg / ha and 2016 - 3,294 kg / ha), Czech Republic, Croatia (four years with levels above 3,000 kg / ha - 2009, 2008, 2017 and 2013), France (except for 2015 - 1,918 kg / ha), Germany (except for five years with productions that did not reach 2,000 kg / ha - 2008, 2010, 2011, 2015 and 2018, but when the indicator did not fall below 1,800 kg / ha), Greece (except for the first three years when the level of 2,000 kg / ha was not reached), Italy (only in 2012 the indicator was 1,661 kg / ha), Slovakia (with one exception in 2010), Slovenia (five years below 2,000 kg / ha - 2007, 2008, 2009, 2013 and 2017), Hungary (which, however, recorded a level below 2,000 kg / ha - 1,934 in 2010 and one above 3,000 kg / ha - 3,026 in 2019); average yields between 1,000 and 2,000 kg / ha: Poland and Spain (an exception - 853 kg / ha in 2012); yields between 500 and 1,700 kg / ha for Portugal (seven years with levels below 1,000 kg / ha - 2007-2013 and six years above 1,000 kg / ha - 2014-2019). The correlations between area, total production and average production in Romania and in the EU are shown in Table 4. The area and the total production are in a direct correlation, resulting from the values of r (0.8098791 and 0.7562288) and of R^2 for the linear function (0.6559 and 0.5719), aspect highlighted by Figure 1. This direct correlation is not very strong.

Table 4. Values of correlation coefficient (r) anddetermination coefficient (R^2) of surface, total production and average yield*

Correlation	Reference level	r	R^2
Surface (ha) – total production (t)	Romania	0.8098791	0.6559
	EU 28	0.7562288	0.5719
Surface (ha) – average yield (kg/ha)	Romania	0,640222	0.4099
	EU 28	0.512407	0.2626
Average yield (kg/ha) - total production (t)	Romania	0.960473	0.9225
	EU 28	0.9475	0.8978

Source: *own calculation.

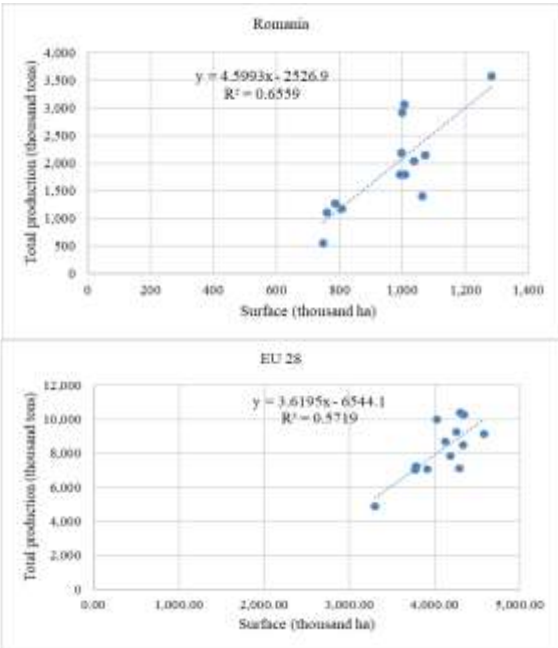

Fig 1. Correlation between surface (thousand ha) and total production (thousand tons) in Romania and in the EU
Source: own calculation.

Between the surface and the average production there are correlation coefficients of 0.640222 and 0.512407, respectively a low dependence between the two aspects. The coefficient of determination R^2 has values of: 0.4099 and 0.2626 (Figure 2). Consequently, a correlation between phenomena is found, but the mathematical model cannot be recommended.

If we analyze the dependence between the average production and the total production, we find the existence of a significant positive correlation (0.960473 and 0.9475). Starting from the values of the coefficients of determination (0.9225 and 0.8978) it is found that the mathematical forecasting model can be recommended for use (Figure 3).

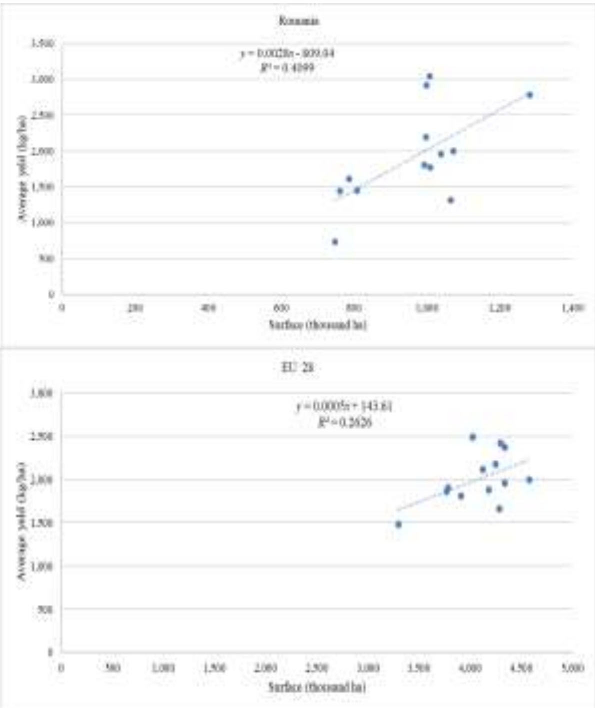

Fig. 2. Correlation between surface (thousand ha) and average yield (kg/ha) in Romania and in the EU
Source: own calculation.

The price level is presented in Table 5. The existence of information for 14 cultivating states is found, with the mention that it discusses the price level at the producer. In the case of Germany, there are no data for the period 2007-2011, for Italy there is information only for 2007, and in Slovenia, for the period 2012-2019 there are no price levels.

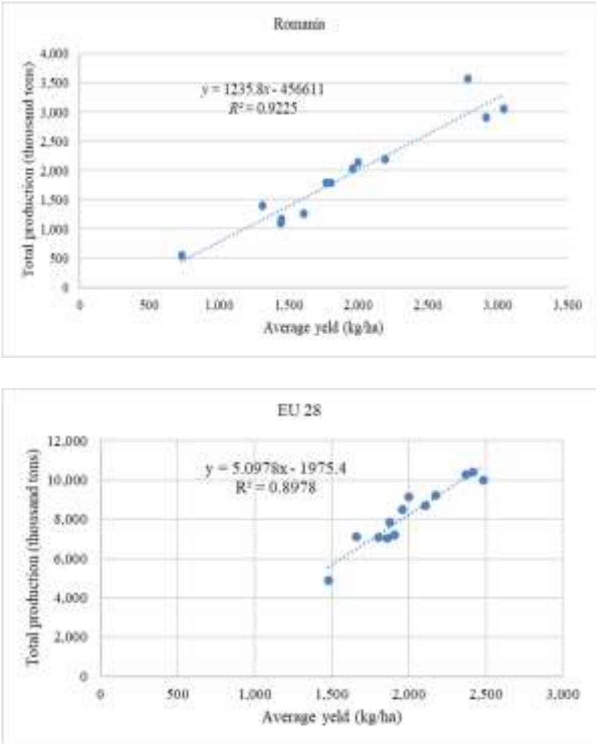

Fig. 3. Correlation between average yield (kg/ha) and total production (thousand tons) in Romania and in the EU
Source: own calculation.

The price variation limits were 216.7 \$/t (2009 - Austria) and 718.2 \$/t (2008 - Portugal), respectively. It can be seen that 2012 was the most favorable for producers, in terms of the price obtained (levels that exceeded the threshold of 500 \$/t, nine states are characterized by values between 500 and 600 \$/t, three countries recorded levels over 600 \$/t). The year 2009 is characterized by the lowest price levels (only for Greece, the threshold of 400 \$/t was exceeded). The evolution of prices is uneven, with inherent variations from one year to another,with tendencies to reduce the levels of the indicator after 2012, which must be analyzed in the context of the increase in total production obtained at Community level.

In Romania, the price varied from 282 \$/t, in 2009, to 530.5 \$/t in the case of 2012 (total amplitude of variation - 248.5 \$/t). Prices charged, at national level, are in line with the trends manifested at Community level (increase from 2007 to 2008, decrease in 2009, increases until 2012, followed by strict decreases of the indicator until 2019).

Romania stands out as a "normal actor" on the community market in terms of price. If we report the situation of Romania at an average annual price level, it can be seen that, in general, we were below the Community average (2007-2010, 2012, 2014-2019), except for 2011 and 2013 when we exceeded the average level (but we were close to it). It is worth noting the totally unfavorable situation specific to 2019, when Romania is characterized by the lowest price level (304.4 $/t), among all EU countries.

The concrete aspects regarding sunflower exports are highlighted in Table 6.

The presentation of the situation of Romanian exports and imports of sunflower is made in the existing situation on the market, at least, European. Romania is the most important producer and exporter of sunflower seeds in the European Union [11].

Table 5. Price level ($/t) *

The country	Year												
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	446.2	313.5	216.7	524.5	468.4	503.7	391.7	325.1	373.7	333	319.7	294	309.1
Bulgaria	309.3	412.8	272.3	364.2	493.2	552.6	411.9	405.6	395.4	394.2	362.8	343.4	336.3
Czech Republic	367.4	544	371.6	375	578.7	535.2	542.1	406.9	361.5	391.4	382.1	362.4	326
Croatia	518.4	461.2	297.3	451.1	474.4	578.9	339.6	310.7	352.6	324.9	333.1	296.8	289.6
France	558.9	449.5	365.6	559.3	593.7	624.4	481	491.2	433.1	427	400.2	420.6	412
Germany	-	-	-	-	-	506.2	487.3	411.3	353.8	-	334.4	371.5	377.7
Greece	342.2	550.8	514	509.9	590.8	578.2	534.1	464.4	388.2	387.2	395.4	413.3	392
Italy	300.8	-	-	-	-	-	-	-	-	--	-	-	-
Portugal	444.2	718.2	347.3	375.5	444.8	668.1	464.7	437.8	415.9	419	434.9	413.3	413.8
Romania	344.5	444.6	282	374.5	518.3	530.5	477.8	376.2	374.5	372	338.1	334.9	304.4
Slovakia	451.6	395.1	278.9	459.3	495.6	573	430.2	368.9	380.8	358.4	352.1	334.5	342.5
Slovenia	410.6	366.2	347.3	331.1	567.1	-	-	-	-	-	-	-	-
Spain	539.7	567	312.9	484	528.4	642.9	451	407.3	404.1	385.2	372	361.7	353.6
Hungary	465.6	466.9	292.6	434.9	543.4	595.6	446.2	413.8	403.3	375.9	364.4	359.8	346.6

Source: *http://www.fao.org/faostat/fr/#data/PP (10.03.2023) [3].

Table 6. Sunflower export (thousands t) *

The country	Year												
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU 28	1,932.13	2,163.63	3,141.13	2,738.37	3,497.31	2,982.41	4,111.69	3,618.04	3,096.35	3,094.88	3,361.68	4,074.17	4,291.63
Bulgaria	332.21	466.77	1,008.42	579.66	1,040.71	753.93	1,240.27	875.17	715.51	688.02	784.08	779.43	732.03
France	428.93	279.17	338,34	429.27	390.51	445.61	423.88	441.92	403.52	303.22	350.73	550.98	489.72
Netherlands	47.89	32.82	108.80	78.34	31.95	34.65	61.39	47.84	50.18	106.37	96.50	82.65	40.72
Romania	382.69	471.39	564.24	557.41	1,182.87	653.32	1,420.17	1,321.97	1,099.35	1,183.71	1,334.74	1,704.36	2,046.75
Slovakia	97.06	84.01	108.45	98.48	113.34	228.56	268.92	218.22	167.02	176.21	223.35	229.40	198.35
Hungary	442.40	535.27	732.85	662.39	397.66	600.31	362.57	436.22	376.08	357.19	321.29	439.37	470.83
Other states	200.95	294.20	280.03	332.82	340.27	266.03	334.56	276.70	284.69	280.16	250.99	287.98	313.23

Source: *http://www.fao.org/faostat/fr/#data/TP (10.03.2023) [3].

Exports of sunflower, realized at Community level, registered limits of 1,932.13 and 4,291.63 thousand t respectively in the years 2007 and 2019. The evolution of the indicator was uneven: ascending from 2007 to 2009, fluctuating in the years 2010, 2011, 2012, 2013, descending for the period 2014-2016 and increasing between 2017-2019.

Romania stands out with export levels below 1,000 thousand t in 2007 (382.69 thousand t - the lowest level), 2008, 2009, 2010 and 2012, levels between 1,000 and 2,000 thousand t (2011 and 2013- 2018), and in the case of 2019 the threshold of 2,000 thousand t was exceeded (2,046.75 thousand t - the highest level). For Romania, exports evolved upwards from 2007 to 2011, 2012 showed a decreasing trend, followed by an increase in 2013, then there are decreases specific to 2014 and 2015, and for the period 2016-2019 the trend is upward. Romania represented the main Community exporter in 2011 and during the period 2013-2019, and the rest ranked 2nd in 2008 (after Hungary) and 2012 (after Bulgaria) and 3rd in 2007 (after France and Hungary), respectively. 2009 (after Bulgaria and Hungary) and 2010 respectively (after Hungary and Bulgaria).

Table 7 shows the situation of imports of sunflower seeds at Community level.

The European Union recorded imports of sunflower between 1,700.63 and 4,327.82

thousand t in 2007 and 2019. It is worth noting that two years in which the level of imports did not reach 2,000 thousand t (2007 and 2008), three years with variable levels. between 2,000 and 3,000 thousand t (2010, 2011 and 2012), six years in which imported quantities were between 3,000 and 4,000 thousand t (2009 and the period 2013-2017), and two years when the threshold of 4,000 thousand t is exceeded (2018 and 2019). The indicator evolved upwards between 2007 and 2009, decreased in 2010, after which there were increases until 2013, there are decreases in 2014 and 2015, and for the period 2016-2019 there is an upward trend.

Romania made imports of sunflower during the entire period under analysis (from 66.65 thousand t in the case of 2007 to 325.20 thousand t in 2019).

Table 7. Import of sunflower (thousands t)*

The country	Year												
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU 28	1,700.63	1,832.55	3,137,61	2,415,36	2,996.48	2,707,32	3,320.39	3,114.03	3,026,35	3,232.29	3,479.47	4,103.98	4,327.83
France	56.30	66.26	329.65	152.26	426.49	142.83	424.79	361.59	252.91	406.00	338.25	276,78	334.15
Germany	243.38	390.16	441,21	478.70	360.77	530,69	501.55	470,31	423.14	356.92	387.84	447.00	448.27
Italy	260.89	230.56	356.17	220.72	228.06	214.62	249.22	176.22	159.74	225.32	222.57	224.01	237.39
Netherlands	355.60	252.96	824.02	555.95	651.88	462,74	635.58	581.97	674.63	543.41	577.99	999.45	664.32
Portugal	60.96	192.13	149.17	147.19	244.87	285.83	311.54	246.88	236.72	201.18	234.39	246.37	261.56
Romania	66.65	89.58	141.06	208.29	237.38	131.29	93.36	118.93	189.25	197.21	277.34	309.53	325.20
Spain	358.97	236.10	404.15	241.99	301.51	476.79	320.25	411.52	376.21	460.23	461.88	412.95	534.87
Other states	297.88	374.80	492.18	410.26	545.52	462.53	784.10	746.61	713.75	842.02	979.21	1,187.89	1,522.07

Source: *http://www.fao.org/faostat/fr/#data/TP (10.03.2023) [3].

The level of imports was below 100 thousand t in 2007, 2008 and 2013, between 100 and 200 thousand t for 2009, 2012, 2014, 2015 and 2016, from 200 to 300 thousand t in 2010 and 2017, and over 300 thousand t in 2018 and 2019. The indicator experienced an upward trend between 2007 and 2011, after which imports decreased in 2012 and 2013, and from 2014 to 2019 the trend was strictly upward. Table 8 shows the correlations between total production, exports and imports.

Table 8. Values of correlation coefficient (r) and determination coefficient (R^2) of total production, exports and imports*

Correlation	Reference level	r	R^2 Linear function
Total production (thousands t) - export (thousands t)	Romania	0.955749	0.9135
	U. E.	0.8557497	0.7323
Total production (thousands t) – import (thousands t)	Romania	0.7914823	0.6264
	U. E.	0.870356	0.7575
Export (thousands t) - import (thousands t)	Romania	0.702616	0.4937
	U. E.	0.928338	0.8618

*own calculation

Between the total production and export, a direct correlation is established which is significant (values of the correlation coefficient of 0.955749 and 0.8557497 for Romania and the EU). The mathematical model used is a convenient one, highlighting a very significant connection between phenomena (R^2 having values of 0.9135 and 0.7323. (Figure 4). The phenomena are more accentuated for Romania compared to the EU.

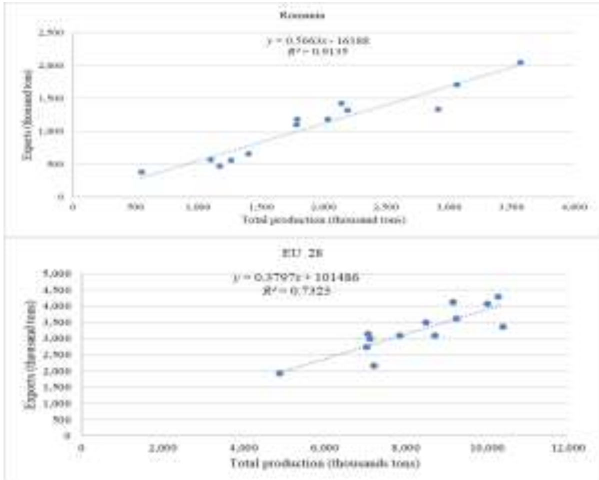

Fig. 4. Correlation between total production (thousand tons) and export (thousand tons), Romania and the EU
Source: own calculation.

The correlation coefficient between the total production and imports, highlights a direct dependence between phenomena, a quite significant one (r has values of 0.7914823 and 0.870356 respectively). The coefficients of determination calculated (R^2), by their values (0.6264 and 0.7575 respectively) underline the links between total production and imports

(Fig. 5). Dependence is stronger in the case of the EU than in the situation of Romania.

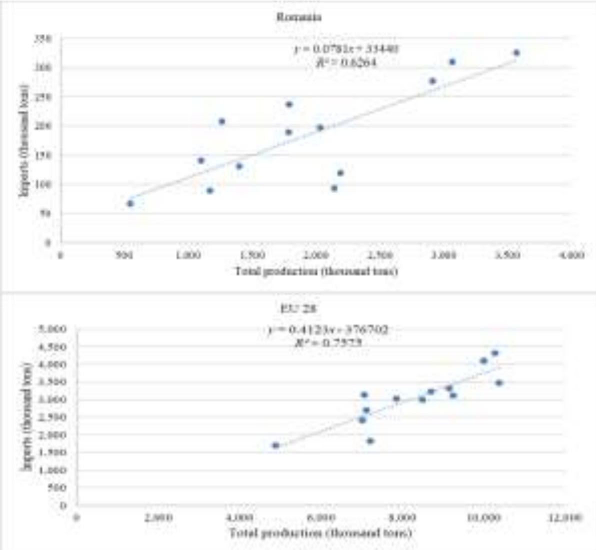

Fig. 5. Correlation between total production (thousand tons) and import (thousand tons) in Romania and in the EU
Source: own calculation.

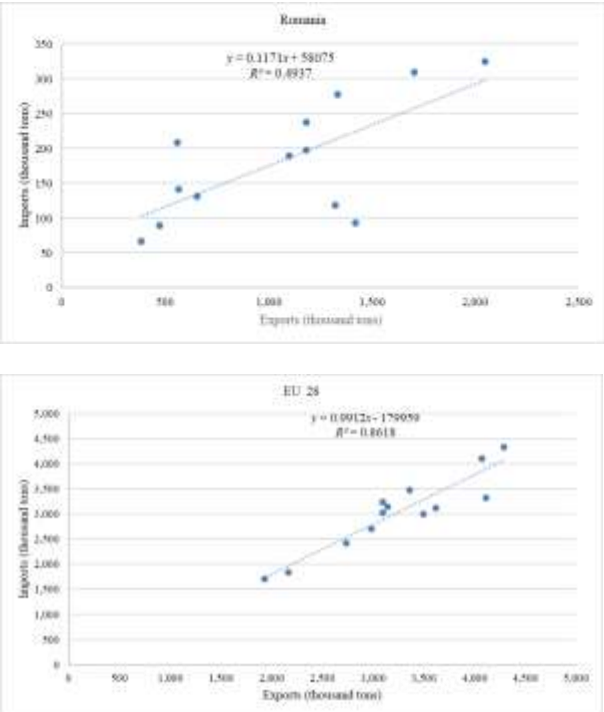

Fig. 6. Correlation between export (thousand tons) and import (thousand tons)
Source: own calculation.

There is a fairly strong link between exports and imports (r has values of 0.702616 and 0.928338 at national and Community level respectively). The linear function, based on the coefficient of determination (R^2 - 0.4937 and 0.8618), can be recommended as a viable mathematical model for the EU (Fig. 6).

CONCLUSIONS

The obtained results pointed out the following conclusions:

In terms of area, Romania is the main cultivator at Community level (1st place - 23.63% in the case of the average period), followed by Spain, Bulgaria, France and Hungary which exceeded the threshold of 500 thousand ha. Compared to the pre-accession period (1995-2006), for Romania there is an increase of about 60 thousand ha of the surface, an increase which is even more accentuated compared to the specific situation of the period 1985-1994 (increase of approximately 470 thousand ha). This aspect was also shown by [19, 20].

Romania is the main Community producer of sunflower (1,919.96 thousand tons - 23.23% of the EU total), followed by Bulgaria, Hungary and France which exceeded the level of 1,000 thousand tons. Compared to the period 1995-2006, at national level, there is an increase of approximately 775 thousand tons, and compared to the period 1985-1994, the increase in production was 2.72 times (706.78 thousand tons) as also attested by [20, 21]. These aspects are related to the potential of the food industry, but also to the possibilities of selling the product on foreign markets.

The improvement of the situation is also manifested for the average production - 1,923 kg/ha compared to 1,440 kg/ha in the period 1985-1994 or compared to the situation of the period 1995-2006 (1,254 kg/ha) as mentioned by [19, 20].

In terms of exports, Romania achieved, on average, 1,070.99 thousand tons, a level that clearly exceeds the specific situations of 1985-1994 and 1995-2006, respectively (200.23 thousand tons and 32.07% of EU exports, respectively). As a result, Romania ranks first in the top of EU exporters for sunflower (we are followed by Bulgaria and Hungary respectively - 768.94 and 471.88 thousand tons respectively).

In terms of imports, Romania ranks 7th in the EU (183.47 thousand tons - 6.05% of the EU total, average for the period). Domestic imports increased about 10 times compared to the pre-accession period (19.02 thousand tons) [20]. However, the trade balance is a surplus, Romania representing an important player on the Community and even world market of sunflower seeds.

Romania can take greater advantage of the opportunities on the international market, but only if it does not discount restrictions on the practice of cultivation and as intensified efforts to capitalize and subsidize producers properly, from plant sector.

REFERENCES

[1]Bozek, J., Sin, A., Grabowski, T., Nowak, C., Nowakowska-Grunt, J., 2016, Structure and dynamics of major crops sown in the European Union, NARDI Fundulea, Romanian Agricultural Research, No. 33, 331-337.

[2]Dana, D., Chiurciu, I.-A., Voicu, V., Soare, E., Popescu, O. M., Popescu, C., 2019, The effect of special foliar fertilization applied on inbred sunflower lines in hybrid sunflower seed production, 2019, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 19(1), 123-126.

[3]FAOStat data base, http://www.fao.org/, Accessed on 10.03.2023.

[4]Hristov, K., Beluhova-Uzunova, R., Shishkova, M., 2019, Competitive advantages of Bulgarian sunflower industry after the accession into the European Union, 2019, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 19(2), 197-202.

[5]Katerji, N., van Hoorn, J. W., Hamdy, A., Mastrorilli, M., 2000, Salt tolerance classification of crops according to soil salinity and to water stress day index, Agricultural Water Management, 43(1), 99–109.

[6]Leite, J., G. D., Justino, F., B., Silva, J.V., Florin, M., J., van Ittersum, M., K., 2014, Socioeconomic and environmental assessment of biodiesel crops on family systems in Brazil, Agricultural Systems, Vol. 133, 22-34.

[7]Mijić, A., Liović, I., Zdunić, Z., Marić, S., Marjanović, J. A., Jankulovska, M., 2009, Quantitative analysis of oil yield and its components in sunflower (*Helianthus annuus* L.), Romanian Agricultural Research, No. 26, 41-46.

[8]Mirshekari, M., Hosseini, N., M., Amiril, R., Zandvakili, O., R., 2012, Study the effects of planting date and low irrigation stress on quantitative traits of spring sunflower (*Helianthus annuus* L.), NARDI Fundulea, Romanian Agricultural Research, No. 29, 189-199.

[9]Păcureanu-Joița, M., Stanciu, D., Petcu, E., Raranciuc, S., Sorega, I., 2005, Sunflower genotypes with high oleic acid content, Romanian Agricultural Research, Number 22/2005, 23-26.

[10]Petcu, E., Popa, O., Partal, E., Pricop, S.-M., 2010, Effect of planting date, plant population and genotype on oil content and fatty acid composition in sunflower, NARDI Fundulea, Romanian Agricultural Research, No. 27, 53-57.

[11]Popescu, A., 2018, Romania's sunflower seeds production, export and import- analysis of the 2007-2017 period and forecast for 2018-2022 horizon, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 18(4), 261-270.

[12]Popescu, A., Cărăba-Meiță, N.-L., 2020, Price elasticity of production in Romania's agriculture - a territorial approach by micro-region, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 20(1), 489-504.

[13]Portlas, Z., Tetlie, J., Prischmann-Voldseth, D., Hulk, B., Prasifka, J., 2018, Variation in floret size explains differences in wild bee visitation to cultivated sunflowers, Plant genetic resources-characterization and utilization, Vol. 16(6), 498-503.

[14]Roman, G., V., Epure, L.L., Toader, M., Lombardi, A., R., 2016, Grain legumes – main source of vegetal proteins for European consumption, AgroLife Scientific Journal, Vol. 5(1), 178-183.

[15]Saucă, F., 2010, Introgression of drought-resistance gene (S) from *Helianthus argophyllus* to *Helianthus annuus* species, using embryo rescue techniques, 2010, NARDI Fundulea, Romanian Agricultural Research, No. 27, 47-51.

[16]Sharma, M., Gupta, S., K., Mondal, A., K., 2012, Production and trade of major world oil crops, Tehnological innovations in major world oil crops, Vol. 1, 1-15.

[17]Soare, E., Chiurciu, I.-A., 2018, Considerations concerning worldwide production and marketing of sunflower seeds, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 18(3), 421-428.

[18]Stanciu, D., Stanciu, M., 2010, Influence of seed quality of parental forms on sunflower hybrid seed, 2010, Romanian Agricultural Research, No. 13-14, 31-44.

[19]Statistical Yearbook of Romania, 1995, National Statistics Commission, Bucharest.

[20]Tempo online, National Institute of Statistics, http://www.insse.ro/, Accessed on 10.03.2023.

[21]Vilvert, E., Lana, M., Zander, P., Sieber S., 2017, Multi-model approach for assessing the sunflower food value chain in Tanzania, Agricultural Systems, Vol. 159, 103-110.

EXPLORING THE STRUCTURE OF INTERNAL COMMUNICATION OF AGRICULTURAL HOLDINGS: AN ANALYSIS THROUGH THE NETWORK APPROACH

Anka-Roxana PASCARIU[1,2], Marius-Ionuț GORDAN[1,2], Tabita-Cornelia ADAMOV[1], Tiberiu IANCU[1,2]

[1]University of Life Sciences"King Mihai I" from Timisoara, 119 Calea Aradului, 300645, Timisoara, Romania, E-mails: suba.anka@yahoo.com, mariusgordan@usvt.ro, tabitaadamov2003@yahoo.com, iancutiberiu10@gmail.com
[2]Doctoral school of Plant and Animal ResourcesEngineering, University of Life Sciences "King Mihai I" from Timișoara, 119 CaleaAradului, 300645, Timisoara, Romania, suba.anka@yahoo.com, mariusgordan@usvt.ro, iancutiberiu10@gmail.com

Corresponding author:mariusgordan@usvt.ro

Abstract

The present work studied the role and efficiency of internal communication in the production activities within the agricultural structures in the Western Region of Romania. Internal communication can be a key element in addressing and solving the major challenges posed by the current competitive environment in the field.This research provides a comprehensive analysis of communication processes within organisations with an agricultural profile, addressing a knowledge gap in the research literature in this field, enhancing the understanding of the role of communication in agriculture. In this context, the main aim of this researchis to investigate various factors like flow, coordination, barriers, communicational efficiency, actuality, frequency, and the effectiveness of communication channels in the context of Western Romania's agricultural holdings. The present study employs a quantitative approach, surveying 503 respondents from 40 agricultural holdings, and uses network analysis and correlation matrices in order to understand communication patterns and the relationships among these factors. The findings highlight the need for customized communication strategies to accommodate differences in age, education, and professional backgrounds among staff. They also stress the importance of using multiple communication channels for timely information exchange, the impact of channel choice on information flow, and the importance of addressing communication barriers. Overall, the study underscores the significance of strategic communication in agriculture for efficiency and coordination among employees, suggesting potential future research in this area.

Key words*: *internal communication, agricultural holdings, production processes

INTRODUCTION

In the 21st century, the financial success of agricultural enterprises is based on the company's ability to have good communication between employees on the one hand, but also with beneficiaries, consumers, and stakeholders [9]. There are noticeable differences from one agricultural structure to another in terms of productions and communication management, which involve a variety of strategies, methods and techniques that must be used to increase the profitability and efficiency of agricultural production processes [32].

Two fundamental pillars that must be included in every organizational strategy, to facilitate the restart of competition in the industrial sector of agribusiness, are innovation and creativity. Every high-performing organization has these two pillars in its internal communication strategy, which add value and are success factors. Organizational communication processes are constantly evolving and changing, so that every agricultural enterprise must anchor itself to the current environmental conditions to survive a dynamic market, considering that today, the Internet has had a major impact, revolutionizing both the social and the professional environment [36].

Internal communication is a process through which employees of agricultural structures share information, ideas, opinions, different professional relationships are established [14], the foundations of valuesand an organizational culture are laid, and the relationships developed as a result of this type of communication lay the foundations for the functioning and development of the structures in the sector agricultural [2, 15]. The complexity of the internal communication process contributes to motivating employees, to increasing their level of confidence, but also to strengthening the organizational culture [6, 18]. Regarding the distribution of internal information, this is done through two types of internal networks, formal and informal [8, 39]. In the formal type network, messages are transmitted through the official channels, predetermined by organization[30]. Informal communication involves the transmission of information, using unofficial communication channels [19]. Most of the time this is done through spontaneously chosen channels. An important aspect in this case is the fact that this type of communication cannot be banned or abolished, as it has two advantages: on the one hand, it provides the organization with utilitarian value, contributing to bonding between employees, but also a therapeutic role [29]. There are three types of internal communication: vertical, horizontally and diagonally [24, 30]. Vertical communication, in turn, can be upward or downward. Vertical upward communication takes place from the subordinate to the manager, respectively from the lower hierarchical positions to the higher ones. The role of this type of internal communication is to provide feedback from subordinates to managers. The effects of such communication are significant, both on productivity and on the working climate [29]. Without information from subordinates, managers would not have at their disposal the data necessary to carry out their work, nor would they have information about how employees perform tasks, solve problems encountered by them. Without upward communication, problems become more acute and harder to solve. Downward vertical communication takes place from the manager to the subordinate, from the higher hierarchical positions to the lower ones. Through this type of communication, the manager can exercise his specific functions of planning, coordination, organization, control, can establish long-term and short-term objectives and can transmit the decisions taken.

Horizontal or lateral communication is a process of sending information from peer to peer [21], between departments or between different functional structures. The last type of communication is the diagonal one, in which information is exchanged directly between managers for example and employees of different departments, but who belong to distinct hierarchical levels. Agricultural structures are legal entities [2, 15] that should be rooted in strong organizational core values, with forward-looking institutional vision and mission. Organizational communication is much more than a simple tool nowadays [7], and can instead be considered an field utilising scientific methodologies, which have been developed over time, from the simplest communication theories and models to complex networks and types [38]. Technological evolution was the main vector that gave a strong impetus to the development of the branch of communication, becoming today's complex science [17].

Within this context, the aim of this research endeavour is to explore the effects of various factors, including flow and direction, coordination/information exchange, barriers in communication, communication efficiency, actuality, and the frequency and efficiency of communication channels, on communication practices in agricultural holdings in Western Romania. In doing so, we address a knowledge gap in the field of agricultural communication, specifically the role of internal communication within agricultural holdings.

MATERIALS AND METHODS

The primary objective of this study is to evaluate the significance of communicational practices within agricultural enterprises.

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Our investigation employs a quantitative approach, primarily focusing on the analysis of variables relevant to the communication process. To this end, the data collection procedures entailed a comprehensive survey administered to respondents within the agricultural sector.

The questionnaire comprised 31 items, which were grouped into 7 variables of interest. Besides those variables of interest, we also collected some limited information regarding the demographic characteristics of the respondents and their position within the workplace. The questionnaire was developed in Romanian, as this is the native language of the respondents.

The list of variables and items are evidenced in Table 1.

Table 1. Variables studied and number of items

Variable name	Number of items
Flow and direction	6 items
Coordination/information exchange	6 items
Barriers in communication	3 items
Communication efficiency	4 items
Actuality and punctuality	4 items
Frequency of communication channels	2 items
Efficiency of communication channels	6 items

Source: Own elaboration, based on review of literature.

The flow and direction variable encompasses assessments of communication between managers and their subordinates (classified as vertical communication) and communication between co-workers (classified as horizontal communication) [7, 41].

Coordination and information exchange is a variable through which we examined the easiness and naturalness of communication within the organization [6].

Communication barriers addresses challenges related to difficulties in mastering the technical jargon relevant to the profession, partial and truncated information exchange between departments, as well as difficulties in intercultural and foreign language communication [41].

Communication efficiency is a variable comprised of items that evaluate the level of detail and quality in communication, with managers, co-workers, both in the same and in a different department [28, 40].

Actuality and punctuality refers to items assessing the timeliness of managerial communication and its role in preventing missed deadlines [31].

The frequency of communication variable quantifies the variety of ways through which communication is attained within the organization [27].

On the other hand, efficiency of communication channels examines the overall effectiveness of the communication channels mix employed by the organization [16].

In conducting the survey, we assembled a sample of 503 respondents drawn from 40 agricultural holdings located in Timiș County, which is situated in Western Romania. This sample includes individuals occupying diverse roles within these agricultural enterprises, encompassing both operational and managerial positions. Moreover, our selection criteria involved exclusively those agricultural holdings employing more than 15 hired workers, where communicational patterns and issues might be more apparent than in smaller, family-operated structures.

Informed consent was obtained from all participants in the study and all legislation pertaining to the protection of personal data was observed. No ethical concerns were identified by the researchers while undertaking this study.

The data collection phase for our study occurred from July 3rd to August 3rd, 2023.

After collecting the results from the respondents, an extensive data input and screening process was undertaken.

Following data collection and cleanup, we performed network structure estimation using the R software suite, utilizing the packages "bootnet" and "qgraph" [10, 11]. This analytical approach allowed us to explore the intricate relationships and patterns within the communication practices of agricultural enterprises while maintaining a graphical and mathematical construct that is accessible,

through the usage of the Gaussian Graphical Model, where positive relationships are shown as green edges (lines) between nodes (variables), while negative relationships are shown as red edges between variables [13]. Additionally, this approach allowed us to test for existing relations between variables simultaneously, reducing the risk of a Type-I error or false positive findings associated with repeated testing [26]. Furthermore, we conducted an analysis of centrality measures within the network to assess the contribution of each variable to the network [4, 5].
In addition to the network analysis, we also constructed pairwise and partial correlation matrices using Spearman and Pearson formulas for the variables presented in the study. The pairwise correlations are calculated independently between two variables, while the partial correlation coefficient is calculated between two variables by taking into consideration all other variables as controls [23]. We consider this a way to verify and compare the findings of the more elaborate network statistics methods utilized.

RESULTS AND DISCUSSIONS

Several descriptive statistics pertaining to the demographic characteristics of the respondents and to their answers in the questionnaire are detailed as follows:
The gender distribution of the respondents is slightly biased towards male respondents, who amount to 55.27% of the sample, while females represent 44.73% (Fig. 1). No respondents self-reported non-binary gender identities.

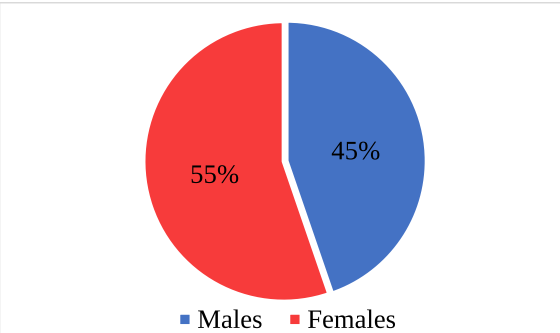

Fig 1. Gender distribution of respondents in the survey
Source: Based on the data from the survey.

The average age of respondents was 44 years. Categorizing respondents by age groups, we find that 32% fall within the 46-55 years category, 28% in the 36-45 years category, 23% in the 27-35 years category, and 17% in the 56-65 years category (Fig 2).
In terms of the education level of the respondents, a notable plurality, constituting 48% of the sample, had completed high school.

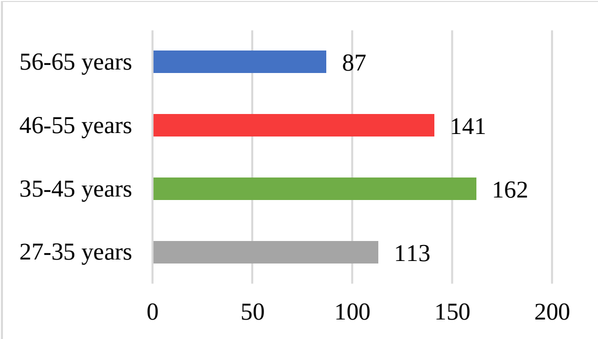

Fig. 2. Distribution of respondents by age
Source: Based on the data from the survey.

A significant portion, representing 31% of the respondents, possessed some form of higher education. In contrast, 21% of the participants had achieved only a middle school education (Fig. 3). This distribution underscores the diverse educational profiles of the surveyed population and can underline the need for effective communication policies and practices between people of different skill and education levels [27].

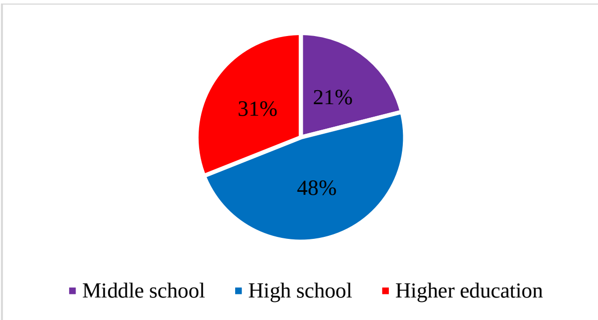

Fig. 3. Distribution of respondents by education level
Source: Based on the data from the survey.

Furthermore, with respect to the professional background of the respondents, it is noteworthy that the sample comprises a diverse array of professions. Among the respondents, 20.15% are categorized as unskilled laborers, 16.4% as engineers, 14.22% as technicians, 11.46% as tractor drivers, 7.9% as caretakers, 7.5% as mechanics, and 5.7% as managers. The remaining respondents hold positions as accountants, veterinarians, human resources personnel, and researchers. This broad spectrum of professions underscores the multifaceted nature of the agricultural workforce and emphasizes the need for efficient communication practices, given the varied roles and responsibilities within both the surveyed sample, the agricultural sector as a whole and in individual enterprises [27].

Table 2. Descriptive statistics for variables

Variable	Mean	St. dev.	Min	Median	Max
Actuality	17.96	4.06	9	19	25
Barriers	8.95	2.54	3	9	14
Channel Efficiency	20.94	5.90	8	23	30
Channel Frequency	21.73	4.37	12	23	30
Coordination	18.42	3.63	9	19	26
Efficiency	11.61	3.42	5	12	20
Flow	17.01	4.53	6	18	24

Source: Own elaboration based on the data from the survey.

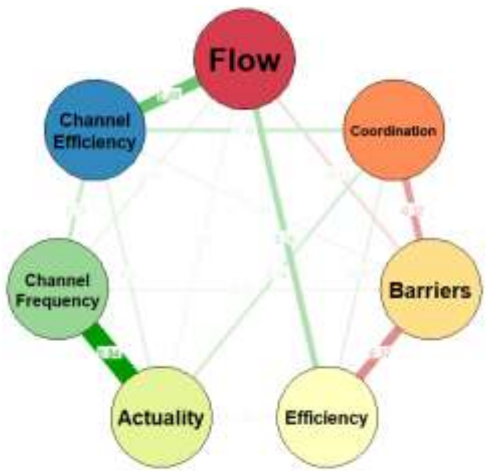

Fig. 4. The network model obtained from the dataset
Source: Own concept.

Following this, the questions assessed the variables of interest for the study, as detailed in the previous section. Central tendency parameters and descriptive statistics for the variables mentioned are presented (Table 2).

A Gaussian Graphical Model for the network was modelled using the partial correlation method [12, 22] (Fig. 4).

The strongest relationships in the dataset are between channel frequency and actuality, suggesting that by utilizing a larger number of communication channels allows workers to access up to date information from the management and to convey their own observations, grievances, and information, allowing them to better perform on the job. The findings imply that as the agricultural workforce utilizes a greater variety of communication channels, there is a corresponding improvement in the punctuality and timeliness of communication with managerial personnel and other staff. This may indicate that a diversified communication approach, encompassing various channels such as face-to-face interactions, phone calls digital platforms, and other modes of communication, contributes to more efficient managerial exchanges within the sector. Such a robust positive correlation underscores the practical significance of adopting multiple communication avenues in enhancing the timeliness of managerial communications, a factor of paramount importance in the agricultural domain where timely decisions and actions are often imperative for successful operations and resource management, for example in pest-control operations, animal feeding or veterinary operations [3, 33].

Secondly, the observed relation between communication flow and channel efficiency within the organizational context suggests an intriguing dynamic. Specifically, it indicates that the effectiveness of the communication channels employed by the organization is intricately linked to the flow and direction of communication among employees. This finding implies that the organization's chosen mix of communication channels significantly influences how smoothly and efficiently communication occurs both vertically, between managers and subordinates, and horizontally, among co-workers. A positive correlation between these variables may signify that when communication channels are optimized for effectiveness, it positively impacts the overall flow and direction of information exchange within the organization. This insight underscores the interplay between communication channels and the structural aspects of communication flow, highlighting the importance of a strategic approach to channel selection in achieving efficient communication dynamics within the organizational framework.

A weaker relationship was observed between channel efficiency and coordination, suggesting that efficient communication networks are of some importance to coordination efforts within the organizations.

Other relatively weak relationships were identified between actuality and coordination, as well as between flow and efficiency and channel efficiency and frequency.

The identified negative relationships between communication barriers and efficiency, coordination, and flow within the organizational context also signify noteworthy dynamics. These findings suggest that as communication barriers, such as difficulties in mastering technical jargon, incomplete information exchange, and intercultural communication challenges, increase in prevalence, there is a corresponding decrease in the overall efficiency, coordination, and flow of communication within the organization. This observation underscores the detrimental impact that impediments to effective communication can have on organizational processes. It implies that mitigating communication barriers is crucial for enhancing the efficiency, coordination, and flow of information exchange, which are essential components of effective organizational communication. Consequently, addressing these barriers through targeted interventions and strategies may be imperative for optimizing communication dynamics within the organizational context, thereby fostering smoother operations and improved coordination among employees.

Some centrality indices for the network were calculated (Fig. 5). The nodes actuality, channel frequency, and flow exhibit the highest strength centrality, suggesting that these nodes are strongly connected to a number of other nodes within the network [25]. On the other hand, channel efficiency emerges as the node with the highest betweenness centrality, signifying that it frequently falls on the shortest paths between other nodes and thusly plays a significant role in moderating the effect of other nodes [25]. Additionally, channel efficiency also attains the highest closeness centrality, implying that, on average, it is relatively close to all other nodes in the network [25]. Interestingly, actuality stands out as having the lowest betweenness and closeness centrality indices, indicating that while the relation between actuality and channel frequency is very strong, its impact on the overall network is significantly reduced.

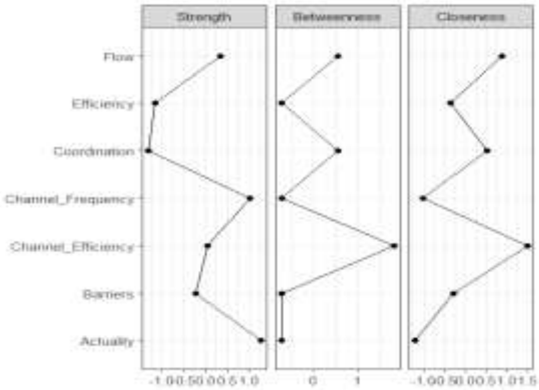

Fig. 5. Centrality indices for studied network
Source: Own determination.

Finally, complementary to the network approach, we modelled the pairwise correlation matrices between the studied variables by using Pearson and Spearman correlations, respectively (Figs. 6 and 7). It is discernible that in all cases, the Pearson correlation coefficient surpasses the Spearman coefficient, indicating the presence of a predominantly linear relationship among these variables [35, 37]. Moreover, disparities emerge between the partial correlations employed within the network model and the pairwise correlations depicted in the figures. Particularly noteworthy is the inverse association observed between barriers and all other variables, while robust correlations manifest among the remaining variables.

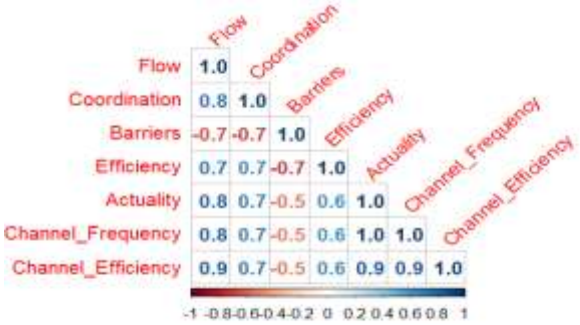

Fig. 6. Pearson correlation matrix
Source: Own determination.

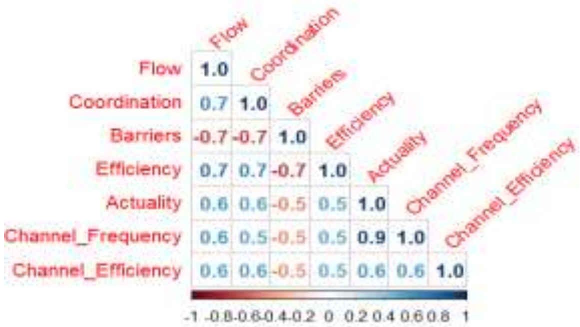

Fig. 7. Spearman correlation matrix
Source: Own determination.

Considering the linear relationship between the variables, we model the partial correlation matrix using Pearson correlation coefficients (Fig 8).

Fig. 8. Partial correlation matrix
Source: Own determination.

The obtained results align more closely with those derived from the network approach. Statistically insignificant correlations have been appropriately marked. An additional noteworthy distinction between the partial and pairwise correlation matrices is the unexpected positive association between barriers and channel efficiency, which warrants further scrutiny as it may represent a spurious correlation. Consequently, we contend that the incorporation of pairwise correlations into future research endeavours can serve as a valuable complement to more computationally intensive statistical techniques, aiding researchers in the detection and mitigation of such spurious associations. It should however be noted that previous works in psychometry found that pairwise correlations to be more prone to error, as such we consider that further references to the literature should be presented in the case of differing results [34]. In our case, we can assume that barriers in communication cannot have positive relations with the other variables, as they signify positive aspects of communication [1].

CONCLUSIONS

After analysing the answers provided by the 503 respondents, it was proven that the internal communication process is essential for the proper functioning of any agricultural structure. A major advantage of good internal communication is increased efficiency and productivity within the agricultural structure, since when team members are well informed about the company's goals and activities, they can work more efficiently and collaborate better to achieve common goals.

The results of the questionnaire show that a faulty internal communication can have negative effects on the organization, the lack of information or erroneous communication, quantified as communicational barriers, leading to the loss of time and resources. In today's times, when digitization increasingly dominates the professional environment, employees tend to communicate mainly in writing. A message can have different meanings for different employees, depending on their age, educational or professional background, and for clarity, we see the utilisation of different communication channels, suited to different employee categories as a possible solution.

Thus, we propose some relevant solutions that contribute to the development and improvement of the communication chain in order to make the production processes within the agricultural structures more efficient. First of all, communication can be made more efficient through discussions within the employee group. Meetings between employees of different generations make it easier to get to know each other and thus help to developeffective long-term communication. They can share experiences, cultural differences, favourite activities and discuss topics that bring them closer together. Thus, they can discover similar passions that unite them and which implicitly also help the unity of the group. At the same time, employees must be encouraged to express their point of view within the company, to share their opinions and knowledge. Bringing this knowledge to the group can make them feel valued and gain the confidence to tackle various issues. Feedback is also a very important element that contributes to the efficiency of communication within agricultural structures. Constant feedback from employees is required to improve existing procedures. In this way, the long-term objectives of the agricultural structure can be protected and the employer brand can be improved. Effective internal communication is possible through flexibility regarding the preferences of each employee, through a close connection between employees, but also through continuous support from the HR department and team managers. In today's conditions, keeping employees motivated and connected is a constant challenge for which the agricultural structure must create a coherent internal communication program, based on a personalized strategy in order to meet the needs of employees and support them in their daily activity. Thus, emphasis is placed on the training of employees, through various training courses [11, 20], foreign language courses, technical courses to develop their communication capacity, thus reducing the communication barriers found at the level of agricultural structures, on the one hand, but also to have wider access to bibliographic documentation resources. The organization of interdepartmental meetings, of meetings at the level of the entire agricultural structure to facilitate the exchange of information, so that employees receive the information in a timely manner in order to perform their tasks effectively. At the same time, actions such as talk shows can be organized monthly to highlight employees (discussions about their passions, problems), as well as new initiatives in business and the development of but also to have a wider access to the bibliographic documentation resources. Any organizational culture is the product of the employees in the respective agricultural structure and the values of that business, and it has several elements in its composition: the dress code and its possible absence, the rules of the agricultural structure, the attitude towards the program and towards the technology used, reporting to people in higher hierarchical positions, the stress experienced by employees. An aspect that agricultural structures must take into account for effective internal communication is the adoption of weekly wellness initiatives. Wellbeing is a complex concept, which implies a constant physical and emotional comfort, including the satisfaction felt at work by the employee. In the present case, the level of belonging of the employees must also be developed - the feeling that they belong to a group, a collective, a team, the level of financial security, the need for respect. In this sense, we propose that the agricultural structures lay the foundations of a strategic, realized narrativethrough visible, communicative and committed leaders; managers/administrators involved in supporting their teams and giving employees the freedom to express themselves freely and creatively, but also to create a story about the agricultural structure they lead, with employees feeling more motivated when they feel part of the story and the history of a business; to have a systematic and systematized approach to the problems of the organization; feedback should be encouraged to understand communication barriers and ambiguities; to carry out specific trainings for each aspect that deserves to be integrated into the organizational culture.

In conclusion, this study provides valuable insights into the demographic characteristics of the surveyed agricultural workforce and their communication dynamics within the organizational context. The demographic profile of the respondents reveals a sample with a wide range of ages and educational backgrounds. The diversity in professions underscores the multifaceted nature of the agricultural sector. These demographic findings emphasize the importance of tailored communication strategies that accommodate the varied skills, education levels, and roles of the workforce.

The analysis of communication variables reveals significant relationships between different aspects of communication. Notably, the positive correlation between channel frequency and actuality highlights the importance of using multiple communication channels to enhance the timeliness of managerial communications, a critical factor in the agricultural sector. Additionally, the link between communication flow and channel efficiency underscores the role of communication channel selection in influencing the overall flow and direction of information exchange within the organization. The study also identifies the detrimental impact of communication barriers on efficiency, coordination, and flow within the organization, emphasizing the need for interventions to mitigate these barriers. Finally, the centrality indices and correlation matrices provide further insights into the network dynamics of the studied variables, offering a comprehensive view of their interrelations.

Overall, this research contributes to our understanding of communication dynamics in the agricultural sector by highlighting the relations between various facets of communication. The findings underscore the need for organizations to adopt a strategic approach to communication channel selection and barrier reduction to optimize communication dynamics, enhance operational efficiency, and facilitate improved coordination among employees. Further research in this area can build upon these insights and explore the practical implications for enhancing communication practices in the agricultural domain.

REFERENCES

[1]Abdullahi, A. H., Jimoh, R. A., Oyewobi, L. O., Isa, R. B., 2016, Effects of construction communication barriers on project objectives in Abuja-Nigeria, Proceeding of the 5th International Conference on Infrastructure Development.

[2]Adamov, C.T., Iancu, T., 2019, Economy of rural space (Economia spațiului rural), In Romanian, Agroprint Publishing House, Timișoara, p.97-107.

[3]Bard, A. M., Main, D., Roe, E., Haase, A., Whay, H. R., Reyher, K. K., 2019, To change or not to change? Veterinarian and farmer perceptions of relational factors influencing the enactment of veterinary advice on dairy farms in the United Kingdom, Journal of Dairy Science, 11, 10379-10394.

[4]Bloch, F., Jackson, M. O., Tebaldi, P., 2023, Centrality measures in networks, Social Choice and Welfare, p. 1-41.

[5]Bringmann, L. F., Elmer, T., Epskamp, S., Krause, R. W., Schoch, D., Wichers, M., Wigman, J. T., Snippe, E., 2019, What do centrality measures measure in psychological networks?, Journal of abnormal psychology, 8, p.892.

[6]Dumitrașcu, V., 2020, Communication management and public relations in business (Managementul comunicării și relații publice în afaceri), In Romanian. Universitara Publishing House, Bucharest, p. 85-89.

[7]Dumitrașcu, V., 2007, Organizations: influencing structures. From communication management to management-communication (Organizațiile: structuri de influențare. De la managementul comunicării la managementul-comunicare), In Romanina. Performantica Publishing House, Iași, p. 51-56.

[8]Dumitru, C., Gîrboveanu, S.P., 2021, Organizational communication (Comunicare organizationala), In Romanian. Pro Universitaria Publishing House, Bucharest, p. 215-227.

[9]El Bilali, H., Botallico, F., Ottomano Pslmisano, G., Capone, R., 2020, Information and communication technologies for smart and sustainable agriculture, In Book: 30th Scientific Experts Conference of Agriculture and Food Industry, Springer, p. 321-334.

[10]Epskamp, S., Cramer, A. O., Waldorp, L. J., Schmittmann, V. D., Borsboom, D., 2012, qgraph: Network visualizations of relationships in psychometric data, Journal of statistical software, Vol.48(4),p.1-18.

[11]Epskamp, S., Fried, E. I., 2018, Package 'bootnet', R package version.

[12]Epskamp, S., Fried, E. I., 2018, A tutorial on regularized partial correlation networks, Psychological methods, Vol.23(4), p.617-634.

[13]Epskamp, S., Waldorp, L. J., Mõttus, R., Borsboom, D., 2018, The Gaussian graphical model in cross-sectional and time-series data, Multivariate behavioral research, Vol.53(4), 453-480.

[14]Feng, X., Yan, F., Liu, X., 2019, Study of wireless communication technologies on Internet of Things for precision agriculture, Wireless Personal Communications, Vol.108(2), 1785-1802.

[15]Gherman, R., Dincu, A.M., Iancu, T., 2013, Agricultural cooperative, fundamental condition for Romanian agricultural development, Lucrări Științifice Management Agricol, Vol. 15 (2), p. 42-45.
[16]Guetzkow, H., 2013, Communications in organizations, Routledge, 111-126.
[17]Haineș, R., 2003, Institutional image (Imaginea Instituțională), In Romanian. Tribuna Economica Publishing House, Bucharest, p. 87-96, p.125-127.
[18]Haineș, R., 2008, Types and techniques of communication in organizations (Tipuri și tehnici de comunicare în organizații), In Romanian. Universitara Publishing House, Bucharest, p. 121-139.
[19]Halic, B. A., Chiciudean, I., 2004, Analysis of the organization images (Analiza imaginii organizaţiilor), In Romanian. Comunicare. ro Publishing House, Bucharest, p. 3-19.
[20]Harizanova-Bartos, H., Stoyanova, Z., 2023, Bulgarian farmer's perception towards risk, Scientific Papers Series Management, Economic Engineering in Agriculture & Rural Development, Vol.23(1), p. 287-292.
[21]Hâncean, M.-G., 2014, Social networks. Theory, methodology and aplications. (Rețele sociale. Teorie, metodologie și aplicații), In Romanian. Polirom Publishing House, Iași, p. 18-39.
[22]Isvoranu, A.-M., Epskamp, S., 2023, Which estimation method to choose in network psychometrics? Deriving guidelines for applied researchers, Psychol Methods, 4, p. 925-946.
[23]Kim, S., 2015, ppcor: an R package for a fast calculation to semi-partial correlation coefficients, Communications for statistical applications and methods, Vol.22(6), p. 665-674.
[24]Marinescu, V., 2011, Introduction in the communication theory (Introducere în teoria comunicării), In Romanian. CH Beck Publishing House, Bucharest, p. 94-122.
[25]Martela, F., Bradshaw, E., Ryan, R., 2019, Expanding the Map of Intrinsic and Extrinsic Aspirations Using Network Analysis and Multidimensional Scaling: Examining Four New Aspirations, Frontiers in Psychology, Vol.10, https://doi.org/10.3389/fpsyg.2019.02174
[26]Matuschek, H., Kliegl, R., Vasishth, S., Baayen, H., Bates, D., 2017, Balancing Type I error and power in linear mixed models, Journal of memory and language, Vol.94., p.305-315.
[27]Men, L. R., 2014, Strategic internal communication: Transformational leadership, communication channels, and employee satisfaction, Management communication quarterly, Vol. 28(2), 264-284.
[28]Miller, K., Barbour, J., 2014, Organizational communication: Approaches and processes, 7th Ed. Cengage Learning, p. 176-195.
[29]Năstase, G. I., 2018, Communication and public relations in business (Comunicare şi relaţii publice în afaceri), Pro Universitaria Publishing House, Bucharest,42-55, p. 103-109.
[30]Olivesi, S., 2005, Managerial communication. A critics of the new forms of power in organizations (Comunicarea managerială, O critică a noilor forme de putere in organizatii), In Romanian. Tritonic Publishing House, Bucharest, p. 22-39.
[31]Onifade, T. A., Opele, A. M., Okafor, L. I., 2018, Communication: An effective tool for employee performance in Unilever Nigeria Plc, International Journal of Management Technology, Vol.5(2), p. 16-27.
[32]Popescu, A., Dinu, T.A., Stoian, E., Serban, V., 2020, Turnover's impact on profitability in the comercial companies dealing with dairy farming, Scientific Papers Series “Management, Economic Engineering in Agriculture and Rural Development, Vol.20(1), p. 437-446
[33]Pradhan, S., Mailapalli, D. R., 2020, Nanopesticides for pest control, Sustainable agriculture reviews 40, p. 43-74.
[34]Schmittmann, V., Jahfari, S., Borsboom, D., Savi, A., Waldorp, L., 2015, Making Large-Scale Networks from fMRI Data, PloS one, 10(9), e0129074, doi: 10.1371/journal.pone.0129074
[35]Schober, P., Vetter, T. R., 2020, Correlation analysis in medical research, Anesthesia & Analgesia, 130(2), 332.
[36]Sipică (Aldea),S.I., Toma, E., 2023, Digital Tools Utilized in Online, Hybrid and Traditional Teaching Models in Pre-University Studies, Scientific Papers Series Management, Economic Engineering in Agriculture & Rural Development, Vol.23(1), p. 833-737.
[37]Thirumalai, C. S., Chandhini, S. A., Madhan, V., 2017, Analysing the concrete compressive strength using Pearson and Spearman, IEEE Cinference on Electronics, Communication and Aerospace Technology IECA, 2017.Coimbatore, India.
[38]Tiwari, S.P., 2022, Information and communication technology initiatives for knowledge sharing in agriculture, Indian Journal of Agricultural Science, 78:9, 737-747. arXiv preprint arXiv:2202.08649.
[39]Voytyuk, V. A., Marinchenko, T. E., Voytyuk, M. M., 2022, New Marketing Communications to Promote Agricultural Products to Foreign Markets, IOP Conference Series: Earth and Environmental Science, 1069012038.DOI 10.1088/1755-1315/1069/1/012038
[40]Widhiastuti, H., 2012, The effectiveness of communications in hierarchical organizational structure, International Journal of Social Science and Humanity, Vol.2(3), p. 185-190.
[41]Yusof, A.N.A.M., Rahmat, N.H., 2020, Communication barriers at the workplace: A case study, European Journal of Education Studies, Vol.7(10),
DOI: http://dx.doi.org/10.46827/ejes.v7i10.3299

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ANALYSIS OF THE INFLUENCE OF SOME TECHNOLOGICAL FACTORS AND COMPARATIVE EFFICIENCY OF THEIR APPLICATION ON YIELD POTENTIAL OF TWO ISOGENIC WHEAT LINES UNDER THE CONDITIONS OF SOUTHERN ROMANIA

Ovidiu PĂNIȚĂ, Paula IANCU, Marin SOARE

University of Craiova, Faculty of Agronomy, 19, Libertatii Street, Phone/Fax: +40 251 418 475, E-mails: ovidiu.panita@edu.ucv.ro, paula.iancu@edu.ucv.ro, marin.soare@edu.ucv.ro

Corresponding author: paula.iancu@edu.ucv.ro

Abstract

In the conditions of southern Romania, on a chernozem type soil, without irrigation, for 3 years, 2 isogenic lines of wheat, M_1 and M_2, with different biological yield potential were analyzed. The analyzed factors were: Nitrogen fertilization doses, Phosphorus fertilization doses and sowing density. Concerning the influence of nitrogen on yield, all calculated average values differ significantly from each other, both for M_1 and for M_2, the highest average values being recorded at a dose of N150 kg a.s./ha. Regarding the influence of phosphorus on seed yield, both for M_1 and M_2, no significant differences are recorded between the two averages values calculated for the analyzed graduations. Related to the influence of density on seed yield, the average value recorded at 700 g.s./m^2, records significant differences compared to the value averages recorded at the density of 500 g.s./m^2, between the value averages recorded on 600 g.s./m^2 and the other value averages, no statistically differences being recorded. Concerning the trend models between Nitrogen doses and wheat yield, all the models are mathematically correct, what differs is the regression coefficient. The regression coefficient is higher under phosphorus fertilization and on high sowing density.

Key words: *Nitrogen, Phosphorus, doses, isogenic lines, yield, efficiency*

INTRODUCTION

Agriculture plays a central role in the economy of the Southern region of Romania. Here, modern crop technologies have come to provide record harvests on some farms, but sometimes agricultural production is highly dependent on weather conditions.

Hence, it appears the need to apply appropriate measures to protect producers in order to adequately exploit the existing national potential [8].

Globally, demand for wheat by 2050 is predicted to increase by 50 percent from present's levels, so identification of better genotypes with desirable traits is an important objective in every breeding programs.

Combining the physiological, chemical, and morphological traits responsible for inherent or environment-induced differences in the plant growth or yield requires thorough growth analysis [6].

Innovative plant improvement techniques respond in part to current challenges. So, improving the quality of the plants has been and is still a significant objective in the activity of breeders, who must create new varieties, which will yield higher yields of useful substances per hectare, with a better nutritional or commercial value.

A basic factor in improving the quality of cultivated plants is the value and diversity of biological material, which must be rich in quality genes or genotypes. The quality traits of the plants are genetic, determined monogenic or polygenic.

Wheat quality is as important as production capacity. The attention paid to improving the quality is highlighted by the numerous meetings and the large volume of research undertaken. They established that both protein and gluten content are heritable traits caused by quantitative physiological differences or as a result of processes of internal elements directed by a particular gene or combination of genes.

Considerable research in the past decade has been devoted to novel techniques and methodologies in wheat biotechnology. The integration of novel techniques and methods into wheat breeding programs is necessary to facilitate continued and accelerated progress in producing new wheat lines. In the past two decades, developments of in vitro culture techniques have enabled the production of large numbers of haploid plants, especially in cereals. Of these techniques, anthers culture and chromosome elimination in inter-generic crosses have been the most widely used. The production of DHs has been an important development in wheat breeding, because, after chromosome doubling to recover fertility, the recovery of homozygous lines can be achieved in a single generation. This can significantly reduce the time taken before advanced comparative trials can be made and new commercial cultivars identified.

Induction of mutations is another possibility to improve quality traits and a useful method to generate new wheat lines. Mutation breeding induces mutations, usually in the seed and includes exposure of seeds to ionizing radiation, ultraviolet radiation or chemical mutagens. The yield and quality of a wheat crop is determined by the complex interaction of water availability, nutrition, environment, pest and disease and genetic make-up [10]. Both chemical and organic fertilization in different technological variants is an important factor to increase wheat grain yield [1, 2, 7, 9, 12]. The establishment of yield performance and their correlation with some quality characteristics in some mutant/recombinant wheat lines was the purpose of this study. Nitrogen management is considered one of the most vital factors affecting wheat growth [4], phenology and grain yield. Nitrogen fertilizer, when supplied at appropriate rates, plays a significant role in enhancing crop productivity [3]. Good nitrogen fertilization practices, including recommended methods and rates, are extremely vital not only for increasing the crop productivity but also for preserving the soil and eco-friendly health [11].

However, insufficient application of synthetic fertilizers, mainly nitrogenous fertilizers, has a negative impact on the growth and yield of crops; it is expected that cumulative N fertilization may cause an enhancement of 23% - 60% of N2O emissions by 2030 [5].

MATERIALS AND METHODS

In the conditions of southern Romania, on a chernozem type soil, without irrigation, for 3 years, 2 isogenic lines of wheat, M_1 and M_2, with different biological yield potential were analyzed. Thus, M_1 is a line with high yield potential but with low gluten content, while M_2 is an isogenic line with a lower yield potential but with good high gluten content.

The analyzed factors were: nitrogen fertilization doses; Phosphorus fertilization doses; sowing density.

Nitrogen fertilization had 4 graduations: N0 - No Nitrogen fertilization; N50 – 50 kg a.s. N/ha; N100 – 50 kg a.s. N/ha; N150 – 50 kg a.s. N/ha.

Phosphorus fertilization had 2 graduations: No Phosphorus fertilization; 80 kg a.s. P_2O_5/ha.

Sowing density measured in germinable seeds/m^2 (g.s.): 500 g.s./m^2; 600 g.s./m^2; 700 g.s./m^2.

Among the pursued objectives of this paper it can mention:

(i) influence of nitrogen on seed yield;
(ii) influence of phosphorus on seed yield;
(iii) influence of density on seed yield;
(iv) influence of the interaction of the three factors on yield;
(v) analysis of the trend models between Nitrogen doses and wheat yield;
(vi) influence of phosphorus on the variation of the regression coefficients between nitrogen dose and seed yield.

RESULTS AND DISCUSSIONS

For the influence of nitrogen on yield, all calculated average values differ significantly from each other, both for M1 and for M_2, the highest average values being recorded at a dose of N150 kg a.s./ha (Table 1).

Table 1. The Nitrogen factor influence on the seed yield (kg/ha)

N doses	M_1	M_2
N_0	3527.83^{d}	2634.5^{d}
N_{50}	4080.0^{c}	2976.0^{c}
N_{100}	5019.17^{b}	4010.17^{b}
N_{150}	6585.67^{a}	5629.5^{a}
LSD 5%	321.85	289.17

Source: Original data.

Related to the influence of phosphorus on seed yield, both for M1 and M_2, no significant differences are recorded between the two averages values calculated at the two graduations (Table 2).

Table 2. The Phosphorus factor influence on the seed yield (kg/ha)

P_2O_5 doses	M1	M_2
P_2O_5 0 kg a.s./ha	4685.5^{ns}	3717.67^{ns}
P_2O_5 80 kg a.s./ha	4920.83^{ns}	3907.42^{ns}
LSD 5%	341.22	278.22

Source: Original data.

Related to the influence of density on seed yield, the average value recorded at 700 g.s./m^2, records significant differences compared to the value averages recorded at the density of 500 g.s./m^2, between the value averages recorded on 600 g.s./m^2 and the other value averages, no statistically differences being recorded (Table 3).

Table 3. The density on sowing factor influence on the seed yield (kg/ha)

Density on sowing	M_1	M_2
500 g.s./m^2	4596.00^{b}	3672.37^{b}
600 g.s./m^2	4825.37^{ab}	3827.37^{ab}
700 g.s./m^2	4988.13^{a}	3937.87^{a}
LSD 5%	376.22	289.14

Source: Original data.

Related to the influence of the interaction of the three factors on yield, in general, Nitrogen is the factor that makes the statistical differentiation between the variants, the superior results being recorded by the variants fertilized abundantly with nitrogen.

The second factor that statistically influences the results is density.

At the same graduation with nitrogen, superior results are obtained by the variants with higher density compared to those at lower density.

Fertilization with Phosphorus influences the production results less, from a statistical point of view influencing those variants fertilized abundantly with nitrogen.

The highest average value is recorded by the variant fertilized with N150 and P_2O_5 80 kg a.s./ha at the density of 700 g.s./m^2, which is significantly different from all the other values recorded, except the values recorded for the N150 variant and P_2O_5 80 kg a.s./ha at the density of 600 g.s./m^2 (Table 4).

Table 4. The influence of the interaction of the three factors on yield variation

N dose	P_2O_5 dose	Density (on sowing)	M_1	M_2
N_0	P_2O_5 0 kg a.s./ha	500 g.s./m^2	3250^{l}	2589^{j}
		600 g.s./m^2	3542^{jkl}	2611^{j}
		700 g.s./m^2	3611^{jkl}	2638^{j}
	P_2O_5 80 kg a.s./ha	500 g.s./m^2	3421^{kl}	2601^{j}
		600 g.s./m^2	3621^{jkl}	2666^{lj}
		700 g.s./m^2	3722^{ijk}	2702^{lj}
N_{50}	P_2O_5 0 kg a.s./ha	500 g.s./m^2	3812^{hij}	2856^{hij}
		600 g.s./m^2	4058^{ghi}	2911^{hij}
		700 g.s./m^2	4122^{gh}	3012^{hi}
	P_2O_5 80 kg a.s./ha	500 g.s./m^2	4025^{ghi}	2896^{hij}
		600 g.s./m^2	4138^{g}	3056^{h}
		700 g.s./m^2	4325^{g}	3125^{h}
N_{100}	P_2O_5 0 kg a.s./ha	500 g.s./m^2	4725^{f}	3785^{g}
		600 g.s./m^2	4938^{e}	3901^{fg}
		700 g.s./m^2	5126^{de}	4102^{efg}
	P_2O_5 80 kg a.s./ha	500 g.s./m^2	4878^{ef}	3902^{fg}
		600 g.s./m^2	5126^{de}	4102^{efg}
		700 g.s./m^2	5322^{d}	4269^{e}
N_{150}	P_2O_5 0 kg a.s./ha	500 g.s./m^2	6136^{c}	5125^{d}
		600 g.s./m^2	6358^{bc}	5452^{cd}
		700 g.s./m^2	6548^{b}	5630^{bc}
	P_2O_5 80 kg a.s./ha	500 g.s./m^2	6521^{b}	5625^{bc}
		600 g.s./m^2	6822^{ab}	5920^{ab}
		700 g.s./m^2	7129^{a}	6025^{a}
LSD 5%			389.22	348.53

Source: Original data.

Concerning the trend models between Nitrogen doses and wheat yield, all the models are mathematically correct, what differs is the regression coefficient. Thus:

For the trend model between Nitrogen doses and wheat yield on 500 g.s./m^2 on P_2O_5 fertilisation, the regression coefficient between nitrogen dose and yield is equal with 16.108, which implies that for each kg of nitrogen a.s. applied, an additional 16.108 kg of wheat yield is obtained (Fig. 1).

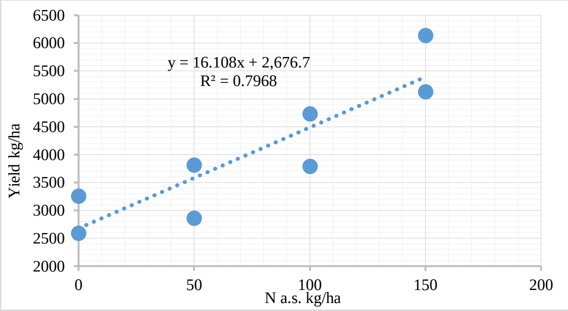

Fig. 1. Trend model between Nitrogen doses and wheat yield on 500 g.s./m^2 and no P_2O_5 fertilisation
Source: Original figure.

For the trend model between Nitrogen doses and wheat yield on 600 g.s./m^2 on no P_2O_5 fertilisation, the regression coefficient between nitrogen dose and yield is equal with 16.841, which implies that for each kg of nitrogen a.s. applied, an additional 16.841 kg of wheat yield is obtained (Fig. 2).

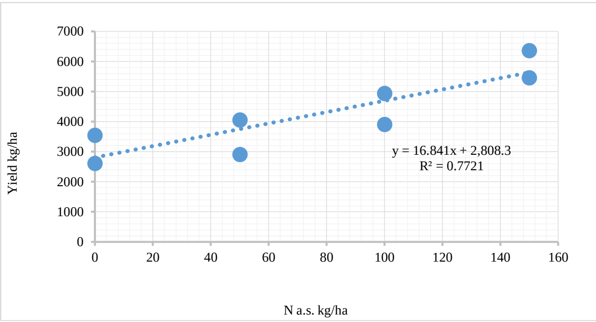

Fig. 2. Trend model between Nitrogen doses and wheat yield on 600 g.s./m^2 and no P_2O_5 fertilisation
Source: Original figure.

For the trend model between Nitrogen doses and wheat yield on 700 g.s./m^2 on no P_2O_5 fertilisation, the regression coefficient between nitrogen dose and yield is equal with 17.568, which implies that for each kg of nitrogen a.s. applied, an additional 17.568 kg of wheat yield is obtained (Fig. 3).

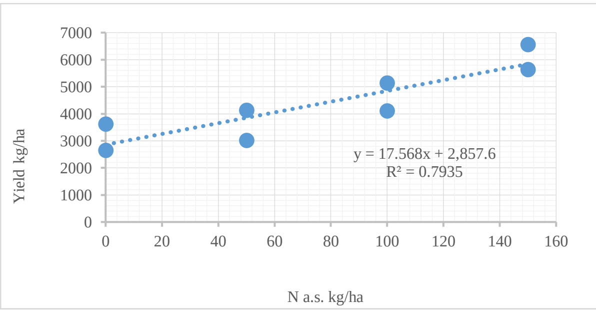

Fig. 3. - Trend model between Nitrogen doses and wheat yield on 700 g.s./m^2 and no P_2O_5 fertilisation
Source: Original figure.

For the trend model between Nitrogen doses and wheat yield on 500 g.s./m^2 and 80 P_2O_5 a.s. kg/ha fertilisation, the regression coefficient between nitrogen dose and yield is equal with 20.231, which implies that for each kg of nitrogen a.s. applied, an additional 20.231 kg of wheat yield is obtained (Fig. 4).

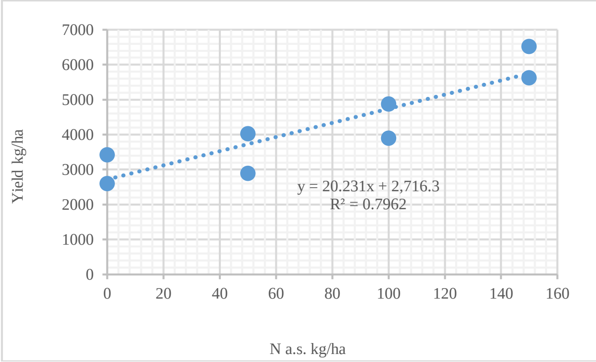

Fig. 4. Trend model between Nitrogen doses and wheat yield on 500 g.s./m^2 and 80 P_2O_5 a.s. kg/ha
Source: Original figure.

For the trend model between Nitrogen doses and wheat yield on 600 g.s./m^2 and 80 P_2O_5 a.s. kg/ha fertilisation, the regression coefficient between nitrogen dose and yield is equal with 21.399, which implies that for each kg of nitrogen a.s. applied, an additional 21.399 kg of wheat yield is obtained (Fig. 5).

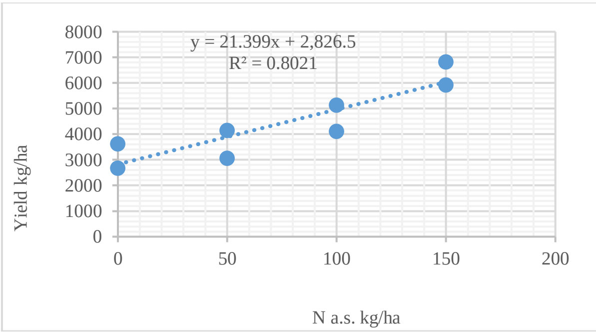

Fig. 5. Trend model between Nitrogen doses and wheat yield on 600 g.s./m^2 and 80 P_2O_5 a.s. kg/ha
Source: Original figure.

For the trend model between Nitrogen doses and wheat yield on 700 g.s./m^2 and 80 P_2O_5 a.s. kg/ha fertilisation, the regression coefficient between nitrogen dose and yield is equal with 22.331, which implies that for each kg of nitrogen a.s. applied, an additional 22.331 kg of wheat yield is obtained (Fig. 6).

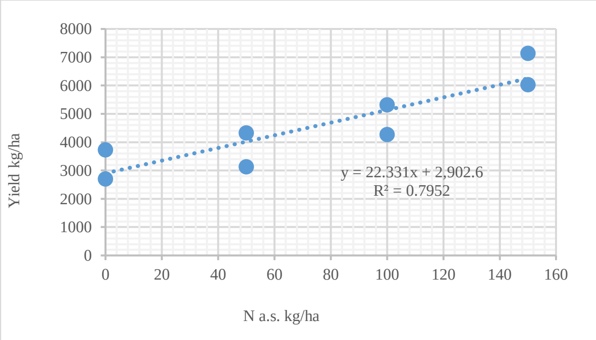

Fig. 6. Trend model between Nitrogen doses and wheat yield on 700 g.s./m^2 and 80 P_2O_5 a.s. kg/ha
Source: Original figure.

Concerning the R values between nitrogen doses and yields, the highest value was recorded on 700 g.s./m^2 and 80 P_2O_5 a.s. kg/ha fertilization, which statistically surpass all the other values, except the value recorded on 600 g.s./m^2 on no P_2O_5 fertilisation. The first 3 ranked values statistically surpass the last 3 ranked values (Fig. 7).

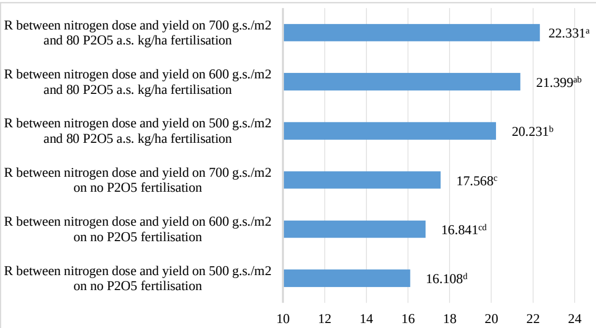

Fig. 7. The R values between nitrogen dose and yields variation. LSD 5%=1.143
Source: Original figure.

Depending on the density on sowing, it was analyzed the influence of phosphorus on the variation of the regression coefficients between nitrogen dose and seed yield.

Thus, on the density on sowing of 500 g.s./m^2, regression coefficient calculated under conditions of phosphorus fertilization recorded a difference of 4.123 compared to the one calculated for conditions without phosphorus fertilization, which implies that, in the case of phosphorus fertilization, for each kg of nitrogen fertilizer, a yield increase of 4.123 kg is obtained compared to the yield increase recorded for each kg of nitrogen fertilizer a.s., but without phosphorus fertilization. From economic efficiency, at an average price of 280 euros/t wheat and 30 euros/50 kg of ammonium nitrate (approx. 1 euro/kg a.s. N), in conditions of fertilization with phosphorus, compared to non-fertilization with phosphorus, at each kg of nitrogen a.s. fertilizer, an additional profit of 1.15 euros is obtained without taking into account the cost of phosphorus (Fig. 8).

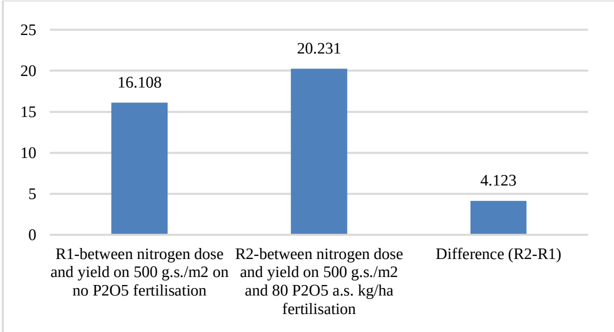

Fig. 8. The influence of phosphorus on the variation of the regression coefficient between nitrogen dose and yield on a density on sowing of 500 g.s./m^2
Source: Original figure.

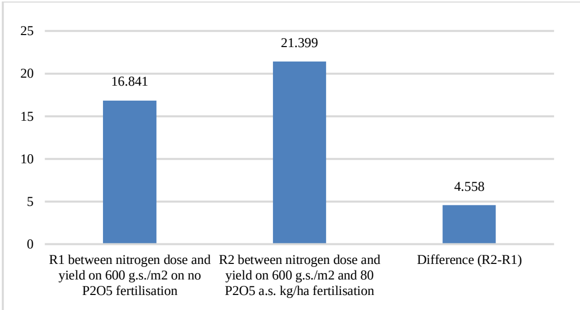

Fig. 9. The influence of phosphorus on the variation of the regression coefficient between nitrogen dose and yield on a density on sowing of 600 g.s./m^2
Source: Original figure.

On the density on sowing of 600 g.s./m^2, regression coefficient calculated under conditions of phosphorus fertilization recorded a difference of 4.558 compared to the one calculated for conditions without phosphorus fertilization, which implies that, in the case of phosphorus fertilization, for each kg of nitrogen fertilizer, a yield increase of 4.558 kg is obtained compared to the yield increase recorded for each kg of nitrogen fertilizer a.s., but without phosphorus fertilization. From economic efficiency, at an average price of 280 euros/t wheat and 30 euros/50 kg of ammonium nitrate (approx. 1 euro/kg a.s. N), in conditions of fertilization with phosphorus, compared to non-fertilization with phosphorus, at each kg of nitrogen a.s. fertilizer, an additional profit of 1.275 euros is obtained without taking into account the cost of phosphorus (Fig. 9).

On a density on sowing of 700 g.s./m^2, regression coefficient calculated under conditions of phosphorus fertilization recorded a difference of 4.763 compared to the one calculated for conditions without phosphorus fertilization, which implies that, in the case of phosphorus fertilization, for each kg of nitrogen fertilizer, a yield increase of 4.763 kg is obtained compared to the yield increase recorded for each kg of nitrogen fertilizer a.s., but without phosphorus fertilization. From economic efficiency, at an average price of 280 euros/t wheat and 30 euros/50 kg of ammonium nitrate (approx. 1 euro/kg a.s. N), in conditions of fertilization with phosphorus, compared to non-fertilization with phosphorus, at each kg of nitrogen a.s. fertilizer, an additional profit of 1.333 euros is obtained without taking into account the cost of phosphorus (Fig. 10).

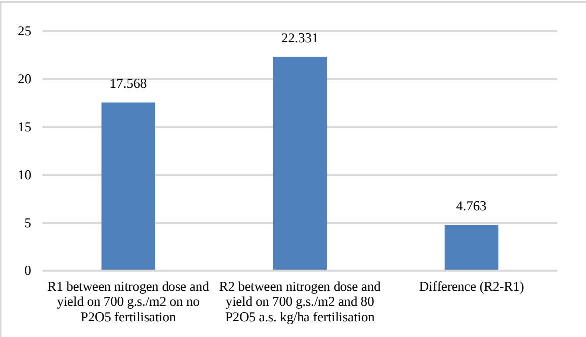

Fig. 10. The influence of phosphorus on the variation of the regression coefficient between nitrogen dose and yield on a density on sowing of 700 g.s./m^2
Source: Original figure.

CONCLUSIONS

Concerning the influence of nitrogen on yield, all calculated average values differ significantly from each other, both for M1 and for M_2, the highest average values being recorded at a dose of N150 kg a.s./ha.

Regarding the influence of phosphorus on seed yield, both for M1 and M_2, no significant differences are recorded between the two averages values calculated at the two graduations.

Related to the influence of density on seed yield, the average value recorded at 700 g.s./m^2, records significant differences compared to the value averages recorded at the density of 500 g.s./m^2, between the value averages recorded on 600 g.s./m^2 and the other value averages, no statistically differences being recorded.

Related to the influence of the interaction of the three factors on yield, in general, Nitrogen is the factor that makes the statistical differentiation between the variants, the superior results being recorded by the variants fertilized abundantly with nitrogen.

The second factor that statistically influences the results is density. At the same graduation with nitrogen, superior results are obtained by the variants with higher density compared to those at lower density.

Fertilization with Phosphorus influences the production results less, from a statistical point of view influencing those variants fertilized abundantly with nitrogen.

Concerning the trend models between Nitrogen doses and wheat yield, all the models are mathematically correct, what differs is the regression coefficient. The regression coefficient is higher under phosphorus fertilization and on high sowing density.

Regarding the influence of phosphorus fertilizer on the variation of the regression coefficients between nitrogen dose and seed yield, on a density on sowing of 500 g.s./m^2, in conditions of fertilization with phosphorus, compared to non-fertilization with phosphorus, at each kg of nitrogen a.s. fertilizer, an additional profit of 1.15 euros is obtained without taking into account the cost of phosphorus fertilizer. On a density on sowing of 600 g.s./m^2, in conditions of fertilization with phosphorus, compared to non-fertilization with phosphorus, at each kg of nitrogen a.s. fertilizer, an additional profit of 1.275 euros is obtained without taking into account the cost of phosphorus fertilizer. On a density on sowing of 700 g.s./m^2 in conditions of fertilization with phosphorus, compared to non-fertilization with phosphorus, at each kg of nitrogen a.s. fertilizer, an additional profit of 1.333 euros is obtained without taking into account the cost of phosphorus fertilizer.

REFERENCES

[1]Atanasov, D., Zorovski, P., Beluhova-Uzunova, R., 2020, Technical and economic efficiency of ancient species, grown under different technologies of organic fertilization, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 20(3), 109-118.

[2]Berca, M., Horias, R,, Pascut, G., 2017, Studies on the use of ammonium nitrate versus urea on wheat crop in Burnas Plateau, Teleorman County, Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 17(2), 9-12.

[3]Chandio, A.A., Shah, M.I., Sethi, N., Mushtaq, Z., 2022, Assessing the effect of climate change and financial development on agricultural production in ASEAN-4: the role of renewable energy, institutional quality, and human capital as moderators. Env. Sci. Pollut. Res. Int. 29, 13211–13225. doi: 10.1007/s11356-021-16670-9.

[4]Chowdhury, M., K., Hasan, M.A., Bahadur, M.M., Islam, M.R., Hakim, M.A., Iqbal, M.A., Javed, T., Raza, A., Shabbir, R., Sorour, S., Elsanafawy, N.E.M., Anwar, S., Alamri, S., El Sabagh, A., Islam, M.S, 2021, Evaluation of drought tolerance of some wheat (*Triticum aestivum* L.) genotypes through phenology, growth, and physiological indices. J. Agronomy 11, 1782–1792. doi: 10.3390/agronomy11091792.

[5]FAO, WHO, 2009, Principles and methods for the risk assessment of chemicals in food. Environmental Health Criteria, 240.

[6]Hawkesford, M.J., Araus, J.L., Park, R., Calderini, D., Miralles, D., Shen, T, Zhang, J., Parry, M.A.J., 2013, Prospects of doubling global wheat yields. Food Energy Security 2 (1), 34–48.

[7]Macra, G., Sala, F., 2022, Variation of Nitrogen use efficiency from mineral fertilizer associated with some foliar treatment, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(4), 379-386.

[8]Medelete, D.M., Pânzaru, R.L., Vladu, M., Matei, Gh., 2018, Some considerations regarding the primary wheat supply in Romania and its composition (2014-2016). Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development. Vol. 18(1), 245-252.

[9]Noreen, F., Noreen, S., 2014, Effect of different fertilizers on yield of wheat, International Journal of Science and Research (IJSR), Vol. 3(11), 1596-1599.

[10]Nuttall, J.G., Leary, G.J., Panozzo, J.F., Walker, C.K., Barlow, K.M., Fitzgerald, G.J., 2017, Models of grain quality in wheat-A review. Field Crop Research, Vol. 202, 136-145.

[11]Panhwar, Q. A., Ali, A., Naher, U. A., Memon, M. Y., 2018, Fertilizer management strategies for enhancing nutrient use efficiency and sustainable wheat production. In Organic Farming, global Perspectives and Methods, 11, 17–39. Doi: 10.1016/B978-0-12-813272-2.00002-1

[12]Radu, V.L., Bonea, D., Dunareanu, I.C., 2021, Effect of different level of Nitrogen fertilizer on grain yield of wheat in central part of Oltenia, Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development", Vol. 21(2), 499-503.

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IMPORTANT ASPECTS OF THE AUDIT PLANNING IN AGRICULTURAL ENTITIES FROM THE REPUBLIC OF MOLDOVA

Elena PETREANU, Silvia ZAHARCO

Moldova State University, 60 Alexei Mateevici str., Block C, Office 330, Chisinau, Republic of Moldova, Phones: +37369589128, +37379544676, Emails: elena.petreanu@usm.md, silvia.zaharco@usm.md

Corresponding author: elena.petreanu@usm.md

Abstract

The study presents relevant aspects regarding the conduct of the audit in agricultural entities and, namely, its planning stage. Determination of the materiality threshold, in terms of financial situations on the one hand and account balances and transactions on the other hand, is a crucial component in the field of audit planning. Contributing factors in approaching this subject constituted the extension in the Republic of Moldova of the demand for an audit obligation in medium and large companies and, as well, the lack of studies in the area of audit of the agricultural entities. After presenting the importance and concepts related to the materiality threshold, the author revealed the method which is considered appropriate for determining the materiality threshold in the framework of audit planning in agricultural entities. As a result of the application of the described method, emphasis is placed on the relationship between the relative value of the materiality and the risk of incorrect organization of the accounting of the agricultural entity; the particularities of the agricultural activity are also taken into account.

Key words**:** *agricultural entity, audit planning, materiality threshold, relative value, basis of comparison*

INTRODUCTION

The practice of auditing in the Republic of Moldova identifies the audit as an independent examination of the annual financial statements, the consolidated annual financial statements and other information related to them of the audited entity in order to express a professional opinion of the auditor on their correspondence, under all significant aspects, to the requirements established for these situations. Until the adoption of the Law no. 287 of 15.12.2017 on Accounting and Financial Reporting [5], the audit was mandatory for public interest entities, which represent entities whose securities are admitted to trading on a regulated market; bank; insurer (reinsurer) / insurance company; body for collective investment in securities with legal personality; large entity that is a state-owned enterprise or a joint-stock company in which the state's share exceeds 50% of the share capital.

Once this law entered into force, the area of application of the audit was expanded and the following are directly subject to the mandatory audit: individual financial statements of medium-sized entities and large entities and groups' consolidated financial statements. In this regard, agricultural entities comprised in the classification of medium and large entities should conduct the audit of the financial situations of the administration period.

The purpose of this research is to investigate the basic features of the planning phase of the audit in agricultural entities, specifically, the interpretation of the questions regarding the evaluation of the materiality threshold in terms of auditing practice of given entities.

We mention that in order to obtain a prosperous exercise of audit operations in agricultural entities, it is essential to set up an academic basis adequate to their planning phase, inclusively the use of the materiality threshold at this stage, considering the specific elements of agricultural activity. Concomitantly, examining the specialized literature, we note a scarcity of works to address the audit components in entities representing the agricultural sector.

Topics regarding the use of the materiality threshold in audit are examined in a limited number of publications in the country. But, at the same time, we can mention the work of the researchers M. Manoli and N. Zlatina [7], which focuses on the materiality threshold in the audit context, and the basic results targets the ways of choosing the materiality threshold and determining the audit risk in the audit planning.

The term ,,audit" is connected to the development of entities with the differentiation of the competencies and responsibilities of managers from those of owners, along with the complex nature of transactions carried out by entities and the development of the economic business sector. The appearance and expansion of auditing was and is a natural necessity, as a consequence of international and European trends and practices in this field [12].

Also, the researcher S. Slobodeanu in his work [9] highlights some aspects of the system of indicators with percentage intervals assigned for the calculation of the materiality threshold recommended by the experts of the Chamber of Financial Auditors from Romania. The results of the conducted research lead to the proposal of a method for calculating the materiality threshold from their average value, and not from the amount of the balance closing the reporting period.

In this regard, acknowledging the must for compulsory audit in medium-sized and large entities, along with the absence of research in the field of audit of agricultural entities, we consider the topic of the present research to be actual and of both, theoretical and practical interest.

MATERIALS AND METHODS

The present study has a theoretical-applied character and is based on both qualitative and quantitative research methods; deductive and inductive; the methods of analysis and synthesis have been used, as well.

The document analysis method was widely used by us, which allowed to carry out a content breakdown of all the approached aspects. The paper took into account the results of studies carried out by local and foreign researchers related to the application of the notion of the materiality threshold when arranging and carrying on the audit.

Concomitantly, the stipulations of the legislative acts of the Republic of Moldova and the auditing regulations of the International Federation of Accountants (IFAC), such as the International Standards on Auditing (ISA), were taken into account.

The data used in the analysis of the method for calculating the materiality threshold were collected from the financial statements and the Balance Sheet of the synthetic accounts of the agricultural entity "Clasicvinagro". The nominated entity is subject to audit, despite the fact that it represents a medium-sized entity and falls under the action of the Law no. 287 of 15.12.2017 on Accounting and Financial Reporting, which provides for the mandatory audit for this type of entities.

According to the latest ascents of international and national economic realities, the responsibility assigned to the audit activity becomes a premise for ensuring correct, objective, transparent, and especially comparable financial-accounting information, on the basis of which the best possible economic decision can be made. In this context, the general accounting and auditing framework is continuously improving the quality of its accounting information by applying accounting regulations in line with European Union Directives. Thus, the European Union seeks to align European accounting principles with International Financial Reporting Standards (IFRS) and, concomitantly, to deploy a standard language in running business by reaching a common point [11].

The method relying on the relationship between the relative value of the materiality and the risk of incorrect organization of the entity's accounting has been used to illustrate in the audit practice within the agricultural entity on the way of determining the materiality threshold.

RESULTS AND DISCUSSIONS

In order to successfully carrying out the planning stage of an audit mission in agricultural entities, it is essential to carefully studying the pertinent regulatory framework of the audit. Here we mention the ISA 300 "Planning an Audit of Financial Statements", ISA 320 "Materiality in Planning and Performing an Audit", which is examined simultaneously with ISA 200 "Overall Objectives of the Independent Auditor and the Conduct of an Audit in Accordance with International Standards on Auditing" and ISA 450 "Evaluation of Misstatements Identified During the Audit". We mention the aspect that these standards have been applied in the Republic of Moldova since 2012. Also, a deep knowledge of the accounting method in agricultural activity is required, which is regulated by the National Accounting Standard (SNC) "Particularities of accounting in agriculture".

The auditor's objective in the planning stage is to plan the activities, so that the audit is carried out in an effective manner. In this context, in accordance with the provisions of ISA 300 "Planning an Audit of Financial Statements" [2], we can mention a number of benefits of planning activities, in case they are appropriate:

▪ ensure that greater attention is paid to the important areas of the audit;
▪ contribute to identifying and solving potential problems in a timely manner;
▪ ensure the correct organization and management of the audit mission;
▪ facilitate the coordination and supervision of all members of the mission team and the review of their work.

At the same time, the auditor will identify the factors on which the volume of planning depends, among which we can nominate: the dimension and complexness of the agricultural entity; the intricacy of the audit; the auditor's former work experience with the particular agricultural unity and the understanding of the character of the client's business.

It is crucial for the auditor to ascertain the key aspects of the planning phase. In the case of the agricultural entities, they can be summarized as follows:

▪ acquiring information about the character of the client's business;
▪ acknowledging and assessing the entity's internal control;
▪ risk assessment and determination of materiality threshold;
▪ establishing the general strategy and developing the audit plan.

An essential element of planning the audit mission is the determination of the materiality threshold. In this regard, it is needed to understand the importance of the materiality threshold, the terms that define materiality and the stages of its determination [1].

We mention the circumstance that the actual financial reporting framework implemented in the Republic of Moldova approaches the notion of materiality threshold considering the establishement and the disclosure of financial statements. Therefore, in accordance with the SNC "Accounting policies, changes in accounting estimates, errors and subsequent events" [10], the materiality threshold is illustrated as a standard created by the entity in order to determine the necessity to introduce or to amend information in the financial statements, taking into account the possibility of the influence of these presentations or corrections on the users' economic decisions. At the same time, in the context of conducting the audit, the materiality threshold is treated as follows from the provisions of ISA 320 "Materiality in Planning and Performing an Audit ", that is, misstatements, including omissions, are considered to be material if it can be estimated, in a reasonable manner, that they, separately or collectively, will affect the economic decisions of the users, based on the financial statements.

Auditing practice shows that certain factors must be taken into account when determining the materiality threshold, such as the relativity of the materiality threshold and the basis of comparison [6]. The relativity of the materiality threshold is demonstrated by the reason that a particular value chosen as a materiality threshold for an agricultural entity might be material, whereas, concomitantly, for another entity it could be remarkable. Furthermore, the relative feature of the materiality threshold leads to the establishment of materiality in relative quantities, which are to be applied to absolute values of the data in the financial statements.

It is critical to state that ascertaining the materiality threshold implies the application of the auditor's professional judgment as evidenced in our previous research [8]. In this regard, for setting a baseline for comparison, the auditor should consider specific factors including: the components of the financial statements (assets, liabilities, equity, income, expenses); the components on which users of the entity's financial statements will draw their attention; the character of the entity and the sector of activity; the ownership composition of the entity and the manner in which it is funded.

According to us, when carrying out audits of the financial statements of agricultural entities, it is necessary to take into account the particularities of agricultural activity. Thus, their financial statements contain elements specific to the field of activity, which can be identified as a basis for comparison when establishing the materiality threshold at the planning stage, such as: biological assets, agricultural products, production in progress, etc. For example, as it follows from the information presented by the agricultural entity "Clasicvinagro", fixed biological assets, which are represented by vine plantations, occupy 71.2% of the total assets of the entity and 86.8% of the total fixed assets whereas the production in progress comprises 76% of the entity's total stocks.

Moreover, we believe that in addition to the peculiarities of the agricultural activity, the auditors should consider the risk of inaccurate organization of the entity's accounting when assessing the materiality threshold. We justify this particular aspect by the idea that the accounting information system constitutes a basic element of the internal control system of the agricultural entity.

We underline the fact that accordingly to ISA 315 "Identifying and Assessing the Risks of Material Misstatement through Understanding the Entity and Its Environment" [3], the auditor should assess, besides the accounting information system, other components of the entity's internal control, namely: the environmental control, the risk assessment process, the control activities pertinent to the audit and the examination of controls.

Correspondingly, we find it relevant to employ the technique of establishing the materiality threshold that relies on the correlation between the relative value of materiality and the risk of inaccurate organization of the entity's accounting [4]. This particular relationship is illustrated by us in Table 1.

Table 1. Correlation between the relative value of materiality and the risk of inaccurate organization of the entity's accounting

Risk of inaccurate organization of the entity's accounting %	**Level**	**The relative value of materiality**	**Level**
10	Low	9	High
20	Low	9	High
30	Low	8	High
40	Medium	7	Medium
50	Medium	6	Medium
60	Medium	5	Medium
70	High	4	Low
80	High	3	Low
90	High	2	Low

Source: Presented by author based on [3].

The information presented in Table 1 is used by us to determine the materiality threshold at the stage of planning the audit in the agricultural entity "Clasicvinagro", whose information flows are used as the object of study in the given paper. We would like to mention that when establishing the basis of comparison (column 1, Table 2) elements were identified, which are of interest to the users of the financial statements and express the particularities of the agricultural activity.

Here we have in mind, first of all, the entity's performance indicators, its debt level, along

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with the value of fixed biological assets. Concomitantly, the risk of inaccurate organization of the entity's "Clasicvinagro" accounting (column 3, Table 2), is determined on the basis of the examination of the internal control at the entity.

Table 2. Determining the materiality threshold within the "Clasicvinagro" agricultural entity

Comparison base	The value of the comparison base, lei	The risk of inaccurate organization of the entity's accounting, %	Relative value of materiality %	Materiality threshold, % (col.4*col.2), lei
1	2	3	4	5
1. Fixed assets	12,881,085	20	9	159,298
2.Fixed biological assets	88,992,956	30	8	7,119,436
3. Production in progress	4,791,621	40	7	335,413
4. Current trade receivables	12,310,989	20	9	1,107,989
5. Long-term loans	52,904,497	20	9	4,761,404
6. Current commercial liabilities	17,014,746	20	9	1,531,327
7. Short-term bank loans	9,346,814	30	8	747,745
8. Net profit in the management period	2,381,774	40	7	166,724
9. Income from sales	42,210,759	20	9	3,798,968
The average of indicators	X	X	X	2,192,034

Source: Developed by the author based on the data of the agricultural entity "Clasicvinagro".

Within the presented method, the materiality threshold, at the level of financial statements as a whole, is determined as the arithmetic average of the indicators calculated in column 5 of Table 2. According to the presented data, the average of the indicators in column 5 makes up 2,192,034 lei. The practical importance of the calculated materiality threshold lies in the aspect that it represents the maximum admissible value of the error in the financial statements of the entity, on which basis the auditor evaluates the integrity of the information shown and the impact on the decisions of the users of the financial statements.

CONCLUSIONS

The findings connected to the carried out research in this paper consists in the following basic points:

▪ In the Republic of Moldova, the audit is an independent examination of the annual financial statements, the consolidated annual financial statements and other information related to the audited entity, in order to express a professional opinion of the auditor on their correspondence, under all significant aspects, to the requirements established for these situations. With the adoption of the new regulations related to accounting and auditing, namely, the entry into force of the Law no. 287 of 15.12.2017 on Accounting and Financial Reporting, the domain of applicability of the audit was broadened by the introduction of the requirement for compulsory auditing of medium and large entities. Therefore, accordingly to the modifications done in the legislation in the field, agricultural entities which satisfy the conditions which allow them to be included in the groups of designated entities are required to conduct the audit of the financial statements.

The investigation of the theoretical and methodological basis regarding the audit in agricultural entities, including its planning stage, shows that it is insufficiently elucidated, while an applied approach to the concept of the materiality threshold in the audit is necessary.

▪ Determining the materiality threshold involves the exercise of the auditor's professional judgment. The auditor is to evaluate a series of factors provided by ISA 320 "Materiality in Planning and Performing an Audit", while, at the same time, he must take into account the particularities of the agricultural activity and the risk of incorrect organization of accounting, as a constituent element of the internal control of the agricultural entity.

▪ Based on the above mentioned, in our opinion, we believe that the use of the method of determining the materiality threshold, which is based on the relationship between the relative value of the materiality and the risk of incorrect organization of the client's accounting, is appropriate in the audit of agricultural entities. The practical approach of the above mentioned method is revealed by the information in Tables 1 and 2 of this paper, as well as by the conclusions made on them.

REFERENCES

[1]Dănescu, T., 2007, Audit procedures and techniques. (Proceduri și tehnici de audit), Irescon Publishing House, București, 393 p.

[2]ISA 300, Planning an audit of the financial statements. Manual of international regulations for quality control, auditing, review, other insurance services and related services. (ISA 300,Planificarea unui audit al situațiilor financiare. Manual de reglementări internaţionale de control al calităţii, audit, revizuire, alte servicii de asigurare şi servicii conexe). https://mf.gov.md/ro/content/standarde-interna%C8%9Bionale-de-audit-emise-de-ifac-%C3%AEn-anul-2018-recep%C8%9Bionate-de-ministerul, Accessed on May 12, 2023.

[3]ISA 315'Identification and assessment of risks of significant distortion by understanding the entity and its environment. Manual of international regulations for quality control, auditing, review, other insurance services and related services. (ISA 315 Identificarea și evaluarea riscurilor de denaturare semnificativă prin înțelegerea entității și a mediului său. Manual de reglementări internaţionale de control al calităţii, audit, revizuire, alte servicii de asigurare şi servicii conexe). https://mf.gov.md/ro/content/standarde-interna%C8%9Bionale-de-audit-emise-de-ifac-%C3%AEn-anul-2018-recep%C8%9Bionate-de-ministerul, Accessed on May 12, 2023.

[4]Lapițkaia, L., 2011, Audit: Advanced Course (Аудит: Углубленныйкурс). Chișinău: ASEM, 359 p.

[5]Law on accounting and financial reporting no. 287 from December 15, 2017 (Legea contabilității și raportării financiare nr. 287 din 15.12.2017). In: Official Gazette of the Republic of Moldova, 15.12.2017, no.1-6.

[6]Loebbecke, A., 2003, Audit. An integrated approach. (Audit. O abordare integrată.) ARC Publishing House, Chișinău, 972 p.

[7]Manoli, M., Zlatina, N., 2013, Materiality threshold in planning and conducting an audit. (Pragul de semnificație în planificarea și desfășurarea unui audit). Annals of Academy of Economic Sciences of Moldova, The XIth edition, no. 1, 162-173.

[8]Petreanu, E., 2014, Determining the materiality threshold in the context of applyingthe International Audit, Policies and Mechanisms stand for innovation and development of economic, financial and social processes at national and international level, (Determinarea pragului de semnificaţie în contextul aplicării Standardelor Internaţionale de Audit, Politici și mecanizme de inovare și dezvoltare a proceselor economico-financiare și sociale în plan național și international), CEP USM, Chişinău, pp. 305-308.

[9]Slobodeanu, S., 2015, Problems of the audit of the procurement-payment cycle: PhD thesis in economic sciences. (Probleme ale auditului ciclului de procurări-plăţi: Teză de dr. în ştiinţe economice). Chişinău, 140 p.

[10]SNC Accounting policies, changes in accounting estimates, errors and subsequent events. (SNC Politici contabile, modificări ale estimărilor contabile, erori și evenimente ulterioare"). https://mf.gov.md/ro/content/standardele-na%C8%9Bionale-de-contabilitate-aprobate-prin-ordinul-nr118, Accessed on April 16, 2023.

[11]Șoimu, S., Bădicu, G., A study on the evolution of the audit in the RM in the context of economic regulations, IEK-AESM, Institutional Repository of Economic Knowledge, ttps://irek.ase.md:443/xmlui/handle/123456789/2052, https://irek.ase.md/xmlui/handle/123456789/2052, Accessed on May 24, 2023.

[12]Șoimu, S., Bădicu, G., Socoliuc, M., 2021, Evolutionary- Conceptual approach to the audit of financial statements: The Republic of Moldova and Romania case study. The USV Annals of Economics and Public Administration, Vol 21, No. 2(34) (2021), http://annals.seap.usv.ro/index.php/annals/article/view Article/1317, Accessed on May 24, 2023.

TRANSPORT DEVELOPMENT OPPORTUNITIES IN THE RURAL AREAS OF THE STARA ZAGORA URBAN AREA IN BULGARIA

Kamen PETROV, Nikolay TSONKOV

University of National and World Economy – Sofia, Faculty "Management and Administration", Department "Regional Development", Students Town, UNWE, Sofia 1700, Bulgaria, Phone: +359 2 8195 647 , Email: petrovk@abv.bg, petrovkamen@abv.bg, kolio_tzonkov@abv.bg, ntzonkov@unwe.bg

Corresponding author: petrovkamen@abv.bg

Abstract

The paper explores the possibility of transport development as a factor for the rural integration of a population of over 100,000 using the example of the city of Stara Zagora in Bulgaria. The analysis showed that improving the access of the rural population to the agglomeration areas can be done through the combination of inter-urban transport that connects the villages with the nearby city The purpose of developing this process is to increase the access of the rural population to the cities and, accordingly, to bring out the problems that the people of the villages have in terms of urban transport. Based on a proposed methodology, we propose to highlight the main public transport problems of the rural population. On the other hand, to propose different views and models to achieve higher efficiency of urban transport and its implementation in rural areas. In this paper, quantitative and qualitative analysis is used and the results are also used to assess the impact of price fluctuations on vegetable marketing channels including vegetable processing enterprises. Data on vegetable prices were extracted from the tempo on line database and the analysis was also based on interviews with key stakeholders in the vegetable processing chain. The results reveal a high coefficient of variation at the farm gate stage, which is also transmitted to the distribution and commercialization stage. The analysis was also carried out at the processing level and the results also show a rather high coefficient of variation.

Key words**:** *public transport, transport connectivity, suburban development, Stara Zagora municipality*

INTRODUCTION

Nowadays, the linkages and interactions between urban and rural areas have become more intensive and an important component of livelihoods and production systems.
The areas around urban centres or along the roads out of such centres, which usually are named "a peri-urban interface, have the strongest connection with the cities, as the rural population depends on urban centres for access to work places, education units, hospitals, banks, and other services. Also, a part of the urban population prefer to live in the surroundings of the cities where life is closer to nature and far away from the stressing cities [14].
In the proximity of the cities, non-farm incomes represent "a large and growing proportion of rural households' incomes and people's mobility is very intensive [15, 12].
The Covid19 pandemic has proved that the rural localities surrounding the cities have been a good place for spending safe week-end short travels [11, 13].
Therefore, for a large range of reasons, roads and rail infrastructure and transport network have to be well developed to assure the shortest travel time between a city and the rural localities in its surroundings.
In this context, a good example is Stara Zahora city in Bulgaria, whose role in urban development and regional planning has become very important and has different territorial dimensions, based on the actual assessed potentials and functions performed as a city-center in the national urban model.
Transportation needs are one of the most diverse aspects of human life. As planners know well, public transit cannot be treated as a one-size-fits-all endeavor. It's especially important to consider the different needs of urban and rural populations when planning

out an appropriate transit system [8]. The historically formed, preserved, and stimulated connections of the city of Stara Zagora with the surrounding settlements and territories are conditioned. Researched and proven (theoretically and practically verified), different in territorial scope and leading functions zones of influence of the city, formed by the degree of intensity and diversity of connections with adjacent territories. The manifestation of the organizing functions of the city. Stara Zagora in its adjacent zones, in terms of economic and transport connections, services, recreation and administrative management activities. In this regard, the strengths in the regional context of the city are the city-center of urban structures, of a high hierarchical level. In practice, Stara Zagora is the nucleus of a large agglomeration area, which makes it a supporting center in the national settlement network, and at the areal level - a city with zoning functions, especially in the service of the areal. The economic potential and the degree of development of the social functions and the related social infrastructure of the town are also important in the city. Stara Zagora gives a positive reflection on the main parameters of the socio-economic complex not only of the Stara Zagora district but also of the South-Eastern planning region [4].

The region provides sufficient opportunities for the realization of the functions necessary for the city, which is facilitated by the well-structured and developed connections between the region and the city, the available opportunities for the construction of at least two common economic zones, the opportunities for the development of new economic clusters. The completion and maintenance of the motorways and high-speed roads, together with the modernization of the railway lines along the identified routes, will ensure a more rational spatial organization of the national transport network, providing connections between different European countries, across the territory of the country, Bulgaria's connections with neighboring countries and connections between the main urbanization centers, within the country and its neighbors [5]. The location of the municipality and of the settlements in Stara Zagora also determine the opportunities for improving transport accessibility by taking targeted measures to develop and improve the public transport service. The provision of a more accessible suburban environment will form a service to develop the socio-economic potential of the suburban areas and improve economic and transport connectivity across the territory.

MATERIALS AND METHODS

For the study of the transport provision of the extra-urban areas within the city of Stara Zagora it is necessary to apply territorial and network approaches due to the complexity of the research field. The research object combines the development of suburban areas in Stara Zagora with the improvement of transport connectivity, as well as the development of public transport in the city. The research field determines the main objective of the authors: to analyze and evaluate the possibilities of improving transport connectivity in Stara Zagora through the development of urban transport. Within the framework of this defined objective, the authors use geographical, demographic, statistical and sociological research methods.

The main part of the research is the development and implementation of a sociological survey. Its main objective is to assess the satisfaction and attitudes of the inhabitants of the settlements (villages) within the municipality of Stara Zagora regarding the services offered by the municipal public transport. In the period from 27 June to 06 July 2022. 41 mayors and deputy mayors of the settlements in the municipality were surveyed. In practice, the survey covered the majority of the settlements, i.e. 41 out of 51 settlements in the municipality. The sociological survey was carried out through the telephone interview method, after which the results were summarized. Software products such as MS Excel and SPSS were used to summarize and systematize the collected data. Statistical methods such as univariate distributions, correlation analysis, regression analysis, and multivariate analyses were also applied in processing the data and drawing the main trends and conclusions [1].

RESULTS AND DISCUSSIONS

Spatial Development and Assessment of the Territory of Stara Zagora Municipality

Stara Zagora Municipality is in Southern Bulgaria, part of the South-Eastern Planning Region. It is one of the 11 municipalities of the same name. Its area represents 0.96% of the territory of Bulgaria, 5.4% of the territory of the Southeast Region and 20.7% of the territory of Stara Zagora District. The municipality is located mainly on three altitudinal belts - lowland (below 200 m), hilly (between 200 and 600 m) and mountainous (above 600 m). There is one town in the municipality - Stara Zagora. Stara Zagora Airport is located 2 km from the town of Stara Zagora and 8 km from the Trakia Motorway.

Stara Zagora Municipality is distant from Plovdiv (80 km.), Burgas (152 km.), Sofia (192 km.), Haskovo (62 km.), Sliven (63 km.), Kazanlak (29 km.) and Istanbul (308 km.), respectively. This shows that the city of Stara Zagora is in a good spatial location in our national space. In addition, the municipality has 51 villages besides the town of Stara Zagora, which occupy a significant part of its territory. These settlements are grouped according to the population indicator. Thus, according to the population data, the villages are grouped as very small (up to 200 inhabitants) - 19, small (between 200 and 1,000 inhabitants) - 28, and large (over 1,000 inhabitants) - 4. From the spatial point of view, it is necessary to emphasize that the settlements in Stara Zagora municipality cover a total area of 68.9 km^2, which makes up 6.3% of the municipality's territory. Considering the transport availability, it is evident that 47 of the villages are very small, which implies that public transport to them is unlikely to be cost-effective. On the other hand, in terms of local self-government, only 28 villages have mayors, the remaining villages have deputy mayors. Five of the town halls are close to the demographic minimum (250 inhabitants), but in practice are in danger of losing their status as self-governing communities.

The economic outlook of the villages is agricultural. Only 8 of all 51 villages have functioning schools, and 29 villages have no medical practices. A positive feature of the commune is the complete electrification and water supply to the villages. In terms of accessibility and inter-village connections, the villages can be divided into three main groups. In the first group are the villages with strong gravitational potential with the town of Stara Zagora, which are located close to the first-class road network. The second group includes villages located in the southern periphery, which in practice have some difficulties using the first-class road network. The third group of villages are in the north-western periphery of the municipality. In this part they have access to the lower quality municipal road network [6]. On the positive side for the settlements of Stara Zagora municipality is the high degree of accessibility to the central part within a maximum 30 minutes by car (for 16 villages - 10 minutes; for 14 villages - 11 to 15 minutes; for 12 villages - 16 to 20 minutes and for only 8 peripheral villages - 21 to 30 minutes).

Untapped resources and significant potential have the city of Stara Zagora as a center of national importance for the territory of the Southeast planning region and Southern Bulgaria, which provides daily, periodic, and episodic service to a significant contingent of the population of the places (municipalities) falling within its urban gravitational field and in its zone of influence. This is primarily due to the city's good geostrategic location and the presence of two transport corridors, which are seen as a major city-forming factor. This also determines the existence of good accessibility, and in addition - the city is rich in natural and anthropogenic resources [2].

Stara Zagora transport connectivity analysis

There are 52 settlements in Stara Zagora municipality, including one town and 51 villages. To the south of the Sarnen, Sredna Gora is the wide and flat Stara Zagora field, with an altitude of 150-170 m, which covers the eastern, south-eastern, and southern parts of the municipality. Its lowest point - 136 m above sea level - is located south of the village of Kozarevets, on the border with Dimitrovgrad municipality. If the whole territory of Stara Zagora municipality has its spatial planning and management, it should be perceived as a territorial spatial system. Thus, in spatial terms, the spatial transport development of the territory must be perceived as a system of measures, acts and actions of a factual and legal nature, which aim at creating balance and order in society and the use of the environment - natural or artificial, for the normal existence of man and his life cycle. This is not a one-off act, but a process that is continuous. According to the modern understanding, it is a purposeful impact on the natural environment, which aims to encompass lands and territories within the borders of a country. In this direction, there is a need to build a homogeneous transport environment that meets the needs of the population of all settlements with urban transport.

Shaping the image and structure of villages suggests bringing to the fore the following factors that can model the need for public transport. These more important factors are:

- Cultural assets of the settlement, shaped by the residential environment, and industries in the broad range from arts to sports.
- Human infrastructure, defined by the conditions for mobility, to those for start-up development, healthcare, finance, etc.
- Network markets, which define the strength of a locality in the community network.
- Architecture and planning of the settlement space and its land.
- Building technical infrastructure (road, bridges, rail, water, internet, education, social and health);
- Formation of socio-economic infrastructure (enterprises, agriculture, narco-op, etc.).
- Cultural exchange: travel and tourism, food, and hospitality.
- Mobility, cars, cycling and transport.

The existing municipal road network, the route schemes developed, the frequency of inter-village transport routes and the time required to travel the various distances between the respective settlements form the individual characteristics of transport accessibility for citizens living outside the municipal center.

Depending on the degree of proximity (distance) to the municipal center, the travel time from a locality to the town of Stara Zagora varies from 10 to 30 minutes per direction. This circumstance determines the travel time of buses on individual routes from the villages to the municipality. As far as the inter-rural lines are concerned, there is not much delay as far as the journey to the city itself is concerned. Delays are accumulated on the journey into the city. It should also be made clear that delays accumulate during peak hours - morning and evening - when people are going to and returning from work.

The average transport accessibility parameters to the municipal center for a settlement are:

- distance - 18.5 km on average.
- one-way travel time - average 14.8 minutes by car.

The degree of development of the municipal transport network determines the mobility possibilities of the population and the level of access to services.

Because there are different distances of the settlements to the municipality of Stara Zagora and considering at which part of the day (peak or off-peak hours) we have different duration of each trip. It is normal for long-distance trips to be longer, and they can be as long as 40-50 minutes. Urban routes are shorter, but they are more runs within working hours, which can compensate for the total mileage. In general, they are shorter, and the duration is less, but it depends on whether it is a peak or off-peak hour of the day. In general, durations average between 20 and 37 minutes in off-peak and peak hours of the day. The extended commute time zone begins at 7:00 am and continues until about 10:00 am. In the evenings, the time zone with the greatest concentration of commuters moving from the workplace to home is 6:00-6:45 PM.

The extended commute-to-home time zone starts at 4:30 p.m. and ends around 8:30 p.m. Respondents cited traffic congestion, travel time, transfers, irregular public transport, and lack of parking spaces as the main problems in getting to and from work in both directions. Respondents felt that getting home takes longer than getting to work. Travelling by car, public transport and taxi are the biggest causes of stress - around 70% of those travelling by the listed means of transport feel stressed to some extent by the journey. The existing municipal road network, the route schemes developed, the frequency of inter-municipal transport and the time taken to travel the various distances between the respective settlements, form the individual characteristics of transport accessibility for citizens living outside the municipal center [10].

Table 1. Territorial access indicators

Up to 10 minutes travel time 14 villages 0 – 12 km distance	**11 – 15 minutes travel time 13 villages 13 – 19 km distance**	**16 – 20 minutes travel time 12 villages 20 – 25 km Distance**	**21 – 30 minutes travel time 10 villages 26 – 35 km Distance**
Bogomilovo	Borilovo	Arnautito	Benkovski
Elenino	Future	Brothes Kunchevi	Vodenicharovo
Zmeiovo	Gorno Botevo	Elhovo	Kazanka
Kalitinovo	Dalboki	Lovetz	Kozarevetz
Kaloqnovetz	Kolena	Lozen	Pshenichno
Kirilovo	Lulqk	Orqhovitza	Pastrovo
Majerito	Lqskovo	Ostra Mogila	Samuilovo
Small Vereq	Novo Selo	Ploska Mogila	Sladak Kladenetz
Small Kadievo	Sulitza	Podslon	Mihailovo
Mogila	Pamukchin	Borovo	Rumanq
Preslaven	Peytrovo	Streletz	
Rakitnitza	Priporetz	Han Asparuhovo	
Hristiqnovo	Starozagorski Bani		
Hrishteni			

Source: Stara Zagora municipality.

The accessibility from small settlements to the city of Stara Zagora, as a combination of distance and frequency indicators, is shown in Table 1.

The average values of transport accessibility to the municipal center for a settlement are:

- distance - 18.5 km.
- one-way travel time - 14.8 min.
- daily round trips - 6 pcs.

The degree of development of the municipal transport network determines the mobility possibilities of the population and the level of access to services.

As a physical structure, the settlement network is well developed, balanced over the entire territory of the municipality. The imbalance is mainly due to the demographic and functional characteristics of the settlements. The differences between the municipal center and the other urbanized areas are very pronounced [17].

Table 2. Personal vehicles access to city center

Up to 10 minutes travel time 16 villages	**11 – 15 minutes travel time 14 villages**	**16 – 20 minutes travel time 12 villages**	**21 – 30 minutes travel time 8 villages**
Bogomilovo	Arnautito	Borovo	Benkovski
Future	Borilovo	Brothes Kunchevi	Vodenicharovo
Zmeiovo	Gorno Botevo	Elhovo	Kazanka
Kalitinovo	Dalboki	Lovetz	Kozarevetz
Kaloqnovetz	Kolena	Lozen	Pshenichno
Kirilovo	Lulqk	Mihailovo	Pastrovo
Majerito	Lqskovo	Ostra Mogila	Samuilovo
Small Vereq	Novo Selo	Ploska Mogila	Sladak Kladenetz
Small Kadievo	Orqhovitza	Podslon	
Mogila	Pamukchin	Rumanq	
Preslaven	Peytrovo	Streletz	
Rakitnitza	Priporetz	Han Asparuhovo	
Hristiqnovo	Starozagorski Bani		
Hrishteni	Sulitza		

Source: Stara Zagora municipality.

Keeping the road network in good condition is a prerequisite for its more efficient use. Improving the quality and performance of a range of infrastructure facilities will increase throughput, with urgency for rail infrastructure. Continuous and consistent transport networks with uniform performance characteristics need to be built to ensure the rapid and safe transport of people and goods. Increasing accessibility is essential to strengthen the regional economy. Efforts should focus on completing priority rail and road routes and on promoting multimodal transport by improving intermodal links [9].

There is also a need to ensure transport efficiency and safety, while minimizing negative environmental impacts. Untapped resources and development potential also exist along the TENT network. Transport policy is important for territorial connectivity, for access to important centers in the European and national polycentric urban network, for mobility and free movement. Transport infrastructure is an important factor in attracting investment, in reducing inter- and intra-regional disparities and in ensuring equitable access to services. Its construction and maintenance depend on the characteristics of the territory, on the possibilities of linking up with Europe's transport networks and on the potential for interaction between different modes of transport [9].

Modern transport terminals require ever larger areas to function properly and safely, combining a variety of communication, service, commercial, recreational, and social functions. The objectives and priorities of national transport policy are determined by the strategic objectives and priorities of EU transport policy, as set out in several key documents. The 2011 White Paper "Roadmap towards a Single European Transport Area - Towards a competitive and resource efficient transport system" is the main European strategic document outlining the guidelines for transport development [9]. Regulation (EU) No 1303/2013 sets out the generally applicable provisions for the "European Structural and Investment Funds" (ESIF) [11]. Eleven thematic objectives are defined for the ESF and an EU Common Strategic Framework (CSF). The Connecting Europe Facility 2 (CEF2) is expected to be a major contributor to this objective, with a target of 60% of its budget to be spent on actions contributing to climate objectives.

Spatial transport development of the territory must be perceived as a system of measures, acts, and actions of a factual and legal nature, which aim at creating balance and order in society and using the environment - natural or artificial, for the normal existence of man and his life cycle. This is not a one-off act, but a process that is continuous. According to the modern understanding, it is a targeted impact on the natural environment, which aims to encompass lands and territories within the borders of a country. In this direction, there is a need to build a homogeneous transport environment that meets the needs of the population of all settlements with urban transport [11].

Assessment of the satisfaction and attitudes of the inhabitants of the settlements (villages) in the municipality of Stara Zagora

For the municipality of Stara Zagora, it is important to have optimal transport accessibility for the citizens according to the specific of the city territory and disparities. It is important for the municipality to function normally, as a system in which there is a relative balance between its different constituent elements, in this case the city and the settlements. In this direction, it is important to bring out the management vision on the role and importance of public transport for the development of the transport system within the municipality of Stara Zagora.

In such studies it has been noticed that men often do not fill in the questionnaires correctly, unlike women who show more diligence. In the case of Stara Zagora municipality, we have a balance of the sample of respondents, which is evenly distributed between the two sexes, with a minimal predominance of men, who are 22 people (Figure 1), and 19 women respondents.

In fact, the distribution of the sample is in line with the demographic picture in the municipality and nationally. Another important aspect of participation in public management is the age structure of the management staff. Both the ageing of the population and legislative changes in setting age limits for retirement have an impact on the population of working age and over [7].

The preponderance of managers shown in Chart 1 and 2 in terms of their gender and age structure suggests that we will have a more conservative view in terms of change in the development of public transport in Stara Zagora municipality.

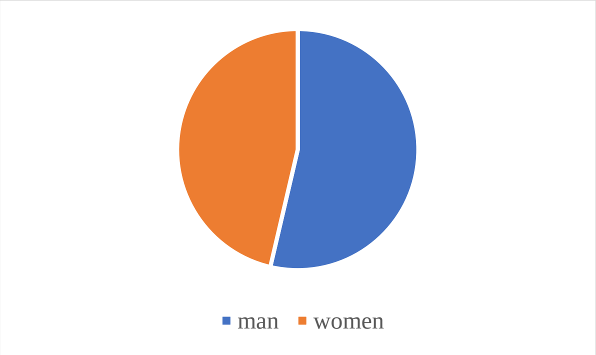

Fig. 1. Point your gender
Source: Own results.

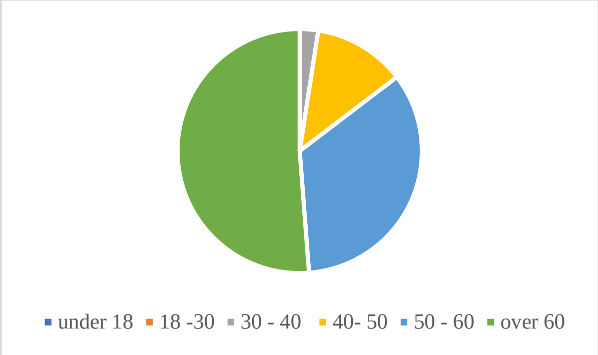

Fig. 2. Point your age
Source: Own results.

Especially the age structure, which can be seen in Figure 2, brings to the fore management staff practically around retirement age. If we look carefully at the reproduction of the working age population in the municipality of Stara Zagora, we see that it is characterized by the demographic replacement rate, which shows the ratio between the number of people entering the working age (15-19 years) and the number of people leaving the working age (60-64 years). By 2022 in Stara Zagora this ratio is 68.5. For comparison, in 2001, 100 people leaving working age were replaced by 117 young people.

The demographic profile of the respondents shows that more than half of all respondents are over 60 years old (51%), 34% are in the age group 50-60, 12% of respondents are between 40-50 years old and only 3% of respondents are in the age group 30-40. This suggests that the main trends are related to other types of problems, mostly with the labor market, rather than with the search for solutions related to the level of labor efficiency and creativity.

The ageing trend of the population is also leading to changes in its basic age structure - below, at and above working age. Both the ageing of the population and legislative changes in the setting of retirement age limits have an impact on the working-age and over-age population [5]. This process is changing the philosophy and perceptions in society on how to address groups of issues and pulling public opinion in a different direction.

Another essential element in determining the priorities of the settlements in the municipality of Stara Zagora is the model of perceived transport accessibility. Accessibility is defined as the ability to get from one place to another. In this context, accessibility refers to the ease of reaching different destinations.

People who are in places that are more accessible will be able to reach activities and destinations faster than those in inaccessible places. The latter will not be able to reach the same number of locations in each period. Mobility is the ability to move or be moved freely and easily. Mobility can be seen as the ability to move through different levels in society or employment, for example. While mobility focuses on moving people and goods to and from different places, accessibility is an approach or input that can be obtained or achieved. Thus, the two forms -mobility and accessibility rely on each other in some way, depending on the scenario, but remain separate entities [16].

A great example of improving accessibility rather than mobility is the case of a rural transport scenario, in which road means and modes are pragmatically chosen to move the population by rail and bus.

Within the municipality of Stara Zagora, apart from bus transport, private transport is an alternative, but it is not a good solution for people under 18 and those over 65. This has also brought to the fore the need to analyze travel options within the settlements of Stara Zagora municipality. This is because accessibility in terms of geography is an important element in the mobility of people, goods, or information. Mobility is determined by people and affects infrastructure, transport policies and regional development.

The question posed to the representatives of the local authorities, what do the inhabitants of the villages in the municipality of Stara Zagora use to get around, produced an interesting result.

It can be seen from Figure 3 that the respondents are almost equally distributed, with own and public transport, with 40% of respondents stating that residents use public mass transport to reach Stara Zagora.

Stara Zagora, while another 33% stated that they usually travel by their own car to the municipal center. A small percentage of those who say they travel to the town of Stara Zagora. Stara Zagora by company car or other means.

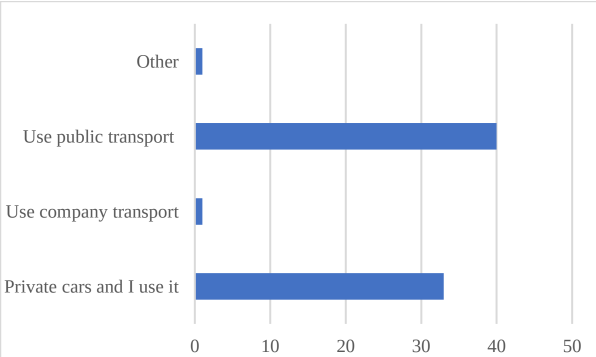

Fig. 3. What do the residents from your locality use to get to Stara Zagora usually?
Source: Own research.

In Figure 4 we can see the intensity of trips from the villages to the city Stara Zagora.

33 of all respondents indicated in their answer that they travel daily to Stara Zagora. Stara Zagora. 7 of the respondents travel to the municipal center several times a week during weekdays.

The intensity of trips is directly related to the purpose and destination of the trip from the villages to the city of Stara Zagora (Figure 5). 31% indicated the workplace as their destination. In fact, these villagers commute daily, and it is important to establish what proportion of them use inter-village transport in the municipality. Due to the lack of public transport accessibility to the industrial area of the city, we could conclude that most of the people who commute use their own cars. 15% of the respondents commute to school. In fact, it is normal for students to use public transport, given the fact that they are provided with discounted travel passes. 16% of all travel to health facilities. For the most part, these commuters are rural residents of working age. This also means that they do not commute daily to the city. And 7% travel to the community center for leisure and shopping, suggesting that they also rather use their own transport.

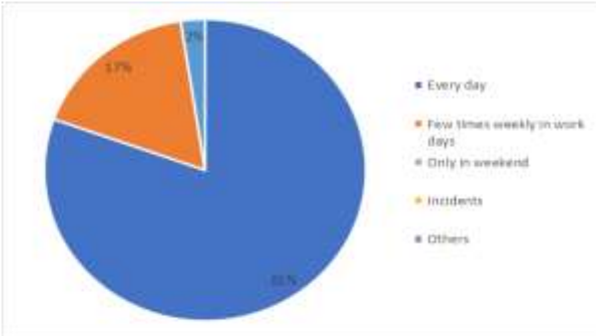

Fig. 4. How often the village citizens travel to the big city during week time?
Source: Own research.

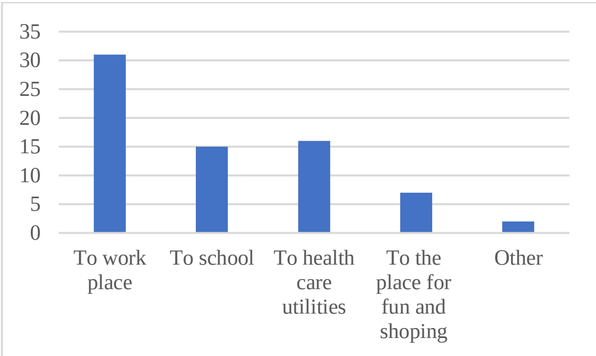

Fig. 5. Where are you travelling to?
Source: Own results.

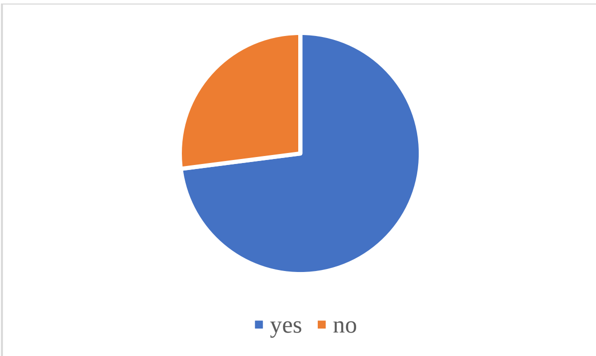

Fig. 6. Are you satisfied with the present timetables of the bus lines?
Source: Own research.

The following Figure 6 provides information on the proposed changes to the timetables of the inter-suburban public transport lines in Stara Zagora.
Responses to this question indicate that people are generally happy with the timetable and minimal changes should be made to maximize their satisfaction.
Figure 7 shows the circumstances that would affect a shift from the use of private cars to public transport for the daily journeys of residents of your locality to the town Stara Zagora.
Unfortunately, 13% of respondents indicated that they could not be motivated in any way to leave the car to use public transport.

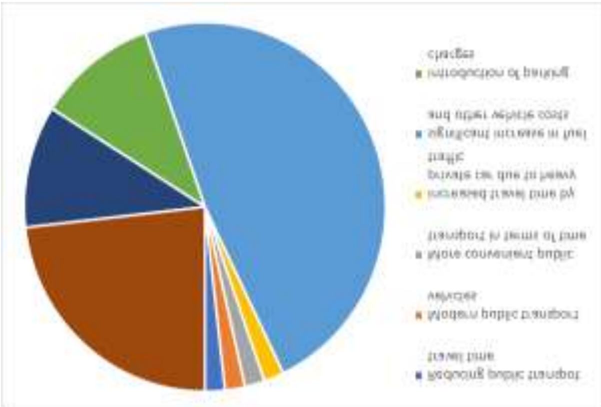

Fig. 7. Please mark these circumstances which may influence changing the way of travel - from personal vehicle to public transport.
Source: Own research.

According to 6 % in the town the introduction of some serious restrictions may motivate commuters from the villages to the city to leave the private car and start using public transport. Such measures are - limited number of parking spaces and introduction of parking fees. 27% are ready to use public transport due to objective reasons such as an increase in fuel prices and all other costs. In today's high inflation environment, a large proportion of rural commuters (27%) are likely to switch from private cars to public transport buses. However, to this end, people in rural areas should be offered flexible timetables. A minimal number of respondents would switch from car to bus if private car travel increased disproportionately, public transport accessibility related to timetable and timing improved substantially, the public transport fleet was upgraded, and public transport travel times were reduced [3].

The issue of what matters most to rural residents is extremely important. 8% say that the ability to travel for free is paramount for them. Another 19% indicate that the most important thing related to public transport is the affordability of fares (i.e., a change in tickets and season tickets is needed). 17% indicate that the quality and comfort of the bus ride is most important. 15% said that the most important thing for them is the shortness of the journey. 19% of all respondents say that the most important thing for them is the intensity and frequency of public transport. And as many as 24% say that the most important thing for them is the improvement of the transport service (punctuality, journey, etc.).

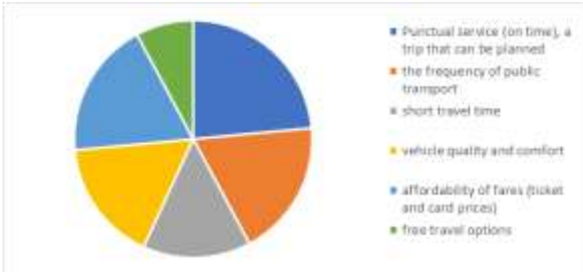

Fig. 8. What is the most important thing for you and the residents when using public transport? Please choose the three most important!
Source. Own Research.

In connection with the optimization of the transport scheme and the possible commissioning of the two regional bus stations in the eastern and western part of the station, we asked the mayors of the villages in the municipality of Stara Zagora whether they agree to use these stations. Figure 9 also shows the respondents' answers regarding changes to public transport timetables and routes. The responses are almost equally distributed in the dichotomy of agreement and disagreement for changes in public transport. 13 (32%) of respondents agreed that changes should be made to public transport timetables and routes. Conversely, 28 (68%) of respondents disagreed that any changes to public transport were necessary, citing a variety of reasons. As many as 16 (39%) of

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those who disagreed felt that it suited and suited them at present.

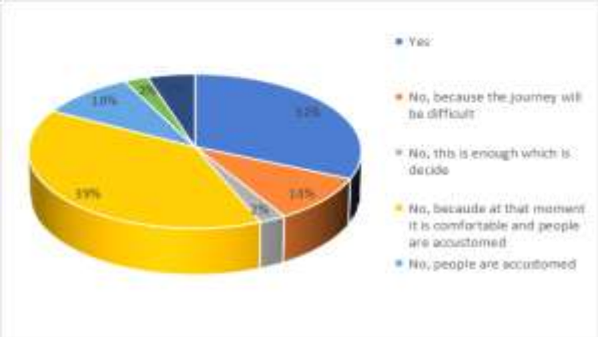

Fig. 9. Do you agree that a change should be made to the bus route(s) to start stopping at the existing east and west bus stations and that the public transport bus lines in Stara Zagora should start from there?
Source. Own Research.

According to 2% (1 person) of the respondents, they believe that enough has been done and they are not comfortable with changes. Another 10% (4 people) said they disagreed because it would be difficult to travel, and they are also used to the current timetables and transport scheme. And 5% (2 people) say that more time will be wasted travelling and are therefore reluctant to agree to the proposed changes.

CONCLUSIONS

The main objective of this study is to describe, analyze and, as far as possible, present a quantitative overview of the need for improvement of public transport within the municipality of Stara Zagora, affecting mainly the settlements within the municipality. Based on a sound methodological approach, empirical evidence and the results of a questionnaire survey, the following results were derived, which include intermodally diverse environmental innovations. They cover both freight and passenger transport. Based on the findings of this survey, recommendations and advice are given to policy makers for the optimization and development of public transport in the municipality of Stara Zagora, which would create conditions for connectivity and development of peri-urban areas. The analysis carried out shows that the density of the transport network and the choice of public transport routes and lines is influenced by many factors, both specific and general. The latter include the number of inhabitants.

The assessment and analysis of rural mayors is an important argument for the definition of transport policies and the implementation of initiatives related to the management and development of urban transport. The aim of the study is to gain a better understanding of the role and importance of public transport for the regional development of municipalities. This predetermines the arrangement of the problems in the development of the urban transport system on the principle of innovation. Thus, first, the methodologies for defining, grouping, and ranking innovative cities and related territorial formations such as municipalities, which are subject to targeted transport policy, are characterized.

Trends show that there is a tendency towards higher density in medium-sized cities such as Stara Zagora, but an increase in population is also visible in the municipality's villages.

On the other hand, the reforms that have taken place since 1990 have sought optimization, cost reduction, etc., which, however, largely lead to impaired daily mobility, as well as congestion at peak times.

In terms of accessibility and inter-village connections, groups of 'privileged' and 'neglected' villages are emerging.

Those located along the first-class road network are unproblematic, while connections between villages south of Kaloyanovets and those in the north-eastern region are severely hampered by the poor condition of the roads.

Within the municipality of Stara Zagora, the establishment of a functioning transport system passes through the creation of several transport schemes and plans of varying degrees, as legal and sub-legal acts, through which assumptions, forecasts, and future actions to modify the existing environment and management are legally anchored.

These activities are an important instrument of public works, especially for municipalities of the rank of Stara Zagora, and at the same time they are an important instrument of spatial planning and policy.

Through them, the goals, intentions, and actions for building the physical living environment of people and the possibilities for public connectivity within the municipality of Stara Zagora are defined.

The schemes, plans and transport lines connecting the villages and the city of Stara Zagora are important in several ways - they implement the principles of territorial connectivity, create conditions for continuity in the development of the different territories, in addition to creating a favorable living environment within the agglomeration area. Finally, the effect of coordination of common transport policies between the competent public authorities and the public is sought in the development of a specific territory.

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REFERENCES

[1]Anselin, L., 2012, From spacestat to CyberGIS twenty years of spatial data analysis software. International Regional Science Review, Vol. 35(2), 131-157.
[2]Bugarinović, M., Dimitrijević, B., Bošković, B., 2015, The missing component in rail charging modeling-access charges principle selection. International Transactions in Operational Research. Vol. 22(5), 841–859.
[3]Copus, A., Psaltopoulos, D., Skuras, D., Terluin, I., Weingarten, P., 2008, Approaches to Rural Typology in the European Union. Luxembourg: Office for Official Publications of the European Communities, pp. 47–54.
[4]Cromartie, J., 2015, Historical Development of ERS Rural Urban Classifications Systems. Paper presented at the Workshop on Rationalizing Rural Area Classifications, April, National Academies of Sciences, Engineering, and Medicine, Washington, DC. http://sites.nationalacademies.org/, Accessed on 13.04.2023.
[5]Dantsis, T., Douma, C., Giourga, C., Loumou, A., Polychronaki, E.A., 2010, A methodological approach to assess and compare the sustainability level of agricultural plant production systems, Ecological Indicators 10 (2010) 256–263
[6]Halfacree, K., 1993, Locality and social representation: Space, discourse and alternative definitions of the rural. Journal of Rural Studies, VOL. 9(1), 23-37.
[7]Kastreva, P., Patarchanova, E., 2021, Creating Spatial Models of Demographic Processes Using Cluster Analysis for Demographic Policy Planning in Bulgaria. Journal of Settlements and Spatial Planning, Vol. 12(2), 119-130, doi:10.24193/jssp.2021.2.05
[8]Kenyon, S., Rafferty, J., Lyons, G., 2003, Social exclusion and transport in the UK: a role for virtual accessibility in the alleviation of mobility-related exclusion? Journal of Social Policy. 32:317.
[9]Mrksa, M., Gajic, T., 2014, Opportunities for sustainable development of rural tourism in the municipality of Vrbas. Ekonomika Poljoprivrede, 61(1), 163.
[10]Niikolova, Hr., 2015, Evaluating average external costs of inland freight transport in South-Eastern European countries: Policy implications - Economic Alternatives, Vol. 3, 64-81.
[11]Pleşoianu, D. M., 2017, Development Strategies for Rural Tourism in Dobrogea. Scientific Papers Series Management, Economic Engineering in Agriculture & Rural Development, Vol. 17(3), 301-305.
[12]Popescu, A., 2013, Considerations on the main features of the agricultural population in the European Union, Scientific Papers Series Management, Economic Engineering in Agriculture, Vol.13(4), 213-220.
[13]Randelli, F., Romei, P., Tortora. M., 2014, The evolution of rural tourism in Tuscany. Bollettino de la Societ ═ Geografica italiana Roma, Serie XIII, Vol. VII, pp. 375-389.
[14]Tacoli, C., 2003, The links between urban and rural development, Environment and Urbanization, Vol.15(1), 3-12, https://www.iied.org/sites/default/files/pdfs/migrate/G00486.pdf, Accessed on May 10, 2023.
[15]Tacoli, C., 2017, Small towns, rural-urban linkages and regional development, URBANET, https://www.urbanet.info/rural-urban-linkages/, Accessed on May 10, 2023.
[16]Todorova, Sq., Rancheva, E., Petkov, T., 2018, Invasion of Low-Cost Carriers on the Bulgarian Air Market - Marketing and Branding Research 5111-5121, www.aimijournal.com, Accessed on 18.04.2023.
[17]Weiss, J., Heinz-Fischer, C., 2022, The More Rural the Less Educated? An Analysis of National Policy Strategies for Enhancing Young Adults' Participation in Formal and Informal Training in European Rural Areas, Young Adults' Participation in Formal and Informal Training in European Rural Areas, Youth 2022, 2, 405–421.

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DIRECTIONS FOR THE DEVELOPMENT OF ORGANIC FARMING IN SIBERIA ON THE INNOVATIVE AND INVESTMENT BASIS

Marina PETUKHOVA, Evgeniy RUDOY

Federal State Budgetary Educational Institution of Higher Education Novosibirsk State Agrarian University, 160, Dobrolyubov street, Novosibirsk, 630039, Russia, Phone: +7 (383) 267-38-11, Mobile: +79231061280, E-mails:russian_basket11@mail.ru, rector@nsau.edu.ru

Corresponding author: russian_basket11@mail.ru

Abstract

The transition to highly productive and environmentally friendly agricultural farming is one of the priorities of the Strategy for Scientific and Technological Development of the Russian Federation. In the current conditions of sanctions policy, the need for a large-scale transfer of agriculture to organic farming increases. The purpose of the article is to develop methods and tools for the development of organic farming on an innovation and investment basis to ensure sustainable development of rural areas. The article presents the evolution of views and methodological approaches to studying the relationship between organic agriculture and sustainable development. The global trends in the development of the organic products market are studied, the dynamics of organic production in Russia are presented both in general and in the context of grain crops, legumes and vegetables. It has been empirically revealed that the bulk of the harvest of organic grain crops remains on the domestic market, and most of the leguminous crops are exported. The article examines global trends in the development of the organic products market. Methodological approaches and principles for the transition to the Organic 3.0 concept, aimed at intensifying the growth of organic product production, have been developed. Promising forms of organizing organic farming have been substantiated and conditions have been created for increasing the efficiency of organic production on an innovation-investment basis, taking into account regional specifics. The economic, social and environmental role of organic farming as a driver of sustainable development in Siberia is substantiated. Methods and tools have been developed to improve the state policy for the development of organic farming in rural areas of Siberia, including subsidies, subsidizing the purchase of certified planting materials, developing competency standards, and improving the regulatory framework. The practical significance of the results lies in the development of theoretical and methodological approaches and methodological tools for sustainable development of rural areas, based on the introduction of advanced organic farming technologies, as well as targeted mechanisms for stimulating organic production.

Key words**:** *organic farming, sustainable development, innovation and investment support, global market trends, Organic 3.0 concept, government support*

INTRODUCTION

Solving the problem of the country's food security is closely related to the transition to a new, environmentally friendly type of production in all sectors of the economy. The relevance of this problem is confirmed by the sustainable development goals adopted by the UN General Assembly, one of which is to eliminate hunger, ensure food security, improve nutrition and promote sustainable agricultural development [35, 39].

According to FAO forecasts, agricultural consumption worldwide will increase by 15-17%, mainly due to increased labor productivity caused by increased investment, as well as the efficient use of inputs. The increase in agricultural production volumes is associated with an increase in yields based on the intensive use of innovations, advanced production technologies, and digital tools.

Increased requirements for the safety of manufactured products, an increase in the anthropogenic load of the agri-food sector, as well as the deterioration of the global environmental situation act as significant restrictions on the growth of agricultural production.

According to the Global Footprint Network, food production accounts for about 30% of humanity's total ecological footprint, which is 3gha/person. The size of the ecological

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footprint varies across continents. Thus, in North America, Oceania and Europe this value ranges from 5 to 7 global hectares per person, and in Asia, Africa, Latin America - from 0 to 3 gha/person. To increase the level of environmental friendliness of production, the transition to a low-carbon economy, increase the biocapacity of the land and increase the level of environmental friendliness of production, a focus on the mass introduction of environmental innovations and ensuring the sustainability of agri-food systems is required [5].

The search for a more sustainable form of agricultural organization aimed at preserving natural resources and biodiversity, producing healthy food, increasing environmental efficiency in agriculture is directly related to organic agriculture [10].

The founders of this direction were A. Howard, W. J. Northbourne, F. King, J. Rodale, I. B. Balfour and others [26].

Subsequently, the International Federation of Organic Agricultural Movement [8] the principles of organic agriculture were formulated. As a result of evolutionary transformations, the process of development of organic agriculture contributed to the formation of a growth trajectory for the supply of these products, as well as an increase in demand from end consumers [38].

According to Barrett [7] modern development of agriculture is closely related to the concept of sustainable development, which involves, along with an increase in production volumes, reducing the negative impact on the environmental situation, ensuring consumer health, balancing income from agricultural production and maintaining the vital activity of rural areas. The concept of sustainable development is implemented in three directions: economic, environmental and social dimensions [12]. The most important direction for implementing environmental innovation is to stimulate the growth of organic production as a source of new economically, environmentally and socially significant products and services that can ensure positive transformations both in the natural environment and in society [9, 34].

The purpose of the article is to develop methods and tools for the development of organic farming on an innovation and investment basis to ensure sustainable development of rural areas.

MATERIALS AND METHODS

The methodological basis of the study was state legislative acts, government regulations and decisions, scientific works of domestic and foreign scientists - economists and agricultural specialists on the problem under study. During the research process, monographic, abstract-logical, analytical, economic-statistical, and expert research methods were used. The materials and reports of the Global Footprint Network Grand View Research, FIBL, IFOAM – Organics International, as well as regulatory documents and materials of scientific literature and periodicals were used as the information base for the study.

The modern development of agri-food systems in most countries of the world is based on the concept of sustainable development. Sustainable development is based on a balanced distribution of economic resources in order to achieve economic growth, rural development and rational environmental management. The main objectives of sustainable development of agriculture in order to achieve food security for the country and regions are related to increasing the efficiency of resource use, achieving environmental safety in agriculture and ensuring social justice.

Theoretical and methodological approaches to the study of sustainable development are widely represented in the works of foreign scientists. The scientific approach of such authors as David William Pearce, Edward Barbier and Anil Markandya is based on the goal setting of meeting both current and future needs of the population, which presupposes the presence of a certain supply of economic resources [27].

William E. Rees explored the specifics of sustainable development in comparison with traditional development. He considered the preservation of ecological diversity in underdeveloped regions to be one of the most important tasks of sustainable development [31].

H.Daly put forward various concepts of sustainable development, justifying the need to highlight environmental and social sustainability [11].

Thus, the concept of organic agriculture has a close relationship with the concept of sustainable development.

Foreign researchers consider three stages in the development of organic agriculture. The first stage (1924-1970) was characterized by the formation of theoretical approaches to the study of this issue, awareness of the need to change the traditional way of managing, and the creation of an image of organic products. The second stage covered the period 1970-1990 and was characterized by a significant expansion of the scale of production; creation of organic farming infrastructure, including non-governmental organizations; formation of the legislative framework. The ongoing third stage is associated with high growth rates and pronounced processes of globalization of organic farming [42].

Organic agriculture research methodology was developed in the first third of the twentieth century. The main element of a fundamentally new agricultural system was humus farming, designed to preserve soil fertility. Some scientists adhered to the principles of biodynamic production as a combination of the biological nature of crop cultivation and the influence of natural climatic resources [46].

W. Albrecht considered the ecological principle of production in close connection with organic farming [4].

The modern paradigm of organic agriculture defines this type of activity as a production system operating on the principles of sustainable development and efficient use of renewable production resources in order to preserve soil fertility and reduce anthropogenic load [21, 23].

Since 1980, organic agriculture has received legislative status at both the national and international levels. The use of international standards for organic production has served as the basis for government support and subsidies for farmers.

Foreign scientists consider the effective management of environmental and biological processes as a necessary condition for the successful functioning of organic production with specified yield parameters and ensuring plant protection [22].

A. Aeberhard, S. Ristemphasize the interest of farmers in organic production due to higher profits compared to traditional production, which is largely due to subsidiary support from the state [2].

The diversity of agricultural production in European countries is based mainly on production technologies, which in recent years have focused on the use of intensive methods and high technology. Thus, organic agriculture in Romania is characterized by dynamic development, which is largely due to the presence of favorable natural and economic conditions.

The growth in demand for organic fuel has predetermined positive dynamic changes in the production and trade of organic products, including exports to the European market. The strategy for the development of organic production in Romania involves further expansion of agricultural areas under organic crops, improving the quality of products, increasing consumption of these products by the population and increasing exports. It is important to strengthen and ensure the acceleration of the development of organic agriculture on an innovation and investment basis [29, 30].

The study by the team of authors [15] is devoted to the development of organic farming in Romania. Romania has significant agricultural potential, including the provision of agricultural land, as well as a high level of scientific and intellectual potential. However, according to Aceleanu et al. (2015), there are still problems of insufficient level of financing of production activities, as well as problems of land management and land use, the impact of unfavorable natural and climatic conditions on production [1].The possibility of ensuring sustainable development of rural

areas is substantiated based on the prospects for the implementation of organic farming projects [43].
The topic of organic production has been widely reflected in the research of the world scientific community, since it covers the problems of economic growth, sustainable development, and food consumption. Some authors [28] note that organic agriculture is a factor influencing consumer behavior by improving the quality of final products and the value of goods offered to consumers. According to some authors [3] agriculture and climate change are connected by a complex cause-and-effect relationship. The negative impact on the environment of gas emissions caused by intensive inorganic agriculture is well known. Other authors [14] analyzed the relationship between agricultural activities and environmental impacts in European Union countries and identified the relationship between agricultural production factors and the value of agricultural products. Thus, highly productive organic production [24] can be the result of optimization provided by the development and implementation of multidimensional analytical systems, taking into account aspects of urbanization, innovation and investment support, safety of manufactured products, social and marketing aspects [44].
In the context of sanctions policy and geopolitical challenges, the effective development of the agri-food complex is closely associated with the use of innovative technologies, therefore the main priority of agricultural policy should be the formation of mechanisms for the introduction of innovative technologies that contribute to the active conduct of research and experimental work, as well as the commercialization of the results achieved [13, 45].

RESULTS AND DISCUSSIONS

The organic food market is one of the most dynamically developing in the world. From 1999 to 2020 it grew more than eightfold from 15.2 to 145 billion US dollars (Fig. 1).

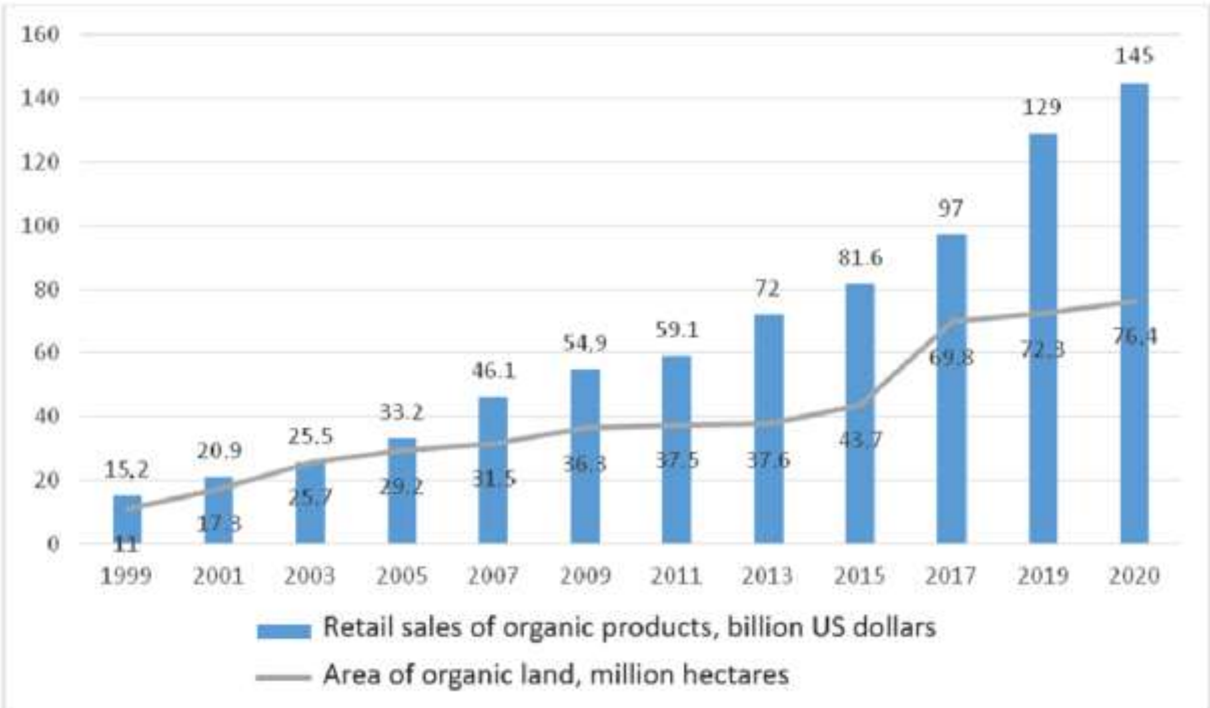

Fig. 1. Indicators of development of the world organic food market, 1999-2020.
Source: Own calculations based on data [40].

According to Grand View Research forecasts, the organic products market will continue to grow at a rate of 12–13% per year, and its capacity in 2025 will be $218–230 billion.

The share of the organic products market in the total global agricultural market products by 2025 it will reach by 3-5%. It should be noted the growing demand for organic products in China (11.3 billion euros) (Fig. 2).

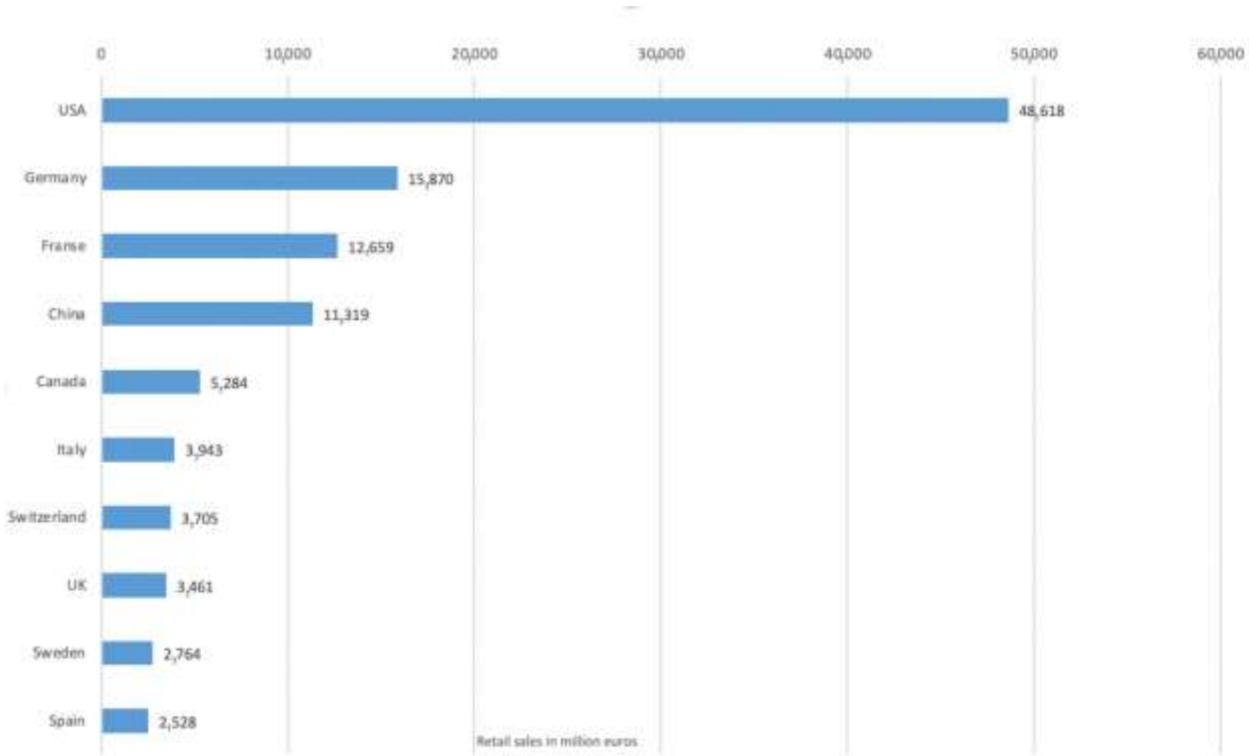

Fig. 2. Top 10 countries with the highest consumption of organic products
Source: Own calculations based on data [40].

Currently, innovation and investment activity in Russia is increasing, but the use of innovative and digital technologies in the production of organic products is in the development stage.

In accordance with the IFOAM report [17] for 2021, experts proposed the “Organic 3.0” Concept, the goal of which is to ensure the widespread dissemination of sustainable agricultural systems based on organic farming. In accordance with this concept, organic farming is an innovative agroecosystem, which includes environmental, social and economic-managerial components.

The evolutionary transformation of organic production covers a long time from the formation of ideas about the relationship between agricultural development and environmental conservation more than 100 years ago, expressed in the concept of Organic 1.0, to the creation of a global market for organic products based on the Organic 2.0 product quality standards system.

The introduction of the Organic 2.0 concept made it possible to ensure positive changes from improving the well-being and health of consumers, increasing the income of producers to solving environmental problems of preserving biodiversity and protecting the environment. At the same time, limitations in the further development of this concept were also identified. They were linked to complex organic certification processes and mechanisms that automatically excluded small farmers from participating in the Organic 2.0 process, despite the fact that they make a huge contribution to feeding a large part of the world's population. In addition, the tools of this concept have not been fully harmonized and coordinated with other regulatory documents in the field of sustainable development and are not aimed at full compliance with agroecology standards, stimulating the development of small and medium-sized farmers, and fair trade. In addition, the economic difficulties of production forced producers to specialize in certain areas and types of food, which did not allow for diversity and the use of new organic methods. As a result, despite significant changes, the world's certified organic agriculture is concentrated on less than 1% of the world's farmland [35].

The most important features of the Organic 3.0 concept are its innovative nature, active study of advanced foreign experience, assessment of opportunities and threats. According to the Organic 3.0 concept, food producers are required to be responsible and honest, as well as ensure transparency in terms of certification. In order to organize sustainable agri-food systems within the framework of the Organic 3.0 concept, it is important to interact and enter into agreements with various organizations and implement a marketing strategy that forms an eco-image. The idea of the concept also involves empowering all participants in the production chain - from farmers to final consumers. It is important to recognize interdependence and develop real partnerships between all participants. This could also be implemented on a territorial basis, where local communities and organizations collaborate to create sustainable and environmentally friendly agri-food systems.

Thus, the Organic 3.0 concept refers not only to an approach to organic production, but also to an innovative approach to the sustainable development of the entire production chain. The implementation of the concept aims to create sustainable and environmentally friendly agri-food systems that will contribute to the well-being of both producers and consumers [6].

The fundamental difference between the Organic 3.0 concept and previous approaches is that it pays attention not only to agricultural producers, but also attracts other interested participants. The organic production sector should involve not only end consumers, but also intermediary organizations - the entire chain of stakeholders. One of the main problems slowing down the development of the organic sector is its isolation. Manufacturers, retailers and consumers are not communicating enough with each other. An important role in the development of organic production is also assigned to research organizations [32, 33].

They can conduct research, develop new technologies and methods of organic farming, and educate farmers and consumers [16].

In this regard, there is a need to create a single cluster in the regions [20].

In accordance with the Strategy for the development of organic production in the Russian Federation until 2030 [37] production of Russian organic products for sale to end consumers within the Russian Federation (excluding consumption within the industry) in 2021 amounted to 9.2 billion rubles, including the production of canned products, juices and other processed products of vegetables, fruits, grains and legumes (canned peas and corn) - 1 billion rubles, cereals, flour, cereals - 1.8 billion rubles, baby food - 1.1 billion rubles, dairy products - 1.4 billion rubles, drinking milk - 1.3 billion rubles, meat products - 1 billion rubles, alcoholic products - 0.6 billion rubles, vegetables and fruits - 0.6 billion rubles, food forest products - 0.3 billion rubles, other organic products - about 0.1 billion rubles.

The share of grains, legumes, oilseeds and feed crops accounts for 31% of all organic products produced; production of juices, butter, canned food – 17%; vegetables and fruits ¬ –12%.

In 2021, the gross harvest of grain crops in the organic sector amounted to 45.3 thousand tons, including wheat - 31 thousand tons, barley - 2.7 thousand tons, buckwheat - 2 thousand tons, rye - 2.6 thousand tons, oats - 3 thousand tons, corn - 2.1 thousand tons (Fig. 3).

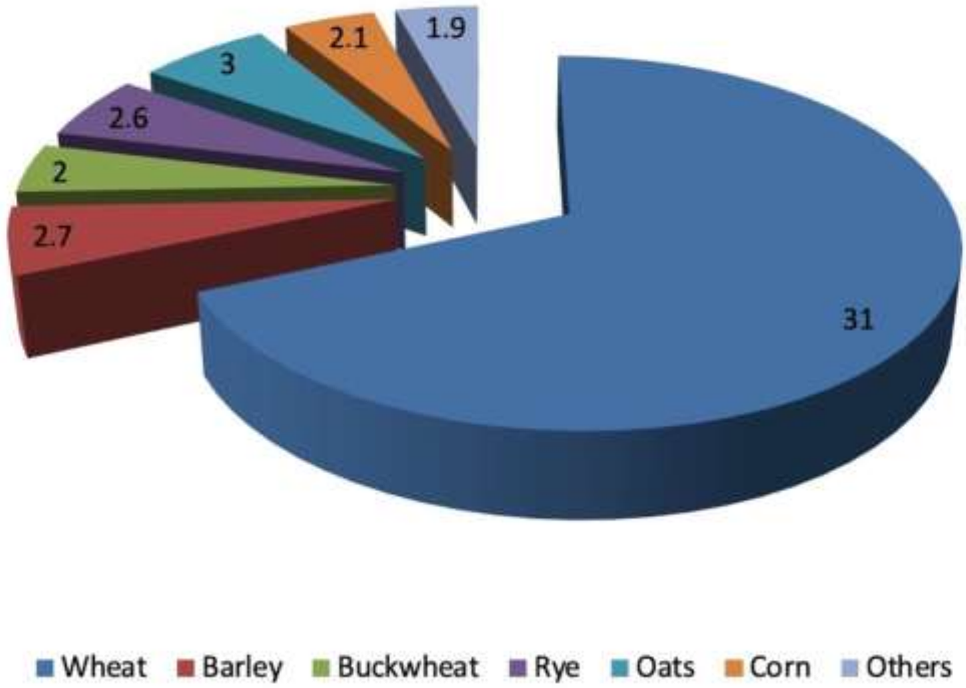

Fig. 3. Structure of grain production in organic farming in Russia, thousand tons (2021).
Source: Own calculations based on data [37].

The gross harvest of grain legumes amounted to 63 thousand tons, including peas - 30.6 thousand tons, soybeans - 32.1 thousand tons, other grain legumes (lentils, chickpeas, broad beans) - 0.3 thousand tons (Fig. 4).

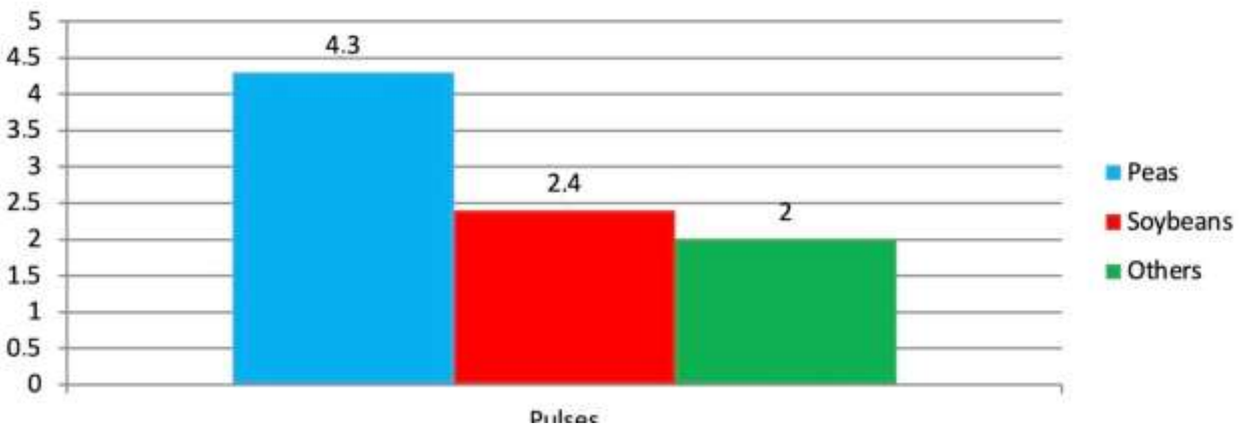

Fig. 4. Production of leguminous crops in organic farming in Russia, thousand tons (2021).
Source: Own calculations based on data [37] .

The average yield of grain and leguminous crops is 26 centners per hectare, including wheat - 30 centners per hectare; barley yield is about 22 quintals per hectare; buckwheat yield – 15 centners per hectare; peas - 25.8 centners per hectare.

The bulk of the organic grain crop remains on the domestic market, and most of the grain legumes are exported.

The gross harvest of organic vegetables in 2021 amounted to 7.1 thousand tons, including 4.5 thousand tons of potatoes, 0.6 thousand tons of beets, 0.6 thousand tons of onions and garlic, 0.5 thousand tons tomatoes, 0.4 thousand tons of carrots and 0.5 thousand other vegetable crops (pumpkin, cucumbers, cabbage, radishes, bell peppers, zucchini), Fig. 5.

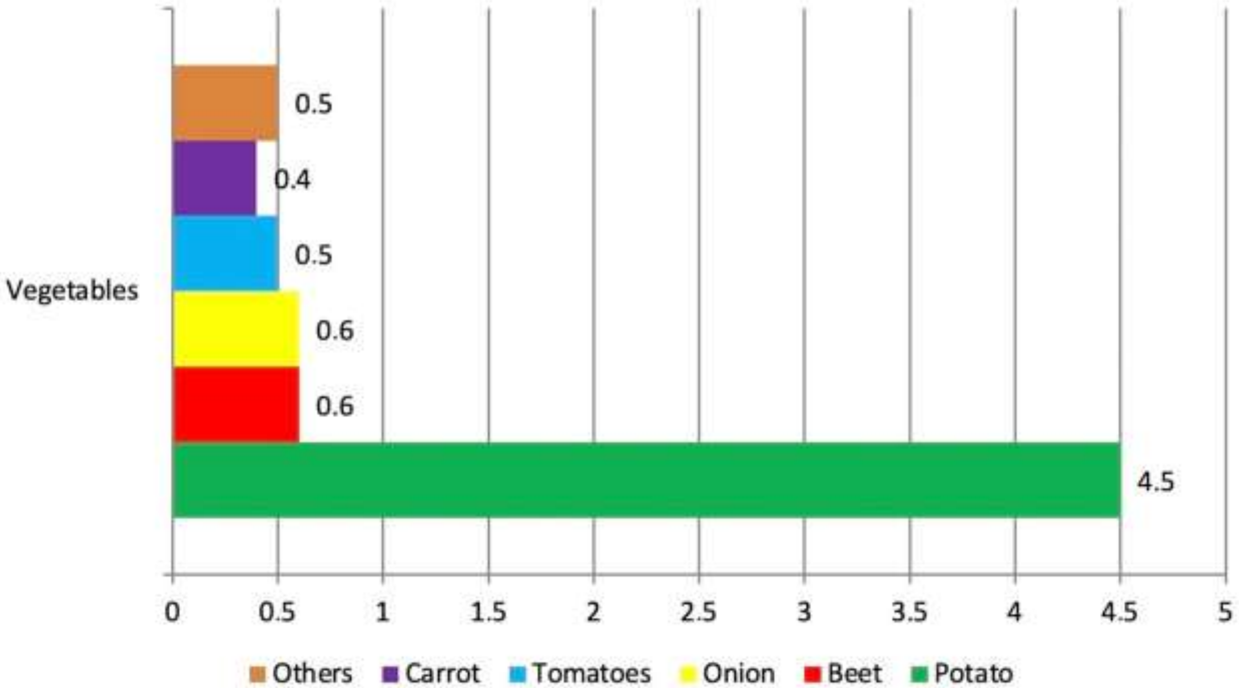

Fig. 5. Vegetable production in organic farming in Russia, thousand tons (2021).
Source: Own calculations based on data [37].

Organic agriculture is an opportunity to preserve natural resources as a result of reducing harmful emissions: preserving organic matter in the soil, which affects its fertility; increasing biodiversity. The positive impact of organic farming on public goods and services is estimated by international organizations at US$40 per hectare per year as a result of reduced carbon emissions. Increasing biodiversity provides an additional benefit of US$30 per hectare per year [25].

The social significance of organic farming is reflected in the creation of new jobs, as well as the formation of new competencies, skills and abilities of workers. Consumption of organic products has a positive effect on public health. With the development of organic agriculture, consumer demand for environmentally friendly products will also increase, which will significantly increase farmers' incomes. Organic farming and organic agriculture are important aspects of sustainable development in Siberia. There is positive experience in organic production in the Muromtsevsky district of the Omsk region, where a significant part farms abandoned the use of pesticides. As a result, the average harvest was higher than the average for the Omsk region, and production costs decreased significantly, which provided the farms with additional profit [36].

Organic farming and organic agriculture are important aspects of sustainable development in Siberia. To organize their successful development, it is necessary to analyze the legal framework and develop targeted support programs. The regulatory framework should create conditions for the production of environmentally friendly food products.

The key tools to include in the support program are:

1.subsidizing agricultural producers specializing in organic farming. This method of farming involves avoiding the use of herbicides, pesticides and chemical fertilizers;

2. subsidizing part of the cost of purchasing certified environmentally friendly planting material and seeds by no more than 50%. This will allow agricultural producers to reduce the cost of purchasing necessary materials and stimulate the transition to organic farming;

3.informing the population about the benefits of ecological agriculture, organic farming and the consumption of organic food. The transfer of information will familiarize consumers

with the benefits of such products and promote their demand for them;
4. development and implementation of a certification system for organic products. This will help set quality and safety standards for organic products and also increase consumer confidence in such products;
5. holding promotional events, fairs, exhibitions, competitions will help to popularize and develop organic farming; the development and adoption of local regulatory legal acts in the constituent entities of the Russian Federation will allow the use of modern environmentally friendly biotechnologies, and will also accompany the implementation of various support measures [41]. To effectively manage organic production processes, it is necessary to organize an information technology system, including the use of special equipment and software that meets modern international standards [18,19]. Creating conditions for certification of production of products intended for export is also an important step in the development of organic farming in Russia. Thus, for the successful implementation of this concept, it is necessary to take into account the development features and natural and climatic conditions of Siberia. Funding for activities should come from the federal and regional budgets, as well as extra-budgetary funds. The development and implementation of a program to support the development of organic farming in Siberia contributes to the dynamic development of agriculture and is aimed at increasing the competitiveness of domestic products and their compliance with international requirements [35]. Organic agriculture as a priority for environmental investments in the Republic of Mordovia (development opportunities and challenges), The Eurasian Scientific Journal, Vol. 14(6): 1-11.

CONCLUSIONS

The article develops theoretical and methodological approaches to the transition to organic production as a priority of the Strategy for Scientific and Technological Development of the Russian Federation. The need to develop methods and tools for the development of organic farming on an innovation and investment basis is substantiated. A study of global trends in the organic production market was conducted, which made it possible to determine the directions of development and stimulate demand for domestic organic products. The evolution of views and methodological approaches to studying the connection between organic agriculture and sustainable development is presented. The global trends in the development of the organic products market are studied, the dynamics of organic production in Russia are presented both in general and in the context of grain crops, legumes and vegetables. It has been empirically revealed that the bulk of the harvest of organic grain crops remains on the domestic market, and most of the leguminous crops are exported. The transformation of the Organic 3.0 concept is presented, approaches and principles for its implementation are developed. Organizational, economic and financial mechanisms and instruments for state support for the development of organic farming in rural areas of Siberia have been developed, including subsidies, subsidizing the purchase of certified planting materials, developing competency standards, and improving the regulatory framework. The economic, social and environmental role of organic farming as a driver of sustainable development in Siberia is substantiated. The practical significance of the results lies in the development of theoretical and methodological approaches and methodological tools for sustainable development of rural areas, based on the introduction of advanced organic farming technologies, as well as targeted mechanisms for stimulating organic production.

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REFERENCES

[1]Aceleanu, M.I., Molanescu, A.G., Craciun, L., Voicu, C., 2015, The status of Romanian agriculture and some measures to take.,Theor. Appl. Econ, Vol. 22:123–138.
[2]Aeberhard, A., Rist, S. (2008): Transdisciplinary co-production of knowledge in the development of organic agriculture in Switzerland, Ecological Economics Vol. 68 No. 4 pp. 1171-1181
[3]Agovino, M., Casaccia, M., Ciommi, M., Ferrara, M., Marchesano, K., 2019, Agriculture, climate change and sustainability, The case of EU-28, Ecological Indicators, Vol. 105: 525-543.
[4]Albrecht, W. A., 1940, Calcium-potassium-phosphorüs relation as a possible factor in ecological array of plants, Journal of the American Society of Agronomy, Vol.32 :411-418.
[5]Antczak, E., 2021, Analyzing Spatiotemporal Development of Organic Farming in Poland, Sustainability, Vol. 13(18): 10399.
[6]Arbenz, M., Gould, D., Stopes, Ch., 2017, ORGANIC 3.0 — the vision of the global organic movement and the need for scientific support, Organic Agriculture, Vol.7 :199–207.
[7]Barrett, S., 1991, Optimal soil conservation and the reform of agricultural pricing policies, Journal of Development Economics, Vol. 36(2):167–187.
[8]BIOFACH 2023 - IFOAM Organics Europe, 2023, https://www.organicseurope.bio/events/biofach-2023, Accessed on September, 14, 2023.
[9]Blakeney, M., 2016 , Organic Versus GM Agriculture in the Courtroom in Australia and the USA,/The Coexistence of Genetically Modified, Organic and Conventional Foods: Government Policies and Market Practices, pp. 113-135.
[10]Commission Regulation (EEC), 16.12.2009, https://www.rsa.ie/docs/default-source/services/s4.8-cvrt/commission-regulation-(eu)-1266-2009.pdf?sfvrsn=5c03bf0e_7, Accessed on September, 14,2023.
[11]Daly, H., 2007, Ecological economics and sustainable development. Edward Elgar Publishing,124 p.
[12]Derunova, E., Kireeva, N., Pruschak, O., 2020, The level and quality of inclusive growth agri-food system in modern conditions. Scientific Papers Series «Management, Economic Engineering in Agriculture and Rural Development», Vol.20(3),193-206.
[13]Derunova, E., Vasilchenko, M., Shabanov, Derunov, V., 2021, Mechanisms to stimulate the acceleration of innovative development in the agroindustrial complex. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development. Vol. 21 (2), 209-222.
[14]Fanelli, R.M., 2019, The (un)sustainability of the land use practices and agricultural production in EU countries, International journal of environmental studies, Vol. 76 (2): 273–294.
[15]Fortea, C., Antohi, V. M., Zlati, M. L., Ionescu, R. V., Lazarescu, I., Petrea, S. M., Cristea, D. S., 2022, The Dynamics of the Implementation of Organic Farming in Romania, Agriculture, Vol. 12(6): 774.
[16]Galkin, D.G., 2022, Organic and traditional agriculture: comparative economics, Bulletin of Chelyabinsk State University, Vol. 4 (462):123–130.
[17]IFOAM – Organics International, https://www.organicseurope.bio/events/biofach-2023/, Accessed on September, 30, 2023.
[18]Ivanov, A.L., 2015, The role of microbiology in assessing soil resources, Bulletin of Russian Agricultural Science, Vol. 6: 26–28.
[19]Ivanov, A.L., 2011, Innovative priorities in the development of farming systems in Russia, Fertility, Vol. 4: 2–6.
[20]Koreva O.V., Sivtsova V.A. (2019), Investment and innovation support for the development of organic farming in Russia, Regional Economics: Theory and Practice,Vol.17 (2): 345– 355.
[21]Kuepper, G., 2010, A brief overview of the history and philosophy of organic agriculture, Kerr Center for Sustainable Agriculture, Oklahoma, USA. 26 p.
[22]Lampkin, N., 1994, Organic Farming: Sustainable Agriculture in Practice in Lapmkin, N., Padel, S. (ed.) (1994): The Economics of Organic Farming – an International Perspective, CABI, pp. 3-8.
[23]Lazić B. et al., 2008, Organic Agriculture, Novi Sad: Institute for Agriculture and Vegetables, Vol.1. 265-280.
[24]Li, J., Li, Y., 2019, Influence measurement of rapid urbanization on agricultural production factors based on provincial panel data, Socio-Economic Planning Sciences, Vol. 67: 69-77. p. 179–199.
[25]Organic agriculture: the step of the countries of Eastern Europe, the Caucasus and Central Asia towards a "green" economy / United Nations Environment Programme. – Geneva, 2014. – P. 4
[26]Paull, J., 2020, Organic food and agriculture, Food and Society, Academic Press, p. 179–199.
[27]Pearce, D, Barbier, E., 2013, Sustainable development: economics and environment in the Third World. Routledge, 230 p
[28] Petrescu, A.G., Oncioiu, I., Petrescu, M., 2017, Perception of Organic Food Consumption in Romania. Foods, Vol. 6 (6): 42.
[29]Popescu, A., 2006, Research concerning the economic impact of investments in dairy farms of various size, International Symposium "Prospects of Agriculture in the 3rd Millennium", Oct. 6-7, 2005, Bulletin UASVM Cluj Napoca, Series Animal Husbandry and Veterinary Medicine, Vol.61, p. 399-403.
[30]Popescu, A., 2013,Considerations regarding the development of organic agriculture in the world, the EU-27 and Romania, Development, Vol. 13 (2):323-329.
[31]Rees, W., 2002, Scale, complexity and the conundrum of sustainability, Planning sustainability. Routledge: 111-137.

[32]Rudoy, E.V., Petukhova, M.S., Isaeva, G.V., Dobryanskaya, S.L., 2021, Organic farming as a promising direction of scientific and technological development of crop production in the Novosibirsk region. IOP Conference Series: Earth and Environmental Science. 723(3). 032031.

[33]Rudoy, E.V., Petukhova, M.S., Dobryanskaya, S.L., Sadokhina, T.A., Kapustyanchik, S.Yu., 2020, Algorithm for the development of the strategy for scientific and technological development of the crop sector of the Novosibirsk region IOP Conference Series: Earth and Environmental Science. conference proceedings. Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations. P. 32032.

[34]Sandu, I., Butorin, S., Ryzhenkova, N., 2019, Scientific basis for forecasting the innovative development of the agricultural sector of the region's economy (on the materials of the Perm region). In Proceedings of International Scientific and Practical Conference on Agrarian Economy in the Era of Globalization and Integration.IOP Conference Series: Earth and Environmental Science, 274(1), 012016

[35]Sausheva, O.S., 2022, Organic agriculture as a priority for environmental investments in the Republic of Mordovia (development opportunities and challenges), The Eurasian Scientific Journal, Vol. 14(6): 1-11

[36]Starovoitova, N.P., 2015, Organic farming in Russia: pros and cons. Business. Education. Law 4. 226-230

[37]Strategy for the development of organic production in the Russian Federation until 2030, 2020, http://static.government.ru/media/files/8tJynEn7pLVLfdqqL6p3BhArPtCQW9Aw.pdf, Accessed on September 25, 2023.

[38]Surpkelova, A., 2023, The economics of diversification of agricultural production in agricultural policy: the example of the organic market, Bulletin of Moscow University, Series 6, Economics, Vol.1:256-273.

[39]Sustainable Development Goals: 17 Goals to Transform our World, https://www.un.org/en/exhibits/page/sdgs-17-goals-transform-world, Accessed on September 29, 2023.

[40]The World of Organic Agriculture Statistics and Emerging Trends 2023, https://www.fibl.org/fileadmin/documents/shop/1254-organic-world-2023.pdf, Accessed on September 29, 2023.

[41]Tikhiy, V.I., Koreva, O.V., 2017, Problems of sustainable development of rural areas of the region: environmental, socio-economic analysis, InterCarto/InterGIS. Proceedings of the international conference "InterCarto/InterGIS", Vol. 23 (1):50–70.

[42]Tomaš-Simin, M., Janković, D., 2014, Applicability of diffusion of innovation theory in organic agriculture, Ekonomika poljoprivrede No. 2 pp. 517-529.

[43]Tudose, G., Enache, E., Culita, G., 2011, Agriculture-a Chance for the Economy in Crisis of Romania, Ovidius Univ. Ann. Econ. Sci. Ser, Vol. 11: 175–2180.

[44]Vasilchenko, M., Derunova, E., 2021 Assessment of the contribution of the investment potential to increasing the efficiency of agricultural production. Scientific Papers Series «Management, Economic Engineering in Agriculture and Rural Development», Vol.21(1), 805-816.

[45]Vasilchenko, M., Sandu, I., 2020, Innovative-investment development of agriculture in the conditions of formation of the export-oriented economic sector: system approach, Scientific Papers Series: Management, Economic Engineering in Agriculture and Rural Development, 2020, Vol 20(1), 599–612.

[46]Vogt, G., 2007, The Origins of Organic Farming, in Lockeretz W. (ed.): Organic Farming – an International History, CABI: 9-30.

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WHAT DETERMINES CONSUMPTION EXPENDITURE? ECONOMETRIC EVIDENCE AMONG HOUSEHOLDS IN LEYTE, PHILIPPINES

Mary Cris F. PLEÑOS

National Abaca Research Center, Visayas State University, Visca, Baybay City, Leyte, 6521 Philippines, Phone: +639285861863; E-mail: mc.plenos@vsu.edu.ph

Corresponding author: mc.plenos@vsu.edu.ph

Abstract

Household spending is essential in determining the productive success of an economy since changes in household consumption at the micro level will affect the economy as a whole. This study aims to evaluate the consumption expenditure of households in the province of Leyte and identify demographic characteristics that may affect it. Both descriptive statistics and multiple regression analysis were used to answer the objectives of this study. Based on the findings, the minimum monthly household consumption expenditure is PHP 2,222 (40.29 USD) and the maximum is PHP 71,792.10 (1,294.72 USD). A bigger portion of the overall spending is spent on food while the least is spent on healthcare. By econometric analysis, marital status, sex of the household head, education and income were positively related to the households' overall household spending. This study suggests that a family must increase their spending on healthcare, family planning must be considered to minimize household expenditures, and proper education must be promoted to ensure financial stability among households.

Key words: *household expenditure, consumption, econometric modelling*

INTRODUCTION

Consumption is the usage of goods and services by a household [1]. Household final consumption expenditure covers all purchases made by resident households to meet their everyday needs such as food, clothing, housing services (e.g. rents), energy, transport, durable goods spending on health, on leisure and on miscellaneous services [7]. Consumption behavior provides a good measure of the total national output in the economy and is a component in the calculation of the Gross Domestic Product (GDP). In fact, household spending accounts 60% of the GDP [13]. Household spending is an essential variable in determining the productive success in an economy [6]. In short run analysis, the level of household consumption determines the aggregate demand in the economy. Changes in the household consumption at micro level will affect the economy as a whole. On the other hand, household consumption also take part in long run analysis because of its influence in the growth of economy because GDP has a high share in GDP.

The level of household expenditures indicates the level of economic system development as a whole. This raises to examining what affects the consumption expenditure pattern at micro economic level. To do this, econometric analysis was done identifying and measuring the effect that may affect the household consumption expenditure. It was already found out in some studies that income is the most important factor that influence household spending however there are other factors that may affect it. This study focuses on identifying demographic characteristics that may influence household spending.

Generally, this study aims to evaluate the consumption expenditure of households in Leyte. The specific objectives are to examine the consumption pattern of households, identify the factors that may have influence on household expenditure, measure the impact of demographic attributes of a household on consumption expenditure of goods and services, evaluate the changes in individual household expenditure across demographic

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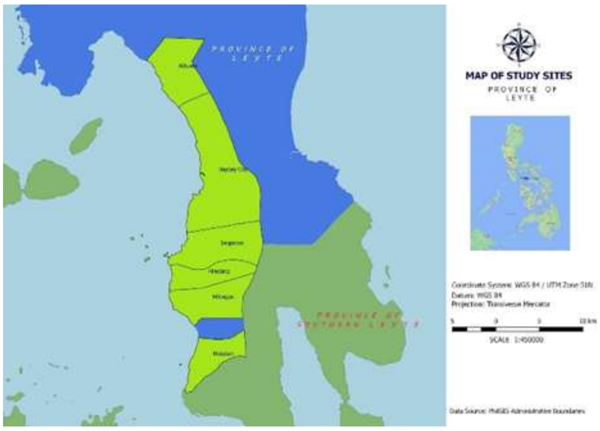
subgroups and recommend policies that would make household consumption healthy.

MATERIALS AND METHODS

Study area

Leyte is an island in the Visayas region in the Philippines (Map 1). It is eighth-largest and sixth-most populous island in the Philippines, with a total population of 2,626,970 as of 2020 census. The island measures about 180 kilometres (110 mi) North-South and about 65 kilometres (40 mi) at its widest point. In the north it nearly joins the island of Samar, separated by the San Juanico Strait, which becomes as narrow as 2 kilometres (1.2 mi) in some places. The island province of Biliran is also to the north of Leyte and is joined to Leyte island by a bridge across the narrow Biliran Strait. To the south, Leyte is separated from Mindanao by the Surigao Strait. To the east, Leyte is somewhat "set back" from the Philippine Sea of the Pacific Ocean, Samar to the northeast and the Dinagat Islands to the southeast forming the Leyte Gulf. To the west is the Camotes Sea [11].



Map 1. Map of Leyte Province
Source: PhilGIS Administrative Boundaries [9].

Sampling

This study recommends using a 95% confidence interval, which suggests that the sample is certain at 95% of the time. The established Z-value for the 95% confidence interval is 1.96. The population variance was estimated using proportions. It was assumed that the proportion is 0.5 since there is limited information available. A close to 1 proportion suggests a best-case assumption. For the margin of error, a modest 6% assumption was used. The bigger the margin of error the lower is the sample size and the smaller the margin of error the bigger is the sample size. Using the equation below, the estimated sample size for the study areas is computed as follows:

$$n_o = \frac{Z^2_{\alpha/2}(p)*(1-p)}{e^2} \quad (1)$$

$$n_o = \frac{1.96^2(0.5)*(1-0.5)}{0.06^2} = 266 \quad (2)$$

where:

n_o	sample size to be determined
$Z_{\alpha/2}$	confidence interval (95%)
p	proportion (0.5)
e	margin of error (6%)

Based on the computation, a total of 266 respondents was surveyed for this study. This 266 sample size was proportionately allocated to selected municipalities in Leyte, Philippines.

Data collection

This study utilizes primary data through a pretested survey questionnaire. Enumerators were trained prior to the conduct of survey to ensure familiarity of the instrument. From each municipality, households were selected randomly and the following information were collected to answer the objectives of the study:
- Demographic characteristics
- Household expenditures
- Household income/s

Descriptive analysis

Descriptive statistics such as frequency counts, percentages, means, and standard deviations were computed to describe the data gathered from households. Analysis were presented using tables and graphs.

Econometric analysis

Multiple regression analysis was used to determine what affects the household consumption expenditures. There were nine models formulated to capture the factors that may affect the household expenditures. The first model uses total monthly expenditures as dependent variable while the rest of the models utilizes expenditure share of item as response variable. In the analysis, the same explanatory variables were used across the models. The general econometric model that measures the impact of demographic characteristics on the expenditure pattern of households is postulated below:

$$\boldsymbol{Y_{it}} = \boldsymbol{\alpha + \beta X_{it} + u_{it}} \quad ....(3)$$

where: Y is the vector of expenditure share used as dependent variables. The expenditures are divided into eight groups. X represents a vector of independent variables, the demographic characteristics while u is an unobserved random disturbance.

Dependent variables

Since there were nine models formulated in the study, the following are the response variables (Table 1). The first model uses the total monthly household consumption expenditure as response variable which is obtained by adding reported expenditure on food and non-food items. The rest of the response variable is the expenditure share of food and non-food items.

Table 1. The explanatory variables

Variable	Definition
Exp_i	the total monthly household consumption expenditures
$Food_i$	the monthly household expenditure on food
$Debt_i$	the monthly payment to debts
$Personal_i$	the monthly personal spending
$Transpo_i$	the monthly expenditure for transportation
$Housing_i$	the monthly expenditure for house repairs
$Utilities_i$	the monthly household expenditure electricity and water
Entertainment	the monthly expenditure on entertainment
$Healthcare_i$	the monthly expenditure on health

Source: Set by the author.

Independent variables

Table 2 displays the seven explanatory variables used in the econometric model. These variables were the demographic characteristics of the respondents. Across the models, the same independent variables were utilized. It consists of three dummy variables and four continuous variables. All these variables were hypothesized to be positively related to the response variables.

Table 2. The explanatory variables and their description

Variable	Definition
$male_i$	a dummy variable that refers to male as household head (1- male, 0-female)
age_i	a continuous variable that refers to age of the respondents (in years)
$married_i$	a dummy variable that refers to married household head (1-married, 0-unmarried)
$educ_i$	a continuous variable that refers to the educational attainment of the respondent
$hhsize_i$	a continuous variable that refers to the size a family
inc_spouse_i	a dummy variable that refers to the availability of income among the spouse of a respondent (1- spouse has income, 0 –spouse has no income)
inc_i	a continuous refers to the monthly income of the respondent (in PHP)
u_i	the error term

Source: Set by the author.

RESULTS AND DISCUSSIONS

Demographic characteristics

In this study, there were a total of 266 households from Leyte who were interviewed. Table 3 below presents the descriptive analysis of the independent variables namely age, civil status (married), sex (male), household size, education, availability of income among spouses and monthly income. The analysis include mean, standard deviation, minimum and maximum values. It was expected that these factors positively influence the response variable(s), monthly household expenditures share. As indicated in the table below, the respondents from household respondents are 45 years old on average and about 80% of them are married. Ninety-seven percent of the household heads are male and have an average of five members in a family. The average education level for the respondents is seven years, meaning the majority of them

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have completed primary school. About 30% responded that their spouses has income. Households make an average monthly income of 10,481 PHP (190.05 USD).

As displayed in Table 4, the minimum monthly household expenditure is 2,222 PHP (40.29 USD) while the maximum value is 71,792.10 PHP (1,301.76 USD).

About half of the respondents consumed about 11,198.01 PHP (203.05 USD), the median value and the rest is above this value. The mean is 13,903.49 PHP (252.10 USD) which is larger than the median. This is due to some households' higher consumption compared to majority of households, as seen by a right- skewness value (2.88, which is more than zero), indicating that the majority of the data are on the graph's left side (high values). The kurtosis value (10.10 > 3) on the other hand also suggests that the consumption data has more extreme values.

Table 3. Descriptive analysis of explanatory variables

Variable	Obs	Mean	Std. Deviation	Min	Max
Age	266	45.37594	13.54634	15	89
Married	266	.8007519	.4001879	0	1
Male	266	.9661654	.181144	0	1
Household size	266	5.030075	2.127187	1	13
Education	266	6.947368	3.078387	0	20
Spouse has income	266	.3045113	.4610676	0	1
Total monthly income	266	10,481.45	8,899.362	240	84,050

Source: Author’s calculation and analysis (2023)
Note: As of 15th February 2023, 1 USD = 55.15 PHP

Table 4. Descriptive results of total monthly household consumption expenditure

	1st Qu.	Median	Mean	3rd Qu.	Min	Max	Skewness	Kurtosis
Value (PHP)	7,960.74	11,198.01	13,903.49	15,492	2,222	71,792.10	2.88	10.10

Source: Author’s calculation and analysis (2023).

Household Expenditures Pattern

The descriptive analysis of household spending is shown in Table 5.

Households spent more for food than any other items that reached up to 6,234.52 PHP (113.05 USD) in a month, that is about half of the total household consumption expenditure as illustrated in Figure 1.

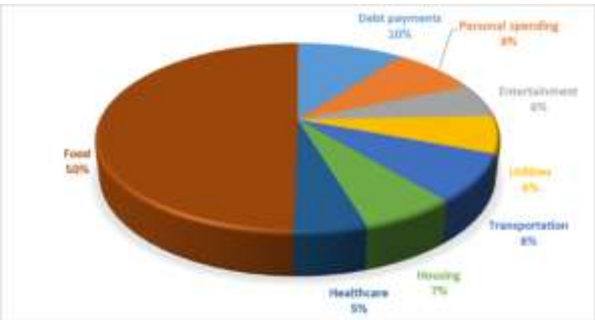

Fig. 1. Household consumption expenditure pattern of households
Source: Authors' design and calculation.

With food as a survival necessity for humans, the amount spent on it is a measure of household food security because it is well known that the poorer and more vulnerable a home is, the greater the percentage of household income spent on food [4]. Following that, a 1,282.84 PHP (23.26 USD) loan payment that equals up to 10% of the total cost was made.

Formal and informal personal loans count as payments on debts. Less money was allocated for personal expenses (such as gifts, clothing, and shoes), which on average totaled 1,046.62 PHP (1,898 USD), or around 8% of the overall.

This is close to transportation expenses (e.g. gas and public transit) which may total up to 1,023.583 PHP (18.56 USD).

Housing and utilities are nearly close, 806.96 PHP (14.63 USD) and 802.94 PHP (14.56 USD), that is about 7% and 6% respectively. Utilities generally include electricity, water bills, phone bills and internet expenses while housing expenses covers everything from rent or mortgage payments to property taxes, and home maintenance costs.

Approximately 727.7632 PHP, or 6% of the total, was spent on entertainment and recreation (e.g. spots, hobbies, vacations).

The least amount, 619.5113 PHP, or around 5% of total spending, is on healthcare. Medication, dietary supplements, and vitamins are all part of healthcare.

Table 5. Descriptive analysis of household expenditure items

Statistics	Food	Healthcare	Housing	Transportation	Utilities	Entertainment	Personal spending	Debt payments
Mean	6,234.52	619.51	806.96	1,023.58	802.94	727.76	1,046.62	1,282.83
Std. Error of Mean	241.293	196.912	239.342	94.1	56.833	82.558	87.342	229.204
Median	5,470.5	0	0	510	540	260	725	0
Std. Deviation	3,935.377	3,211.536	3,903.544	1,523.137	926.919	1,346.479	1,424.511	3,738.207
Skewness	3.102	9.977	9.218	2.584	3.099	3.692	5.431	6.021
Kurtosis	18.075	113.938	102.846	7.737	12.742	16.585	40.618	40.896
Range	34,000	41,666	50,000	10,200	6,520	10,000	13,166	30,000
Minimum	0	0	0	0	0	0	0	0
Maximum	34,000	41,666	50,000	10,200	6,520	10,000	13,166	30,000

Source: Author's calculation and analysis (2023)
USD 1 = PHP 55.15 (as of 15th February 2023)

Comparison of household consumption expenditure and income by demographic characteristics

Table 6 displayed the comparison of household consumption expenditure and income by selected demographic characteristics such as sex, marital status, household size and higher educational attainment of the respondents. With male as the household head, household consumption expenditures is higher than the females as household head however female as household heads earned higher than males. Meanwhile, married respondents has higher incomes than the unmarried ones which leads higher consumption expenditures since having a family implies more members in a family resulted to higher expenses. Household size with more than five members has higher expenditures and incomes due to the fact that there are more members in a family, more member leads to higher demand especially on basic needs. In terms of education, those respondents who have higher education tend to have higher incomes and higher expenditure which is in parallel to the work of [3].

Table 6. Descriptive analysis of expenditure and income

Demographic characteristics		Expenditures (in PHP)	Expenditures (in USD)	Income (in PHP)	Income (in USD)
Sex	Male	14,021.56	254.24	10,433.62	189.19
	Female	10,532	190.97	12,851.11	233.02
Marital Status	Unmarried	8,586.96	155.70	9,839.53	178.41
	Married	15,226.38	276.09	10,680.8	193.67
Household size	3 and below	14,520.8	263.30	9,696.49	175.82
	3 to 5	12,576.65	228.04	10,132.79	183.73
	above 5	15,151.88	274.74	11,556.02	209.54
Education	Elementary level	12,686.55	230.04	8,957.99	162.43
	High school level	12,305.55	223.13	10,384.75	188.30
	College level	14,559.71	264	10,784.91	195.56

Source: Author's calculation and analysis.
USD 1 = PHP 55.15 (as of 15th February 2023).

Econometric Analysis

This section illustrates the demographic characteristics that significantly influence the household expenditures. When the household respondent is married, household expenditures increases by 206.4 PHP, it shows statistical significance at 1% level. An additional years of education also increases the expenditure of a family by 31.08 PHP, it is significant at 1% level. Increase in income increases the expenditure by 0.00755 PHP significant at 5%. This means that for one additional unit in income it increases the expenditure by 0.00755. Other selected variables such as age, household size, and the presence of income for spouse showed to have positive impact in household expenditures however no statistical evidence to show their significance. The econometric model is significant since there is at least one variables which is significantly related to total expenditures. Only about 19.2% of the variation of total expenditures was explained by the sex, marital status, educational attainment and monthly income while the rest of 80.8% is due to other factors not mentioned in the econometric model.

Table 7. Regression analysis results

VARIABLES	Total expenditures	Food	Debt payments	Personal spending	Transportation	Housing	Utilities	Entertainment	Health care
Male as HH head	4,892**	833.7	1,541**	232.6	411.9	1,021	252.2	227.8	378.9
	(-2,082)	(-1,209)	(-619.9)	(-207.2)	(-268.2)	(-682.3)	(-156.6)	(-359.3)	(-337.7)
Age	21.3	1.793	-7.013	-11.93	-0.677	31.8	8.228**	-9.729	8.816
	(-47.84)	(-14.2)	(-22.09)	(-8.787)	(-7.964)	(-20.04)	(-3.664)	(-6.999)	(-11.71)
Married	5,014***	2,363***	978.4**	543.8***	-35.99	158.2	105.8	328.9*	517.6
	(-1,233)	(-531.6)	(-441.9)	(-203.5)	(-292.4)	(-306.2)	(-122.7)	(-191.9)	(-322.5)
Education	970.1***	169.4*	138.8	45.45	56.97*	347.6*	41.19**	-7.987	174.4
	(-311.4)	(-86.58)	(-109)	(-40.36)	(-32.36)	(-177.4)	(-17.04)	(-27.18)	(-110)
Household size	-221.3	-33.99	57.1	-10.59	-33.2	-29.05	-13.1	-24.68	-134.5
	(-256.6)	(-113.6)	(-98.17)	(-44.69)	(-36.67)	(-77.12)	(-26.12)	(-39.74)	(-113)
Spouse has income	590.6	-485.4	56.53	-36.21	62.79	1,170*	146.2	-22.66	-231.4
	(-1,350)	(-498.4)	(-530.7)	(-214.9)	(-190.4)	(-663.6)	(-129.6)	(-201.2)	(-423.1)
Monthly income	0.238***	0.0779***	0.109	0.00853	0.0182	-0.00714	0.0273**	0.0176	-0.0124
	(-0.0859)	(-0.0291)	(-0.069)	(-0.00974)	(-0.013)	-(0.0131)	(-0.0135)	(-0.0135)	(-0.0137)
Constant	-5,473	1,781	-3,081	586.7	244.5	-4,299*	-450.1	688	-895.8
	(-4,909)	(-1,783)	(-2,296)	(-697.9)	(-521.9)	(-2,497)	(-362.6)	(-569.9)	(-1,060)
Observations	262	266	266	266	262	266	266	266	266
R-squared	0.192	0.108	0.101	0.043	0.03	0.106	0.112	0.031	0.042

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Source: Author's calculation and analysis (2023).

Food

Food expenses consist of food and nonalcoholic beverages purchased at grocery, convenience, stores dining at restaurants [10]. As seen in Table 7, expenditure share on food is higher by 2,363 PHP (152.45 USD) when the head of the household is married. The difference of food expenditure between married and unmarried household heads is statistically significant at 1%. This is due to that fact that married people have larger families with more members, thus there is a corresponding rise in food consumption. Education was also found to be significantly related with households' food expenditure share at 10% level. That is, as educational level increases by one unit, the level of expenditure share on food rises by 169.4 PHP (11.18 USD). This is in parallel to the study of Hogan et al. We find that investments made in education can increase expenditure on fresh fruits and vegetables among food insecure household (FAO, 2023) [3]. Meanwhile, results appeared that monthly income had a positive effect on a household's food expenditure share. For every peso increase in monthly income, there was a 0.0779 PHP (0.0014 USD) rise in monthly food spending. This outcome is in contrary to Engel's law that states other things being equal, the share of the household budget spent on food will rise as household income falls [5]. This scenario may be because as income rise, consumers purchase more expensive foods because they are more health conscious because prices play an important role in household's expenditures. Other factors including age, household size, and the availability of income among spouses did not appear to be significantly related to household monthly food expenses.

Debt Payment

Debt payments include formal and informal loans. Based on the econometric analysis, the share for debt payments is higher by 1,541 PHP (27.94 USD) when males are the household heads in the family, this difference is statistically significant at 5%. Married respondents' payments of debts increases by 978.4 PHP (17.74 USD) than unmarried individuals. This outcome is due to the fact that married individuals are having more financial responsibilities thus they are more exposed to having debts. On the other hand, a negative relationship was posted by age to debt payments but not statistically significant. Other variables such as education, household size, availability of income among spouses and monthly income displayed positive impact to debt payments however no statistical evidence to support this.

Personal Spending

This expenditure covers personal care products (e.g. soap) or lifestyle expense and includes things like clothes and shoes. When married, share on personal expenditure increases by 543.8 PHP (9.86 USD), this results is statistically significant at 1%. One possible explanation for this outcome is that married individuals have more members in a family thus increasing their personal expenditures. Other variables such as age, household size, presence of income among spouse showed to have negative influence to personal expenditures however it has no statistical significance for this. Sex of household heads, educational attainment and monthly income are positively related to personal expenditures however it has no sufficient evidence to prove this.

Transportation

Transportation expenses consist of the monthly payments on vehicle loans, down payments, gasoline and motor oil, maintenance and repairs, insurance, and public transportation including airline fares [10]. Based on the results, with higher education so also the transportation expenditure increases. That is, one unit increase in education increases the transportation spending by 56.97 PHP (1.03 USD), this outcome is significant at 10% level. That is, more educated individuals have higher incomes resulted to more decent jobs and higher incomes thus most of them have their own vehicles thus increasing their expenditures in terms of gas. Those with lower incomes prefer to commute since it is quite cheaper on their side than buying their own vehicle [12].

Housing

Housing expenses consist of shelter mortgage payments, property taxes, or rent; maintenance and repairs; and insurance [10]. As illustrated in Table 7, education is statistically significant to affect housing expenditures. This translates to a one unit increase in education increases the housing spending by 347.6 PHP (6.03 USD). According to [8] there is a strong link between education and income. When spouse has income, their housing spending is higher by 1,170 PHP (21.21 USD) than those families whose spouses who don't income, significant at 5%. This is because when spouses are working they have additional income resulting to more income and more capacity to pay for housing expenditures.

Other variables such as male as head, age, civil status, household size and monthly income showed no statistical evidence of its impact to housing expenditures.

Utilities

Utility expense is the cost incurred by using utilities such as electricity, water, waste disposal, heating, and sewage [2]. As seen in the Table 7, one unit increase in age significantly increases the monthly utilities by 2.23 PHP (0.04 USD). Education also affects this spending significantly. That is, one year increase in education increases this spending by 41.19 PHP (0.74 USD). Meanwhile, increase in income also increases the amount spent for utilities. A one unit increase in income increases the utility by 0.0273 PHP (0.0005 USD).

Entertainment

Married individuals spent 328.9 PHP (5.96 USD) higher than unmarried individuals, significant at 10%. Male as household head, availability of income for spouse and monthly income showed to have positive influence to entertainment expenditure while age, marital status, educational attainment and household size displayed to be negatively related but no enough evidence to show its significance.

Healthcare

Healthcare expense consists of any costs incurred in the prevention or treatment of injury or disease. It include health and dental insurance premiums, doctor and hospital visits, co-pays, prescription and over-the-counter drugs, glasses and contacts. As reported in Table 7, no demographic variables showed to have significant impacts to share for healthcare.

CONCLUSIONS

This study examines the consumption expenditure of 266 households in Leyte, Philippines. The respondents were selected randomly from each municipalities in the said province. Based on the results obtained in descriptive analysis, the minimum monthly household consumption expenditure is PHP 2,222 (USD) and the maximum is PHP 71,792.10 (USD). This indicates that there is a high difference among household consumption expenditure. A significant portion is spent on the overall spending on food. The household spent more on food than any other items, this was followed by payments to debts while the least spent is on healthcare. By descriptive analysis, female as household heads has higher incomes than male as household head. However, male household heads has higher expenditures than females. Meanwhile, married respondents has higher incomes than unmarried ones leading to higher expenditures due to the fact that married individual children in the family. Those respondents who have higher educational level as higher income thus, increasing their expenditures as well. Using econometric analysis, monthly household consumption expenditures is determined by sex of household head, marital status, education and monthly income. They appeared to be positively related to overall household spending.

It was observed that more money is spent on food however households spent less on healthcare. With this, it is recommended that a family must increase their spending on healthcare (e.g. health insurance, vitamins). Second, since more household size mean higher expenditure, family planning must be considered to minimize household expenditures. Third, considering higher education leads to higher income, proper education must be promoted to ensure financial stability among households. Lastly, since the regression showed to have a lower R squared, meaning only a small portion of the response variable was explained by the explanatory variables it is highly suggested to add more demographic variables hypothesized to be related to consumption expenditure.

REFERENCES

[1]Corporate Finance Institute, 2015, https://corporatefinanceinstitute.com/resources/economics/consumption/. Accessed on 15 January 2023.
[2]Corporate Finance Institute, 2022, https://corporatefinanceinstitute.com/resources/account

ing/utilities-expense/ Accessed on 15 January 2023.
[3]Food and Agriculture Organization of the United Nations, 2023, Estimating the Relationship between Education and Food Purchases among Food Insecure Households.
[4]International Dietary Data Expansion, 2015, https://inddex.nutrition.tufts.edu/data4diets/indicator/household-food-expenditure-share. Accessed on 15 January, 2023.
[5]Mulamba, K. C., 2022, Relationship between households' share of food expenditure and income across South African districts: a multilevel regression analysis. Humanities and Social Sciences Communications, 9(1), 1-11.
[6]Organization for Economic Cooperation and Development, 2023, https://www.oecd-ilibrary.org/economics/national-accounts-at-a-glance-2013/household-consumption. Accessed on 15 January, 2023.
[7]Organization for Economic Cooperation and Development, 2012, National Accounts of OECD Countries, OECD Publishing. http://dx.doi.org/10.1787/2221433x.
[8]Patrinos, H.A., Psacharopoulos, G., 2018, Strong link between education and earnings. https://blogs.worldbank.org/education/strong-link-between-education-and-earnings. Accessed on 15 January, 2023.
[9]PhilGIS Administrative Boundaries. https://www.igismap.com/ Accessed on 23 August, 2022.
[10]Washington State Department of Social and Health Services 2010. https://www.dshs.wa.gov/sites. Accessed on 15 December, 2022.
[11]Wikipedia, https://en.wikipedia.org/wiki/Leyte. Accessed on 15 January, 2023.
[12]Wolla, S. A., Sullivan J., 2017, Education, Income, and Wealth. https://research.stlouisfed.org/. Accessed on 15 January, 2023.
[13]Varlamova, J., Larionova N., 2015, Macroeconomic and demographic determinants of household expenditures in OECD countries. Procedia Economics and Finance 24 (2015) 727-733.

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CONCENTRATION TRENDS IN MILK PRODUCTION AND NUMBER OF DAIRY COWS IN ROMANIA, 2013-2022

Agatha POPESCU[1,2,3], Cristina TINDECHE[1], Alina MARCUTA[1], Liviu MARCUTA[1], Adelaida HONTUS[1], Mirela STANCIU[4]

[1]University of Agronomic Sciences and Veterinary Medicine Bucharest, 59 Marasti Blvd, District 1, 011464, Bucharest Romania, Phone: +40213182564, Fax: +40213182888, Emails: agatha_popescu@yahoo.com, tindeche_cristina@yahoo.com, alinamarcuta@yahoo.com, liviumarcuta@yahoo.com, adelaidahontus@yahoo.com
[2]Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu-Sisesti", 61 Marasti Blvd, District 1, 011464, Bucharest Romania, Email: agatha_popescu@yahoo.com
[3]Academy of the Romanian Scientists, 1 Ilfov Street, Bucharest, 030167, Romania,
Email: agatha_popescu@yahoo.com
[4]"Lucian Blaga" University of Sibiu, Faculty of Agricultural Sciences, Food Industry and Environmental Protection, 7-9, Dr. Ion Rațiu Street, 550003, Sibiu, Romania, Phone:+40269211338; E-mail: mirela.stanciu@ulbsibiu.ro

Corresponding author: agatha_popescu@yahoo.com

Abstract

The goal of this study is the analysis of the dynamics of milk production, yield and dairy cows in Romania in the period 2013-2022. The empirical data were provided by National Institute of Statistics and were processed using the fixed basis index, and concentration method based on Herfindahl-Hirschman index, graphical representation of the regression equations and R square. The results confirmed the general declining trend in milk production which reached 35,300 thousand hl in 2022, being by 9.1% smaller than in 2013. The bovine livestock also decline and the number of dairy cows decreased, in 2022 accounting for 1,075.6 thousands heads by 9.2% smaller than in 2013. Milk yield in Romania also declined in the analyzed interval by 7.6% from 3,643.8 kg in 2013 to 3,367 kg per cow in 2022. Milk yield in Romania is the smallest in the EU-27, being twice lower than the EU mean accounting for 7,653 kg/cow. The factors which led o such a critical situation in dairy farming have been: the non corresponding farm structure, where 80% are small farms raising 1-2 cows, 13% have 2-5 cows and just 0.32% of farms raise over 50 cows. Also, during the last years, climate change in terms of low precipitations and long and severe drought affected forage production. Farm inputs price increased by 70% which led to high production costs that the low milk price of Lei 1.4-1.8 imposed by milk processors could not covered. The degree of concentration of milk production and of the number of dairy cows in Romania is enough small, ranging between 015-0.20 reflecting a moderate concentration. The subsidies per animal and milk were not enough to save the situation, and in consequence, a part of farms failed and other farms sold their animals to slaughterhouses. To avoid milk imports which have significantly raised during the years 2021-2022, the breeders have to be sustained by consistent subsidies to help their cows to produce more milk as dairy cows farming is in the most critical situation as never before.

Key words**:** *milk, production, yield, dairy cows, trends, Romania*

INTRODUCTION

From 497 million metric tons of cow milk in 2015, in 2022, the world milk production reached 549 million metric tons, meaning a surplus of 10.46%. Liquid milk value have the largest share on the dairy market [31].
The EU is one of the most important milk producer in the world and in 2022, it carried out 159.34 million tonnes raw milk, of which 154.3 million tonnes (96.43%) came from cows. Milk is produced in each member state, but the top producers are Germany, France, Poland, Netherlands and Italy and the lowest one Malta.
In 2022, milk delivered to dairies accounted for 149.9 million tonnes, meaning 91% of total milk production, the difference of 9%

being consumed by the farmer's family. Cow milk delivered to dairies accounted for 145.6 million tonnes, meaning 97.13%, the rest being supplied by buffaloes, sheep and goats [6].

In 2021, the EU-27 produced 23,2 millions tonnes milk for consumption, the key contributors being Germany (4.4 million), Spain (3.4 million), France (3 million) and Italy (2.5 million.

Romania is situated on a lower position in the EU, producing a smaller milk amount for consumption (400 thousand tonnes). Bulgaria, Latvia and Cyprus are not able to exceed 100 thousand tonnes [9, 18, 21].

Milk producing sector of Romania's agriculture is in a critical situation during the last decades. First of all, the bovine livestock is in a continuous decline, the number of dairy cows and heifers is difficult to increase, and production is not sustained by breed structure and mainly by a corresponding technology, feeding being not balanced and sufficient from a quantitatively point of view and forages are not of high nutritive value. Productivity is also low due to the farms structure dominated 80% by small subsistence farms raising 1-2 cows and only a few farms, less than 0.5% grow over 50 cows.

Milk yield is small and gross margin as well, taking into account the high share of variables costs [16, 17].

An important part of milk produced is consumed in the farm and milk marketed to dairies is in a continuous decline which call imports in the last two years to assure a corresponding offer on the domestic market [21].

Milk price at farm gate imposed by milk processors is not able to cover production cost which deeply affect the producers [24].

Subsidies are not of much help being offered per surface unit stimulating vegetal sector, and per animal head have been discriminatory sustaining only the farms with more animals [25].

In this context, the paper aimed to study the dynamics of milk production, milk yield and dairy cows number in the last decade 2013-2022 in order to identify the main trends and causes which affect milk sector in Romania at present. Finally, recommendations for improving the situation have been done.

MATERIALS AND METHODS

This study is based on a large literature on the topic in Romania and also on the empirical data provided by National Institute of Statistics for the period 2013-2022.

The main studied indicators have been: milk production, yield, the number of dairy cows and buffaloes.

The data were analyzed in their dynamics using fixed basis index and setting up graphics and determining the trend equation and coefficient of determination.

Fixed basis indices, whose formula is:

$I_{FB}=(y_t/y_0)*100$ .... (1)

Average growth rate, having the formula:

$\bar{R}_a = (\sqrt[n-1]{\frac{y_n}{y_0}} - 1)*100$ ....(2)

Trend method using the linear regression function according to the formula:

$\widehat{yt}= bt + a$ .... (3)

or polynomial regression of the 2nd degree

$\widehat{yt}= bt^2 + bt + a$ .... (4)

Herfindhal-Hirschman index was used to determine the concentration of milk production and of the number of dairy cows in Romania, using the formula:

$HHI_j= \sum_{i=1}^{n} g_i^2$ ....(5)

It was calculated by squaring the share of milk production by each micro region in total production or squaring the share of the number of dairy cows and buffaloes by each micro region in the total

The graphical method was used to illustrate the results for a better understanding.

Comparison method shows the differences between the analyzed indicators in Romania versus EU level and among micro-regions in the country.

The results were illustrated in graphics and correspondingly interpreted.

RESULTS AND DISCUSSIONS

Dynamics of milk production

In Romania, milk production comes in the highest proportion from dairy cows and buffaloes, and in a lower proportion from sheep and goats and other species.

In the analyzed period total milk production (calves' milk consumption excluded) registered a continuous decline from 44,786 thousand hl in 2013 to 41,360 thousand hl in 2022, meaning by 1.65% less.

The coefficient of determination $R^2 = 0.85$ reflects how much milk production variation depended on time changes. More than this, negative x value reflects that in the future milk production will continue to decline (Fig. 1).

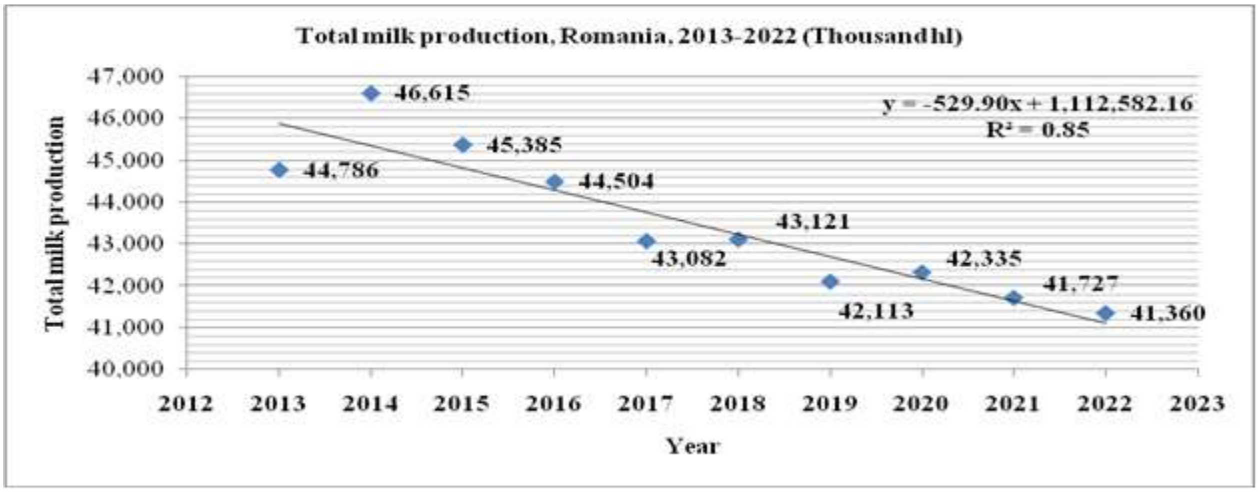

Fig. 1. Total milk production in Romania (calves' consumption excluded), 2013-2022 (Thousand hl)
Source: Own design and calculation based on the data from NIS, 2023 [13] and Statista [32].

But, milk production produced by dairy cows and buffaloes (calves' consumption excluded) recorded a sharp decrease accounting for 8.67% from 38,651 thousand hl in 2013 to 35,300 thousand hl in 2022 (Fig. 2).

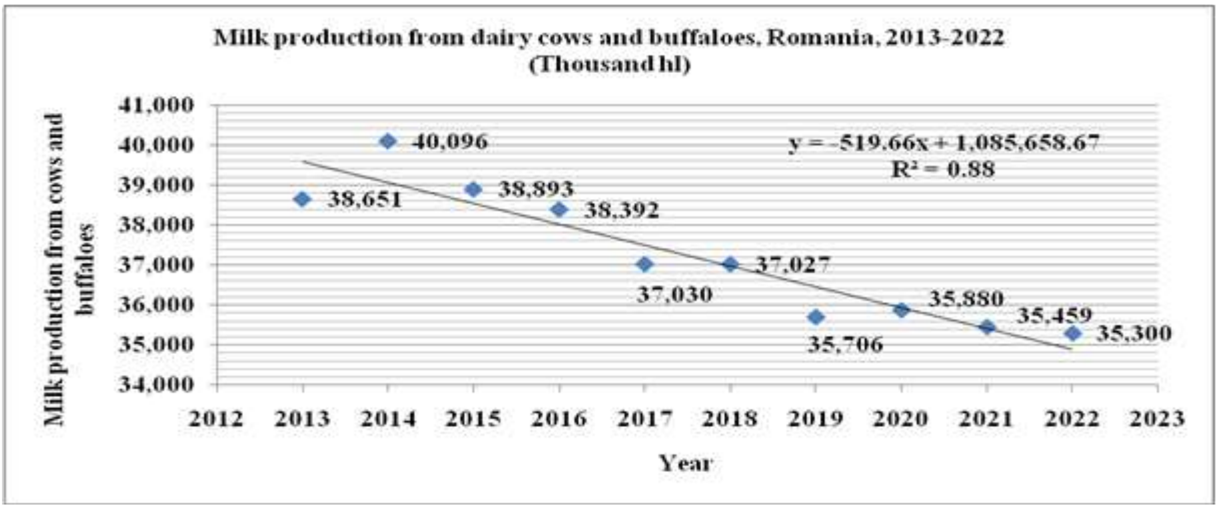

Fig. 2. Milk production from dairy cows and buffaloes in Romania (calves' consumption excluded), 2013-2022 (Thousand hl)
Source: Own design and calculation based on the data from NIS, 2023 [13].

As a result, the share of milk production coming from dairy cows and buffaloes in total milk production decreased from 86.30% in the year 2013 to 85.34%, therefore, by -0.96 percentage points. This difference reflects that the contribution of other species like sheep and goats etc increased.

Distribution of milk production by micro-regions of development

Milk production is produced in all the regions of Romania, but there are important differences regarding their contribution to total output.

In 2013, on the first positions were situated the following micro-regions: North East, North West and Central area, where the most numerous dairy cows are raised. Then, on the 4th and 5th position are South Muntenia and South East regions. South West Oltenia and West regions were on the 6th and 7th position, and finally Bucharest-Ilfov area (Fig. 3).

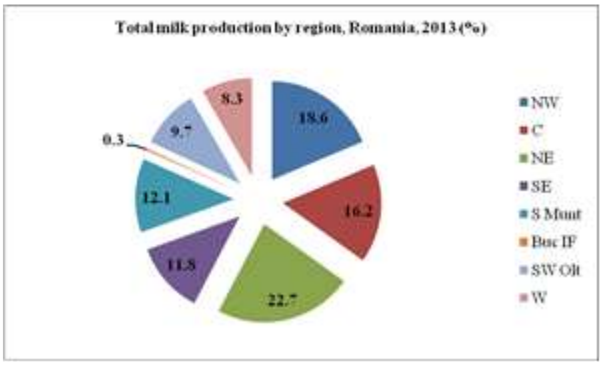

Fig. 3. Distribution of total milk production by micro-region, Romania, 2013 (%)
Source: Own design and calculation based on NIS data, 2023 [13].

In 2022, it happened a structural change as follows; North East micro-region preserved it top position, but the Central area came on the 2nd position, while North West area passed on the 3rd.

South Muntenia and South East remained on their 4th and 5th positions, but South West Oltenia and West passed on the 6th position. Bucharest Ilfov is always ranked the last (Fig. 4).

According to a detailed research reflecting the distribution of milk production by counties, it was found that Mures, Bihor and Suceava counties have the highest records in milk production, accounting for about one 5th of the total production in the country [3].

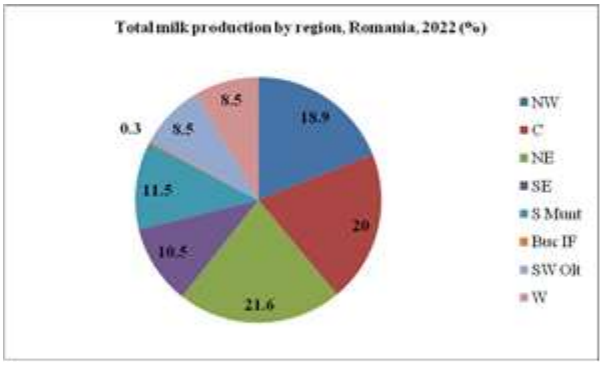

Fig. 4. Distribution of total milk production by micro-region, Romania, 2022 (%)
Source: Own design and calculation based on NIS data, 2023 [13].

The decline of milk production in Romania reflects a critical situation on the milk market, affecting milk offer from internal source and encouraging imports of gross milk. This situation is caused by numerous factors.

First of all, the decrease in the number of milking farm animals especially of dairy cows and buffaloes, which continued like in the previous years. In its turn, this aspect was caused by:

- The reduced forage production, affected both quantitatively and qualitatively, which was determined by the climate change in terms of low precipitation levels and long and severe droughts in the last years; and this happened both in the plain, hilly and mountain areas, resulting a low production of green grass, hay, silage and other forages.

-Degradation of pastures and meadows due to the damage on the floristic structure caused by the lack of natural fertilizers (manure) determined by the livestock declined and irrational grazing etc in the mountain areas.

- Taking into consideration that the farmers could not harvest the necessary volume of forages for their animals, they had to buy forages from the market, but the increased demand has led to a forage price higher by even 70%.

-But, the price of acquisition of all the farm inputs (forages, fuel, energy, medicines, services etc) increased, leading to high production costs in dairy farming.

-Monthly production cost per dairy cow reached about Lei 1,500, as affirmed Farmers Association of Romania.

-Milk price at farm gate offered by processors is not enough to cover production cost in case of many farms. Negotiations with milk processors are difficult and always advantage the dairies which impose their price as the farmer needs to sell the milk. Many farmers are obliged to accept a price at farm of Lei 1.6-1.8 per milk kg, instead of a double price which could cover production cost. This is not a fair situation because the same milk processors operating in Romania, in other countries, offer Eurocents 50 for milk litre and sell the milk in the supermarkets shelves at a price of Euro 2 per litre, like in Romania Lei 10.

-Also, milk price is determined by its quality, an aspect where it is still a "free box" to fill. Manual milking in the most of subsistence farms do not assure in most of the cases a milk quality fitting the hygiene and sanitary standards, which is a reason as milk price to be low or the delivery of milk to be rejected by processors.

-Many farmers raising dairy cows are facing such a situation being obliged either to fail or to sell a part of the cows to other farmers (But just a few farmers have the capacity to purchase new cows) or to deliver the cows to the slaughterhouses.

-As a result, the number of dairy cows was difficult to be kept and started to decline. Not only fattened bovines, but also dairy cows were sent to slaughterhouses, as it happened in the year 2021 and also in 2022. The most affected regions by increased number of slaughtered bovines were South Oltenia, South Muntenia and South East regions, as affirmed Farmers Association of Romania.

-The reduction in the number of animals in dairy farms has to be seen as a high risk for farmers who will not fulfil the conditions imposed by Payment and Intervention Agency in Agriculture (APIA) to receive subsidies for a certain number of cows.

- The reduced offer of raw milk has favored milk imports which were much higher in 2022 compared to the year 2021. And even the rhythm of imports exceeded the decreasing rate of milk production, which led to a higher share of milk imports in milk production.

- The subsidies offered in the animal sector does not favor the increase of dairy animals and milk production. Many years the subsidy per surface unit favored the development of vegetal production and disadvantaged animal sector, dairy farming being included.

The subsidies per animal and milk liter are discriminatory being related to the number of animals in the farm, which favors only the larger dairy farms.

- Another cause of this critical situation in milk production in Romania is the non corresponding farm structure which is dominated by small farms, both regarding the surface and the number of dairy cows and heifers [26, 30].

In 2020, in Romania there were 475,121 dairy farms, of which 80% raised 1-2 cows, and about 13% farms had 3-5 heads.

The farms raising over 50 cows have a small share of only 0.32% in the total number of dairy farms [1].

The majority of family farms have breeders lacked of possibilities to develop their activity and also are old persons. The majority of the farms of this type are situated in the North East and North West regions and account for 46% of the family farms.

Dynamics of milk yield

In the analyzed period, milk yield varied from a year to another, depending on soil and climate conditions, zone of growing cows, farm size, farm resources (surface per cow, forage production quantitatively and qualitatively, watering etc), feeding, reproductive activity, cows' maintenance, hygiene and sanitary conditions and farm management.

In 2022, the milk yield in Romania accounted for 3,367 kg per cow being by 7.6% lower than in 2013, when it was 3,643.8 kg. Therefore, it registered a slight decline (-7.2%) in 2022 versus 3,624.8 kg in 2021 (Fig. 5).

This yield level reflects the lowest milk productivity in the EU, Bulgaria and Romania being on the last two position for

3,621 kg/cow, and, respectively, 3,367 kg/cow. The EU-27 average milk yield is 7,653 kg/cow. therefore, Romania's milk yield is twice smaller than the E-27 average.

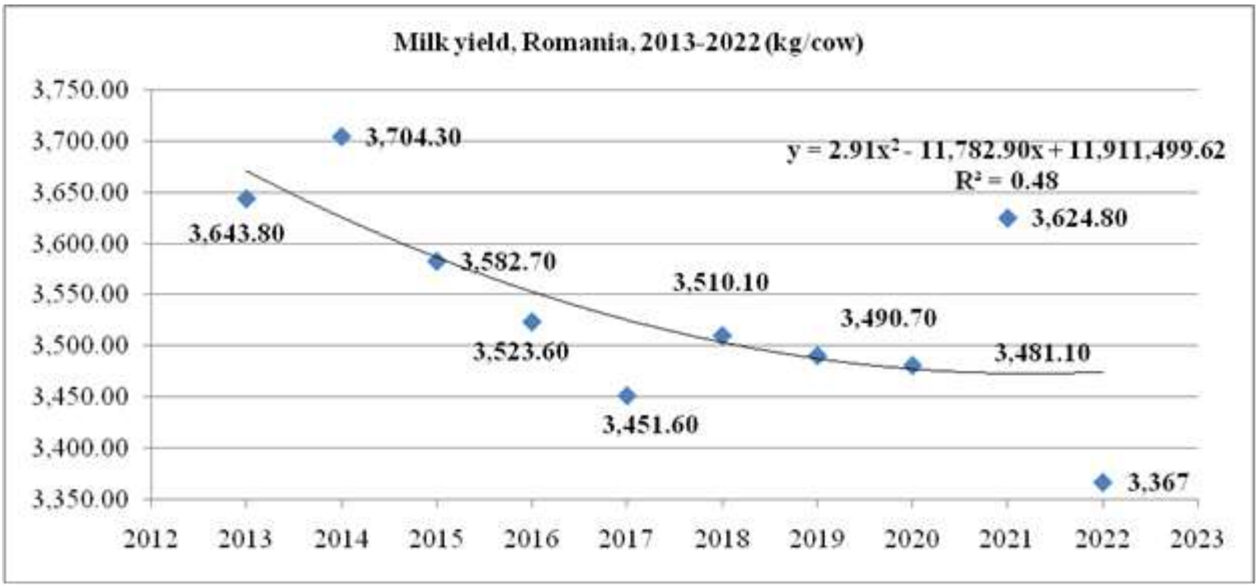

Fig. 5. Dynamics of milk yield, Romania, 2013-2022 (1,000 hl).
Source: Own design and calculation based on the data from NIS, 2023 [13].

The top yield in the EU was obtained by Denmark (10,187 kg) and Estonia (10,128 kg) and other important producers with yields over the EU mean are France, Poland, Italy, Netherlands and Germany [6].

The level of milk yield depends on many factors.

First of all, it depends on the breed raised in the farms and its production potential. In Romania the most productive breed is Holstein and The Black and White Spotted Breed. A lower milk production is given by Romanian Spotted Breed, Brown breed, and the smallest production by Pinzgau and Grey Steppe Breed, the last two breeds being under a programme of conservation [4].

A high importance have the raising conditions: feeding, cow maintenance, milking, reproduction, movement etc which have to contribute to the cow health and production. Ration structure is not always balanced to include selected forages suitable to cows in a corresponding amount and quality.

In the last years, the low precipitations level and the long and severe drought have deeply affected forage production as explained before and milk yield too.

The maintenance conditions do not always meet the requirements for the dairy cow welfare.

The EU legislation regarding dairy cows was recently revised emphasizing the importance that dairy cows "need more space to move around freely, rest comfortably indoor the sheds in cubicles of 9m^2 per cow and benefit of a thick bedding material, and outdoors to graze on pastures where trees and bushes to offer them shade. Mastitis, lameness, metabolic disorders and other health problems have to be regularly monitored and brushes to be available as cows to clean themselves. Therefore, more attention has to be paid by farmers for assuring the welfare of dairy cows [5].

Reproduction activity is the key of putting into practice the breeding programme, the pairs mating, as cows must be artificially inseminated with frozen semen from the best high value breeding bulls which could ensure a selection pressure of 70% by males. Every year, a cow has to give birth to a calf and assure milk production level, under the condition of a good feeding, reproductive activity and health.

However, in Romania artificial insemination rate is very small and usually practiced by the large farms, and calving interval is higher than 400 days, with a negative impact on milk production.

Milking system is preferred to be mechanized to ensure milk hygiene, but in many small family farms in Romania it is still practiced manual milking, and this is the reason why milk quality does not fit to the standards imposed by milk processors according to the legislation in charge [28].

The hygiene in the shed, micro climate conditions, milking technique, sanitary problems have to be kept under control for avoiding mastitis, lameness and other diseases.

In addition, the success in dairy farming depends on availability of resources, farmer's experience and managerial skills.

Number of dairy cows

At the end of December 2022, Romania had 1,833.7 thousand bovines compared to 2,022.4 thousand in 2013, meaning by -9.4% less. But, for its bovine livestock, Romania is ranked the 8th in the EU, after France, Germany, Spain, Poland, Ireland, Italy, Netherlands, and Belgium [29].

This decreasing tendency in bovine livestock is a feature of the EU too, as shown by statistics, which mention that the EU had in December 2022 about 74,807.63 thousand bovines compared to 75,705.3 thousand in the year 2021 (-0.2 %) [7, 8].

The number of dairy cows in Romania accounted for 1,075.6 thousands in December 2022 compared to 1,168.9 thousand at the end of December 2013, which mean a loss of 8% in the last decade (Fig. 6).

However, the bovine livestock deeply decreased since the year 2006 till 2011, but then it remained at a relatively constant level [23].

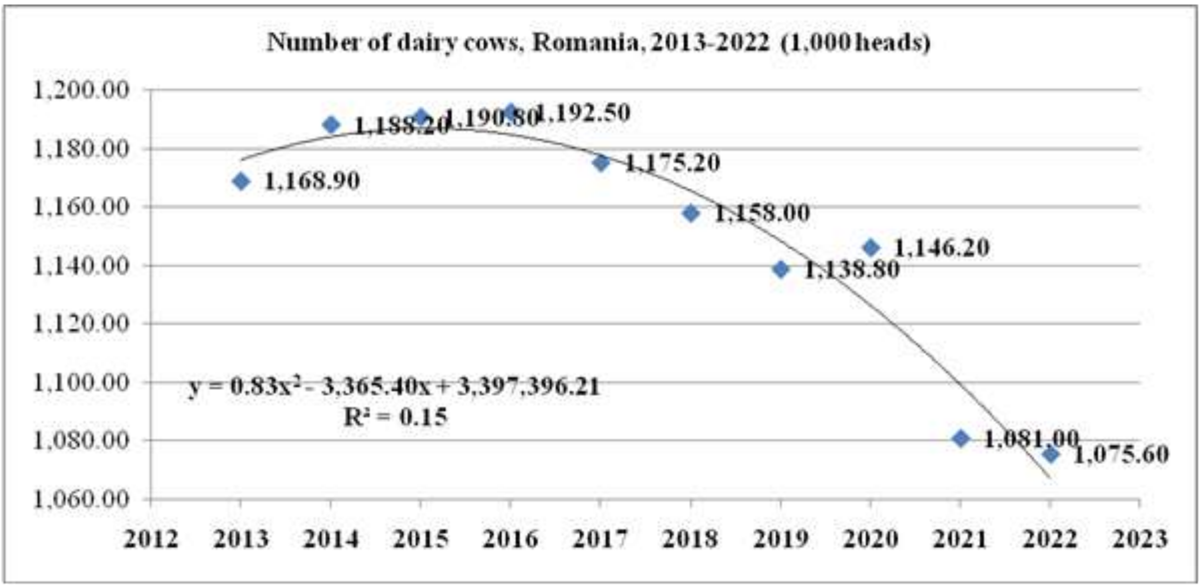

Fig. 6. Dynamics of the number of dairy cows, Romania, 2013-2022 (Thousand heads)
Source: Own design and calculation based on the data from NIS, 2023 [13].

The distribution of dairy cows on the territory of Romania varies from a micro-region to another depending of the local conditions which favor dairy cows growing and the number of farms.

The decreasing order of the region based on the number of dairy cows in 2013 is shown in Fig. 7, from which it is easily to notice that on the top positions are North East, North West and Central area, followed by South Muntenia, South East, South West Oltenia and West (Fig. 7).

In the year 2023, North East region maintained it top position, being followed by Central area which passed on the 2nd position, while North West passed on the 3rd

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one. South Muntenia remained on the 4th position and South East region on the 5th, no changes. tthe West region was ranked 7th, South West Oltenia was ranked 8th and Bucharest-Ilfov preserved its last position (Fig. 8).

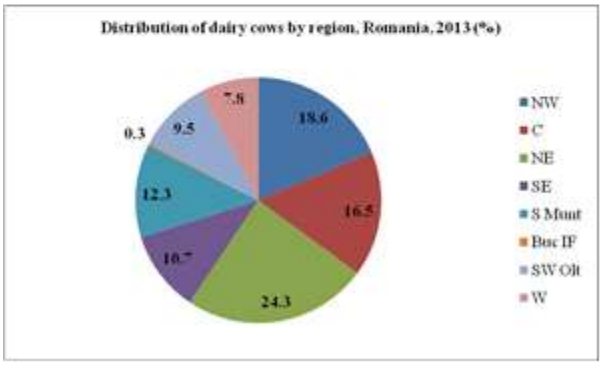

Fig. 7. Distribution of dairy cows by micro-region, Romania, 2013 (%)
Source: Own design and calculation based on the data from NIS, 2023 [13].

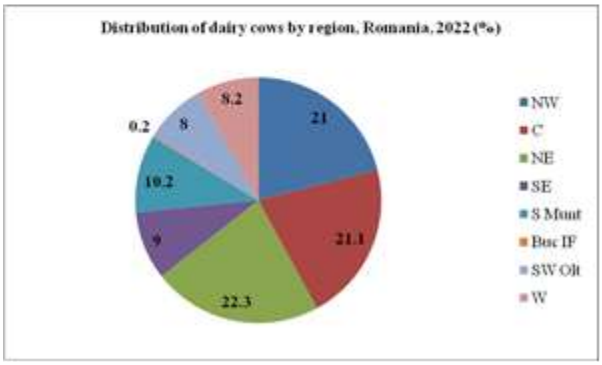

Fig. 8. Distribution of dairy cows by micro-region, Romania, 2022 (%)
Source: Own design and calculation based on the data from NIS, 2023 [13].

Concentration of milk production and of the number of dairy cows in Romania

To solve this aspect, it was calculated Herfindhal-Hirschman index (HHI) whose values are enough small, ranging between 0.15 and 0.25 in the both cases, which reflects a moderate concentration.

The obtained value for HHI are shown in Table 1.

HHI for milk production varied from a year to another, but from 2019 it started a slight increasing trend.

HHI for the number of dairy cows recorded a higher variation, so that in the period 2013-2017 it had lower and lower values, but since 2018 it followed a slight ascending trend.

These small values reflects a moderate concentration in the country, even thou there are three micro-regions with higher shares than the others areas in milk production and number of cows.

In the future, according to the EU, it is expected as the number of bovines to continue to decrease because:

- About 78% of the commercial farms of bovines produce milk, which led to an overproduction.

-Milk demand is relatively covered on the EU market and even in Romania.

-Milk price volatility is high affecting the producers.

-Climate will continue to change, increasing temperatures and bringing droughts with a negative impact on agricultural crop production affecting forage resources for farm animals.

-Bovines are a pollution source, being responsible by a high amount of carbon dioxide with a negative impact on environment and biodiversity.

- New alternatives of forages have to be found for feeding the dairy cows and the rest of bovine livestock. Plants with a high genetic production potential, resistant to drought, diseases and pests attack and with a corresponding nutritive value and energy capable to maintain and to increase milk production are needed.

Table 1. Herfindhal-Hirschman Index for milk production from cows and number of dairy cows in Romania in the period 2013-2022

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
HHI Milk production	0.1623	0.1633	0.16.38	0.1609	0.1636	0.1629	0.1641	0.1653	0.1642	0.1666
HHI No. of dairy cows	0.1624	0.1618	0.1622	0.1608	0.1603	0.1615	0.1617	0.1668	0.1679	0.170

Source: Own calculation.

Economic efficiency in dairy farming

Farmers need to develop their business in dairy farming, increasing yield and production, getting enough income for covering the production costs and finally to obtain profit, showing that this sector could be profitable.

However, in Romania, productivity and profitability in dairy farming is still a big problem in most of the family farms. The slogan in dairy farming is: "The higher milk yield, the higher income and profit" [19, 20, 27].

Recent researches mentioned many differences in yield and production depending on the geographical zone (plain, hilly area and mountain zone), breed, the physical size of the farm (number of dairy cows), economic size (standard output), breeding systems practiced in the farm, feeding technology, milking system, milk valorization along the chain, milk price at farm gate, gross product value, production expenses, income, gross profit/loss, net profit/loss, profitability rate etc. [2, 3].

Profitability rate in dairy farming varies according to the local conditions and resources, farmer's training level and experience in farm management.

For the moment, the scientific research is working to establish models of farms specific of each raising area, farm type and size, breed, milking technology etc which have to be taken into consideration by farmers to develop a profitable business.

Financial support for dairy farming

According to Government Emergency Ordinance no.3/2023 it is allotted a state aid from the state budget for sustaining the activity of the breeders from the bovine sector in the year 2022, in the context of the crises determined by the aggression of Russia against Ukraine. The aid accounts for Euro 73/ adult cow and an addition aid of Euro 37/adult cow. The maximum aid total value cannot exceed the equivalent of Euro 250,000, at the exchange rate established by National Bank of Romania [14].

Since November 2023, it was issues the Order PD-21 a coupled aid for income for dairy cows and PD-23 a coupled aid for income for buffaloes, in this way being assured a balanced and non discriminatory treatment for the farmers who have animals and require direct payments (Euro 338 per head in case of PD-21 and Euro 169,19 in case of PD-23. This support will help the farmers to assure the necessary inputs for running their activity [12].

Within the National Strategic Programme, starting from 2024, it is provided a new subsidy for extensive grazing: Euro 100/ LU dairy cows and beef livestock, under the condition to respect the animal charges according to the grazing type on permanent or temporary grasslands for a period of minimum 120 days a year and at least 6 hours a day [15].

In the period 2023-2027, the dairy cows breeders will benefit of a coupled aid for income, paid by Payment and Intervention Agency according to the new National Strategic Programme published by Ministry of Agriculture and Rural Development. This subsidy will be provided to the farmers who have at least 5 dairy cows or minimum 10 dairy cows, depending on the zone and maximum 250 dairy cows, with the National Sanitary Veterinary and Food Security Authority (ANSVA) code. To be eligible, the animals must be maximum 10 years old and must be registered in the National Register at the date of the request. Also, the breeders need to have a contract concluded, for a minimum period of 6 months, available at the date of the request, with a buyer recognized by the competent authority and at least a legal document which have to attest milk delivery to a processor.

When milk is delivered directly to a consumer, the farmer has to provide a document registering the commercialization of agricultural products and also a legal document according to the sanitary-veterinary legislation in charge.

This aid is provided for maximum 250 dairy cows and the sum allotted per animal head, calculated by MARD are: in 2023: Euro 330.36 for 280,000 heads, in 2024: Euro: 325.55 for 285,000 heads, in 2025: Euro

325.55 for 290,000 heads, in 2026: Euro 320.95 for 296,000 heads and in 2027: Euro 327.03 for 300,000 heads [10].

In the period 2023-2027, new subsidies will be allotted for the wellness of dairy cows as follows: Euro 50.26/LU/year for avoiding the traumatic milking and udder wellness, Euro 29.09/Lu/year for hoofs health and Euro 20.83/L/year for dairy animal monitoring [11].

CONCLUSIONS

This research allowed to draw the following main conclusions:

- Milk production had and will continue to have in the future a declining trend. In 2022, it accounted for 35,300 thousand hl, being by 9.1% smaller than in 2013.

-The bovine livestock also declined and the number of dairy cows decreased as well. In 2022, Romania had 1,075.6 thousands dairy cows, by 9.2% less than in 2013.

-Milk yield in Romania also declined in the analyzed interval by 7.6% from 3,643.8 kg in 2013 to 3,367 kg per cow in 2022.

-Compared to the records in our EU country, Romania comes the last on the list, its milk yield being twice lower than the EU mean accounting for 7,653 kg/cow in 2022.

-The factors which led o such a critical situation in dairy farming have been: the farm structure, dominated in a proportion of 80% by small subsistence farms raising 1-2 cows. A number of 2-5 cows are just in 13% of the number of dairy farms, and just 0.32% of farms raise over 50 cows.

-During the last years, Romania's agriculture was facing low precipitations and long and severe drought affected forage production.

-The needed inputs for farms have become more and more expensive, in case of forages price increased by 70%, with a negative effect on production costs, where usually they have a share of about 70%.

-Milk price of Lei 1.4-1.8 is imposed by milk processors and could not cover production cost in many dairy farms. This obliged some farmers to fail, others to sell a part of their cows and even to send them to slaughterhouses.

-The degree of concentration of milk production and of the number of dairy cows in Romania is enough small, ranging between 0.15-0.20 reflecting a moderate concentration.

-The subsidies allotted per animal and milk were not enough so far, and for this reason urgent measures have been taken by Government to save dairy farming.

As long as milk consumption cannot be covered by internal production, imports of milk increased in 2021 and 2022 as never before.

-To avoid milk imports and the collapse of dairy farming, the breeders have to be sustained by consistent subsidies to help their cows to produce more milk and cover the population' s requirements.

REFERENCES

[1]Chetroiu, R., 2017, Dynamics of dairy cows holdings dimensional structure and their economic performances, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.17(7), 91-94.

[2]Chetroiu, R., 2022, Comparative analysis of economic efforts and effects in milk production at ruminants, Scientific Papers Series Economic Engineering in Agriculture and Rural Development, Vol.22(2), 167-172.

[3]Chetroiu, R., Iurchevici, L., Marin, A., Cismileanu, A.E., 2021, Analysis regarding the economic efficiency in dairy farms from various regions of the country, Terra Nostra Publishing House, Iasi, pp. 3-15.

[4]Davidescu, M.-A., Gradinaru, A.-C., Creanaga, St., 2021, Endangered Romanian cattle breeds-between traditional breeding and genetic conservation, Scientific Papers-Animal Science Series: Lucrări Ştiinţifice - Seria Zootehnie, vol. 75, pp.66-75.

[5]European Good and Safety Authority, EFSA, 2023, Welfare of dairy cows, https://www.efsa.europa.eu/en/infographics/welfare-dairy-cows, Accessed on November 20, 2023

[6]Eurostat Statistics Explained, 2023, Milk and milk product statistics, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Milk_and_milk_product_statistics&oldid=617758, Accessed on November 20, 2023.

[7]Eurostat, 2023, EU livestock population continued to decline in 2022, https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20230322-1#:~:text=The%20EU%20has%20a%20sizeable,millio

n%20goats%20(%2D3%25).
https://ec.europa.eu/eurostat/databrowser/view/APRO_MT_LSCATL__custom_5410182/bookmark/table?lang=en&bookmarkId=ec36805d-35df-4b0a-80eb-98a94069eafa,
https://ec.europa.eu/eurostat/databrowser/view/apro_mt_lscatl/default/table?lang=en, Accessed on November 20, 2023.

[8]Eurostat, 2023, Agricultural production -livestock and meat, https://ec.europa.eu/eurostat/statistics-explained/index.php?oldid=427096, Accessed on November 20, 2023.

[9]Grorcinschi Violina, 2023, România, printre țările din UE cu cea mai mică producție de lapte de consum, https://agrointel.ro/261159/romania-printre-tarile-din-ue-cu-cea-mai-mica-productie-de-lapte-de-consum/#:~:text=Nici%20m%C4%83car%20o%20jum%C4%83tate%20de,de%20Croa%C8%9Bia%2C%20Slovacia%2C%20Slovenia,

[10]Iuga, F., 2023, APIA subsidy of Euro 330/cow, announced by Ministry of Agriculture, AgroTV, http://agro-tv.ro/subventie-apia-de -330-euro-cap-de-vaca, Accessed on November 20, 2023.

[11]Iuga, F., 2022, New APIA subsidies for dairy cows and young bovines, https://agro-tv.ro/noile-subventii-apia-vacile-de-lapte-tineretul-bovin/, Accessed on November 20, 2023.

[12]Ministry of Agriculture and Rural Development, 2023, Order regarding the change and completion of the Order of Minister of agriculture and rural development no.447/2023 for approving in the year 2023 the reallocation of the sums and establishing the conditions for paying the advance for direct decoupled payments financed from FEGA, within the Strategic Programme PAC 2023-2027, https://www.madr.ro/proiecte-de-acte-normative/8578-proiect-ordin-modificare-omadr-nr-447-2023-01-11-2023.html, Accessed on Nov.20, 2023.

[13]NIS, 2023,Tempo Online database, Accessed on November 2, 2023

[14]Payment and Intervention Agency for Agriculture, APIA, 2022, State aid for sustaining the breeders from the bovine sector in the year 2022.

[15]Payment and Intervention Agency for Agriculture, APIA, 2023, A new subsidy for grazing: Euro 100/ LU dairy cows and beef livestock.

[16]Pirvutoiu, I., Popescu, A., 2012, Research concerning standard gross margin depending on milk yield in dairy farming, Scientific Papers Animal Science and Biotechnologies, 45(2):339-342

[17]Popescu, A., 2006a, Gross margin- a barometer of profitability in agriculture, International Symposium "Durable Agriculture–the agriculture of the future ", Craiova, pp.23-24.

[18]Popescu, A., 2006b, Study upon milk market in the EU countries, Bulletin of the University of Agricultural Sciences and Veterinary Medicine, Vol. 62, pp.214, 2006: Animal Husbandry and Biotechnologies, Symposium on Prospects for the 3rd Millenium Agriculture, Oct..5-6, 2006, Cluj-Napoca.

[19]Popescu, A., 2014a, Research on milk cost, return and profitability in dairy farming, Scientific Papers Series Management, Economic Engineering and Rural Development, Vol.14(2):219-223.

[20]Popescu, A., 2014b, Research on profit variation depending on the marketed milk and production cost in dairy farming, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.14(2): 223-230.

[21]Popescu, A., 2015a, Research on the trends in milk production and consumption in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.15(1), 387-392.

[22]Popescu, A., 2015b, Research on the trends in Romania's milk and dairy products foreign trade, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.15(10, 391-398.

[23]Popescu, A, 2015c, Research on the trends in milking livestock and milk production in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 15(10, 366-385.

[24]Popescu, A., 2016, The milk market concentration and competition thresholds in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.16(2), 247-253.

[25]Popescu, A, 2017, Trends in milk market and milk crisis impact in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 17(1), 366-385.

[26]Popescu, A., 2018, Discrepancies in dairy farms structure between Romania and the EU-28 top countries raising cows in the period 2010-2017, Annals of Academy of Romanian Scientists, Annals of the Academy of Romanian Scientists Series Agriculture, Silviculture and Veterinary Medicine Sciences, Vol. 7, No. 2,/2018, pp.22-33.

[27]Popescu, A., Condei, R., 2014, Study on the average marketed milk as a measure of profitableness threshold in dairy farms, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.14(4):219-222.

[28]Popescu, A, Angel, E., 2019, Cow raw milk quality and its factors of influence in relationship with milk price, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.19(1): 421-440.

[29]Popescu, A., Stoian, E., Serban, V., 2019, The EU-28 milk sector trends in the period 2009-2018, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 19(4), 249-263.

[30]Popescu, A., Caratus-Stanciu, M., 2021, Farm structure in animal sector of Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 21(4), 445-458.

[31]Statista, 2023a, Cow milk production worldwide from 2015 to 2023 (million metric tonnes), https://www.statista.com/statistics/263952/production-of-milk-worldwide/, Accessed on November 20, 2023.
[32]Statista, 2023b, Amount of cow milk produced in Romania in 2022, by region (in 1,000 hectoliters), https://www.statista.com/statistics/1133696/romania-cow-milk-production-by-region/#:~:text=Amount%20of%20cow%20milk%20produced%20in%20Romania%202022%2C%20by%20region&text=The%20biggest%20cow%20milk%20production,million%20hectoliters%20of%20cow%20milk.**,** Accessed on November 20, 2023.

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MILK CRISIS IN ROMANIA REFLECTED BY FOOD BALANCE, 2014-2021

Agatha POPESCU[1,2,3], Toma Adrian DINU[1], Elena STOIAN[1], Valentin ŞERBAN[1]

[1]University of Agronomic Sciences and Veterinary Medicine Bucharest, 59 Marasti Blvd, District 1, 011464, Bucharest Romania, Phone: +40213182564, Fax: +40213182888, Emails: agatha_popescu@yahoo.com, tomadinu@yahoo.fr, stoian_ie@yahoo.com, srbn.valentin@yahoo.com
[2]Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu-Sisesti", 61 Marasti Blvd, District 1, 011464, Bucharest Romania, Email: agatha_popescu@yahoo.com
[3]Academy of the Romanian Scientists, 1 Ilfov Street, Bucharest, 030167, Romania,
Email: agatha_popescu@yahoo.com

Corresponding author: agatha_popescu@yahoo.com

Abstract

The aim of this study is to analyze milk resources availabilities and utilizations in their dynamics in the period 2014-2021 pointing out the state of production, import, export and availabilities for human consumption in order to assess in what measure food security and efficiency in milk trade are assured. The data provided by National Institute of Statistics were processed using fixed basis index, regression equations, determination coefficient, graphically illustration and comparison method. In 2021 versus 2014, the results reflected that: utilizable internal production declined by 9.3%, accounting for 51,750; availabilities for human consumption remained relatively stable, in 2021 being 48,881 thousand hl (+ 0.53%). The weight of availability of milk for human consumption in utilizable internal milk production increased from 85.21 % to 94.45%. Import reached 12,988 thousand hl, being 2.58 times higher. The share of import in availability for human consumption increased by 16.28 pp, reaching 26.57%. Milk export was by + 57.28% higher attaining 3,152 thousand hl. The share of export in utilizable production went up from 3.51% to 6.09%. Export/import ratio declined from 0.40 in 2014 to 0.24 in 2021, reflecting a negative milk trade balance. Milk consumption per capita reached 255.6 kg in 2021, being by 4.66% higher than in 2014. In 2021, a Romanian could consume in average 721.3 g milk per day compared to 689.1 g in 2014. The self-sufficiency rate decreased from 95% in 2014 to 84.02 % in 2021, due to the decline in utilized internal production. To diminish milk crisis, it is needed to offer more subsidies for sustaining dairy farming and to stop the decline in the number of dairy cows, in milk production and marketed milk and reduce imports. Processors have to offer Euro 0.5 per milk kg to Romanian farmers and not a discriminatory price of Euro 0.2.-03. Imports have to be reduced and export to be encouraged after assuring the market requirements by internal production. In this way, both self-sufficiency rate and the efficiency in milk trade could be improved.

Key words**:** *milk, resource availability, production, import, utilizations, consumption, export, Romania*

INTRODUCTION

To enable an active life and good health, people need to have at their disposal "enough safe and nutritious food which cover their dietary needs and food preferences" [4].
Any country has to take corresponding measures to ensure food security, but, at present, globally many countries are passing through a period of food crisis due to "limited resources, conflicts, economic shocks, climate change, reduction of fertilization etc" and 783 million people are facing chronic hunger"[26].
Milk is a basic food, compulsory to be consumed at any age by humans and animals because it is a complex food containing many nutrients. Cows are the main milk sources and their milk contains: 87% water and the remaining of 13% are: protein, fat, carbohydrates, vitamins (A, B2, B6, B12) and minerals (Calcium, Potassium, Phosphorus etc).
For this reason, it is recommended to be consumed a cup of milk every day. A cup of 240 g whole milk (3.5%fat) has 140 calories, 7.5 g protein, 12 g natural sugar, 4.5 saturated

fats, 2 monosaturated and 0.5 polysaturated. In a cup of low fat milk (1% fat), there are 102 calories, 8 g protein, 12.5 g sugar, 1.5 saturated fats, 0.7 monosaturated fats and 0.1 polysaturated fats [5].

A cup of 240 g cow milk has a content in Calcium equivalent to 10 cups of raw spinach or 6 cups of brown rice or 3 cups of red kidney beans or 3.5 cups of broccoli or 1 cup of almonds [6].

Milk has to be consumed for maintaining health and preventing osteoporosis, cardiovascular diseases, diabetes, cancer etc.

The highest annual milk consumption in the world in 2023 in 1,000 metric tons is in India (87,450), EU (23,650), USA (20,900), China (16,700), Brazil (10,881), Russia (6,800), United Kingdom (6,000).

In Europe, the highest consumption is in Finland (361.19), Sweden (355.36), Netherlands (320,15) and Switzerland (315.78). In Romania, the annual consumption per capita was 255.6 kg in the year 2021 [25].

In the EU-27, in 2022, the milk consumption per capita is one of the highest in the world [23].

Milk consumption is assured by milk deliveries from internal production and import from which export must be subtracted [11].

In the EU, in 2022, milk balance shows that milk deliveries were 144,652,499 tons, imports of milk equivalent were 2,959,444 tons, exports in milk equivalent were 22,983,276 and as a result, the self-sufficiency rate accounted for 116% [1, 3].

Romania has a good milk producing potential and a long tradition in raising dairy cows, buffaloes, sheep and goats. But, in the last decades dairy farming was affected by many negative factors which led to the decline in milk production [18].

Among the main factors we may specify:

- the extreme climate phenomena like high temperatures and long and severe drafts which reduced the forage production;
-the increased forage price on the market due to the non balanced ratio between high demand and low offer;
-the high price for other farm inputs (fuel, energy, medicines, services etc) [9, 10].
-the growth of production cost [13, 14].
-the low price of raw milk at delivery imposed by milk processors [14].
-problems with milk quality due to the milking system practiced in most of the small farms [22].
- the low subsidies not able to sustain dairy farmers to enhance their business;
-the existence of a non corresponding farm structure, where about 80% farms are small sized subsistence farms raising 1-2 cows, 13 % semi-subsistence farms raising 3-5 cows, and only 0.32% are commercial farms having more than 50 dairy cows, while in the EU-27, the average farm size is 17.4 cows per farm [19, 24].
-milk productivity in term of yield is small accounting for about 3,500 kg/cow/year in average at national level [21].

As a result, a part of the farmers failed, other farmers sold milk in Bulgaria to get a better price, a few farmers sold a part of their cows to other breeders, other farmers sold dairy cows to slaughterhouses [12].

In consequence, in Romania the number of dairy cows started to decline and milk production as well [17, 2] and milk deliveries to the market decreased, favouring imports of milk [16] to supplement the offer for meeting the population milk requirements and reducing the efficiency in milk trade [12, 15, 19, 20].

In this context, the paper aimed to study the dynamics of milk availabilities and utilizations in the period 2014-2021 emphasizing on internal production destined for consumption, imported amounts and exported quantities, to determine the availabilities for human consumption and self-sufficiency rate. In addition, it was determined the export/production and export/import ratio to assess in what measure milk trade is efficient or not.

MATERIALS AND METHODS

First, from the literature on the topic, there were selected the aspects of interest in this study.
The empirical data were collected from Milk Food Balance provided by National Institute of Statistics for the period 2014-2021 for which the data were available.
From "Milk Resources"(MR), there were used the data for Utilizable internal production (UIP) and Import (I), which together form this category in Food Balance, according to the formula:

MR = UIP + I ....(1)

From "Milk Utilizations"(MU), there were used the data concerning: Export (E) and Internal Availabilities for internal consumption (AFC), which together form total utilizations, according to the formula:

MU = E + AFC ....(2)

Availabilities for internal consumption (AFC) include: Intermediary consumption (IC) (forage and industrial transformation), Losses (L), Stock variation (SV) which result from the difference between the Final stock (FS) and Initial stock (IS), and finally Availability for human consumption (AHC), which is calculated using the formula:

AHC = AFC - (IC + L + SV) ....(3)

This methodology belongs to NIS regarding Food Balances [7].
In this research, the dynamics of the following indicators was studied: Utilizable internal production (UIP), Availability for human consumption (AHC), Import (I), Share of Import in Availabilities for internal consumption (AFC), Export (E), the ratio Export/ Utilizable internal production (UIP), the ratio Export (E)/Import (I) and Milk consumption per inhabitant (MCI), and also Self-Sufficiency Rate (SSR).
These indicators were analyzed in their dynamics using fixed basis index, whose formula is
Fixed basis indices, whose formula is:

$I_{FB}=(y_t/y_0)*100$ .... (4)

Average growth rate, having the formula:

$\bar{R}_a = (\sqrt[n-1]{\frac{y_n}{y_0}} - 1)*100$ ....(5)

Regression function to identify the trend according to the formula:

$\widehat{yt} = bt + a$ .... (6)

The data were displayed in illustrative graphics for a better understanding.
Comparison method was used to show the discrepancies between the analyzed indicators level at the end of the period versus with its beginning.
The results were correspondingly interpreted.

RESULTS AND DISCUSSIONS

Dynamics of Utilizable internal production (UIP)

This indicator reflects the capacity of the country to assure milk production from different sources, especially from cows and buffaloes and for different destinations or utilizations.
Its dynamics in the studied interval reflects a continuous decrease from 57,055 thousand hl in 2014 to 51,750 thousand hl in 2021, meaning a loss by 9.3% (Fig. 1).
The decline is a consequence of the reduction of the dairy cows stock, and yield low level determined by the reduced forage production and forage low quality and also due to breed milk potential and other factors.

Dynamics of Availability for human consumption (AHC)

The milk availabilities for human consumption results from Availabilities for internal consumption (AFC) of which Intermediary consumption (IC), Losses (L), and Stock variation (SV) are subtracted.
In the analyzed period, AHC has relatively remained stable, as in the year 2021 it was just 48,881 thousand hl, by 0.53% higher than in the year 2014, when it accounted for

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48,620 thousand hl. However, in 2021 it was recorded the highest AHC, while in 2017 it was registered the minimum level (Fig. 2).

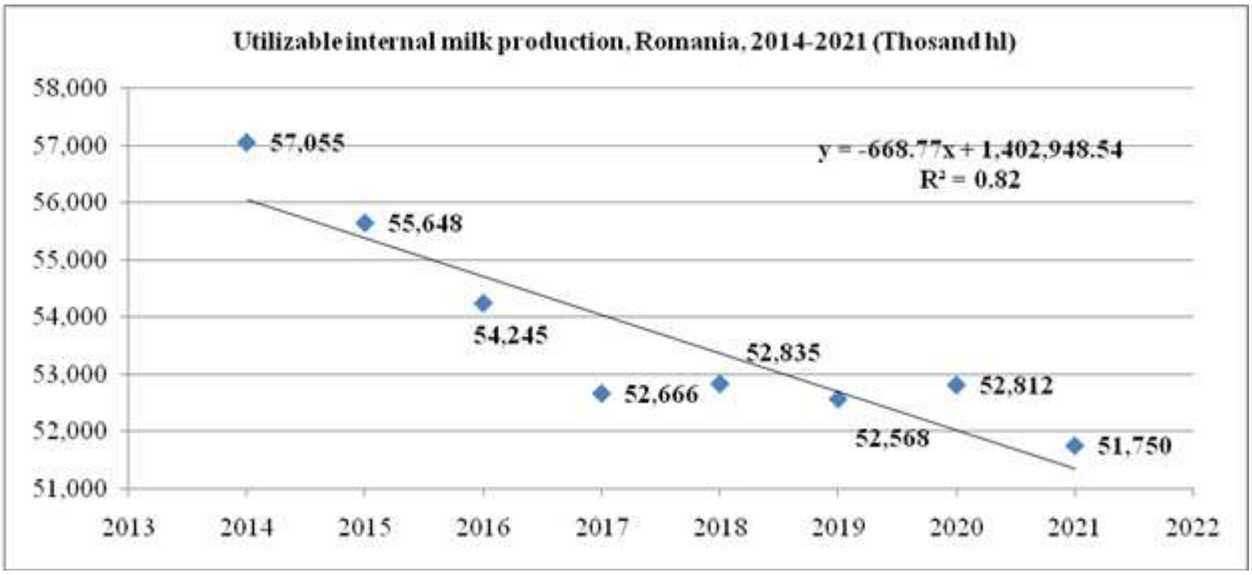

Fig. 1. Dynamics of Utilizable internal milk production, Romania, 2014-2021 (Thousand hl)
Source: Own design and calculation based on the data from NIS [8].

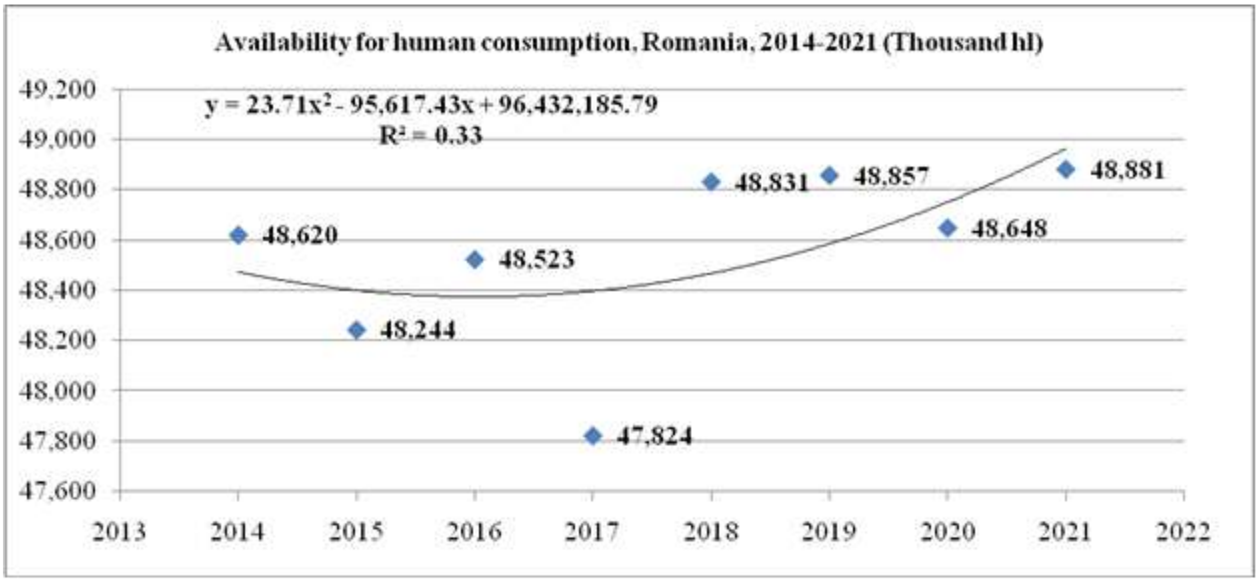

Fig. 2. Dynamics of Availability for human consumption, Romania, 2014-2021 (Thousand hl)
Source: Own design and calculation based on the data from NIS, 2023 [8].

The share of Availability for human consumption (AHC) in Utilizable internal milk production (UIP)

Taking into account the values for AHC and UIP, it was assessed the proportion in which in Romania, the availability for human consumption is assured from utilizable internal milk production. From this point of view, it was noticed an increasing percentage from 85.21 % in the year 2014 to 94.45% in the year 2021 (Fig. 3).

This increase is a positive aspect, not forgetting that Utilizable internal production declined in the same interval.

The explanation lies in the fact how intermediary consumption, losses and stock variation have influenced availability for human consumption.

In the analyzed period 2014-2021, the data showed that intermediary consumption increased by 7.28%, a growth determined by the high increase of 33.49% of industrial

transformation and also by the reduction of -3.02% of forage. Also, losses increased by 4.18% and stock variation by 2.81%.
Therefore, the main contribution to the growth of the share Availability for human consumption (AHC) in Utilizable internal production (UIP) was given especially by industrial transformation of raw milk.
The share of milk for human consumption (AHC) in utilizable internal production is closely connected with the level of food security for this product in Romania.

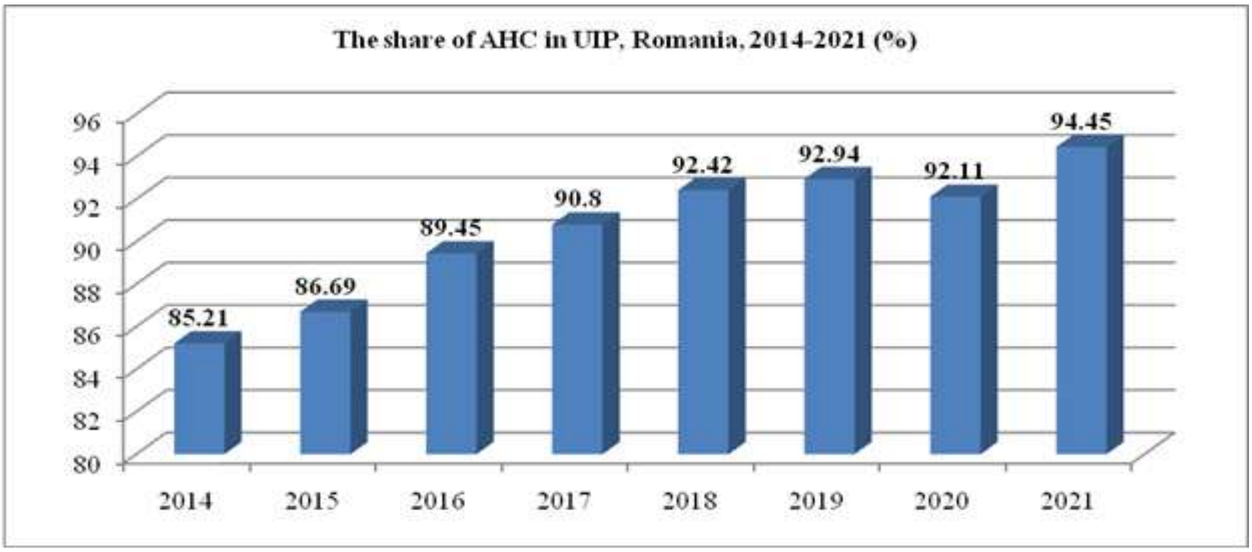

Fig. 3. Dynamics of the share of Availability for human consumption (AHC) in Utilizable internal production (UIP), Romania, 2014-2021 (%)
Source: Own design and calculation based on the data from NIS, 2023 [8].

Quantitative import of milk in milk equivalent of 3.5% (I)

In the studied period, milk import increased by 159.68%, in 2021 reaching 12,988 thousand hl, being 2.58 times higher than in 2014 when it accounted for only 5,003 thousand hl (Fig. 4).

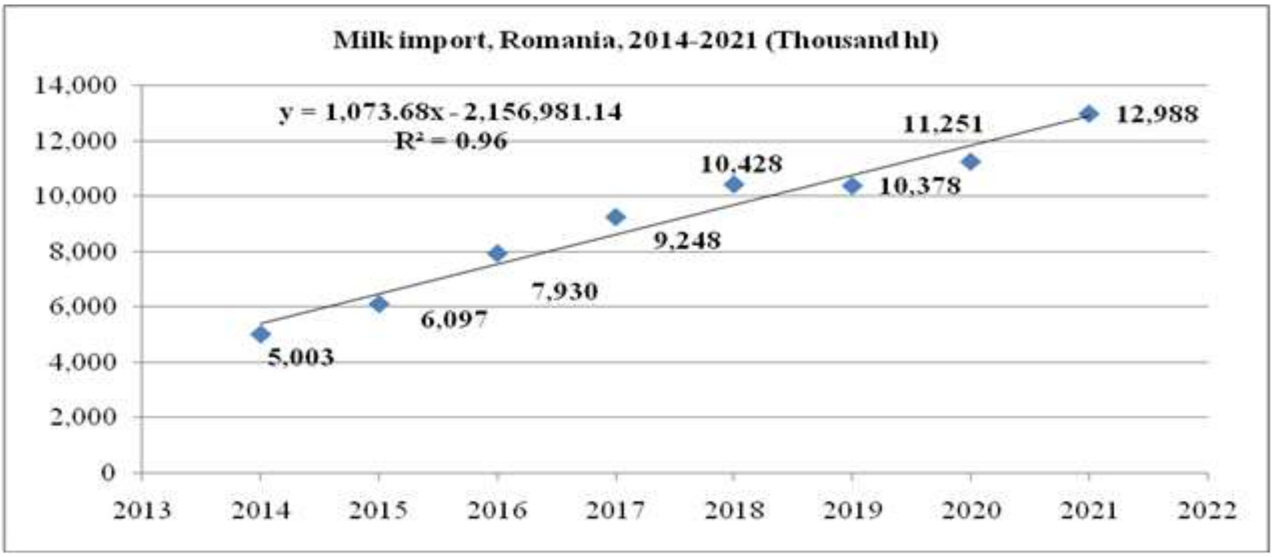

Fig. 4. Dynamics of milk import (I), Romania, 2014-2021 (Thousand hl)
Source: Own design and calculation based on the data from NIS, 2023 [8].

Import was necessary to counterbalance the reduction in usable internal milk production as specified before, due to the decline in the number of dairy cows, low milk yield, high production cost, low price at farm gate, low subsidies, bankruptcy of some farms, and losses in dairy farming.

The share of Import (I) in Availability for human consumption (AHC)

The imported milk quantities were higher and higher from year to another which has also raised their share in the availability of milk for human consumption. In 2021, this share was 26.57% by +16.28 percentage points higher than in the year 2014, when it accounted for 10.29% (Fig. 5).

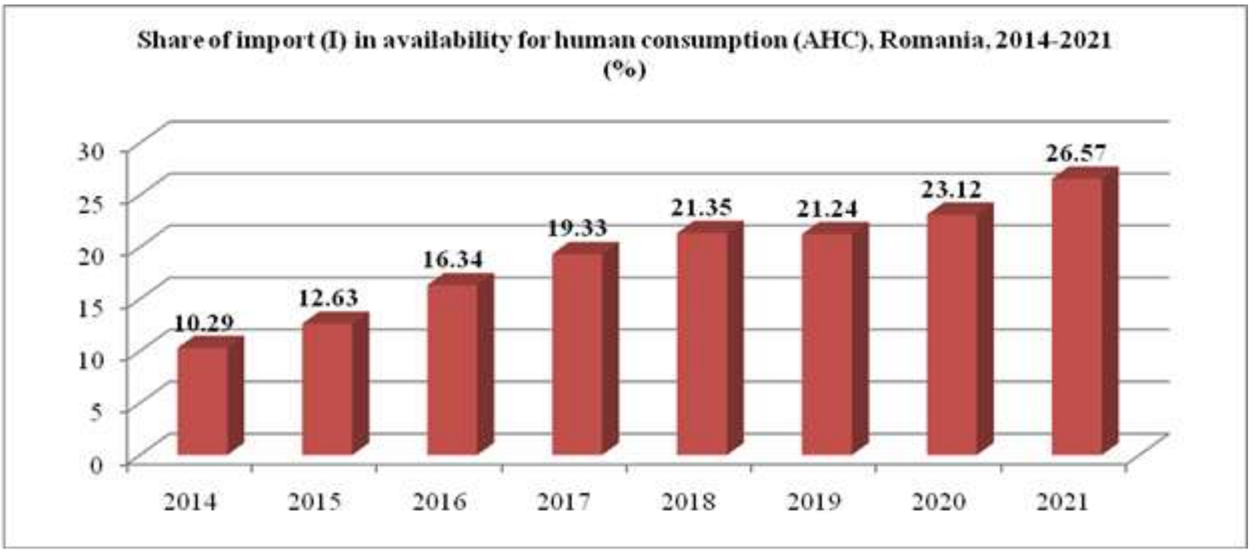

Fig. 5. Share of milk import (I) in Availabilities for human consumption (AHC), Romania, 2014-2021 (%)
Source: Own design and calculation based on the data from NIS, 2023 [8].

Exported milk quantities in milk equivalent of 3.5% (E)

Milk export had an ascending trend from 2,004 thousand hl in the year 2014 to 3,152 thousand hl in 2021, meaning + 57.28% (Fig. 6).

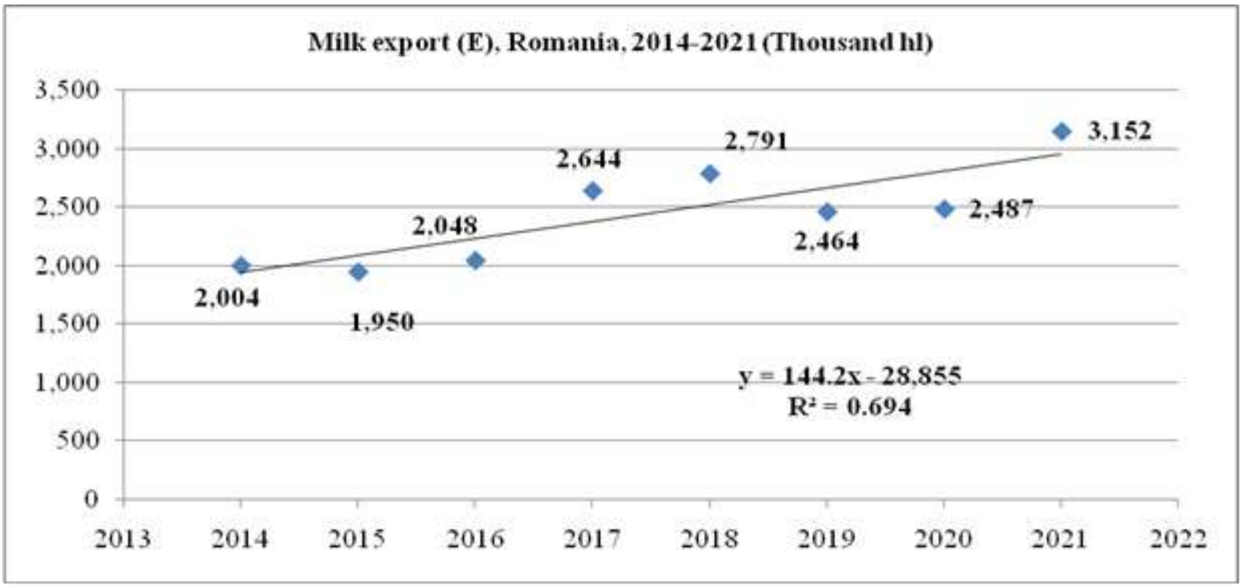

Fig. 6. Dynamics of milk export (E), Romania, 2014-2021 (Thousand hl)
Source: Own design and calculation based on the data from NIS, 2023 [8].

This is a positive aspect, taking into consideration an increased export could bring more foreign currency in the payment balance.

However, it could be also considered a negative aspect because, due to the low milk price at delivery offered by processors in Romania, some farmers sold the milk in Bulgaria for getting a higher price.

The share of Export (E) in Utilizable production (UIP)

Due to the increase in exported amounts, and decline in utilizable production, the share of export (E) in Utilizable production (UIP) has went up from 3.51% in 2014 to 6.09% in 2021, therefore, it became almost double (Fig. 7).

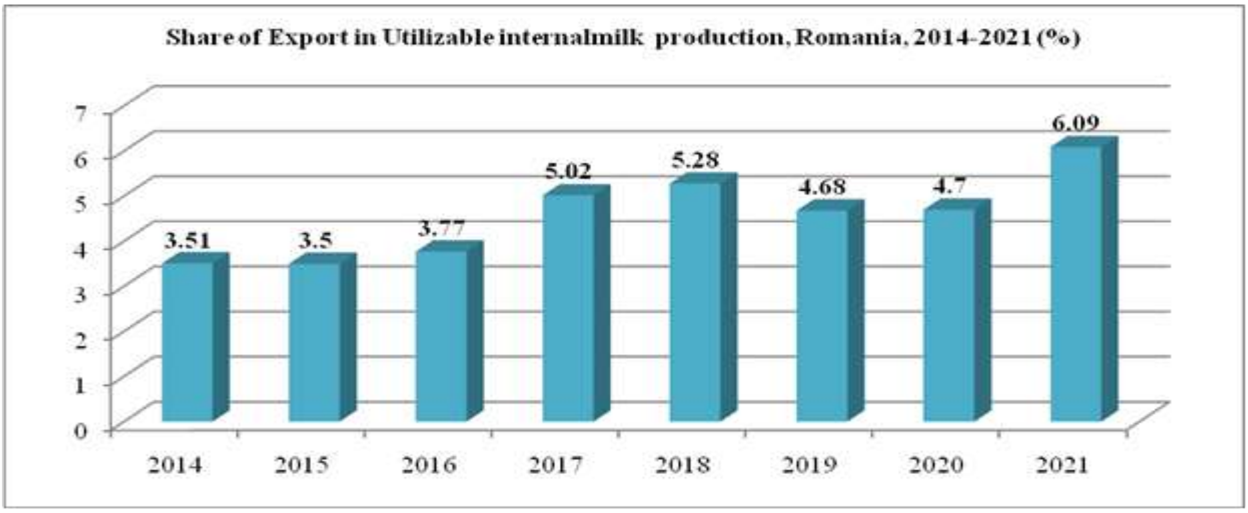

Fig. 7. Share of milk Export (E) in Utilizable internal milk production (UIP), Romania, 2014-2021 (%)
Source: Own design and calculation based on the data from NIS, 2023[8].

This could be considered a positive aspect, reflecting the capacity of the country to valorise this milk and milk products in milk equivalent of 3.5% fat, under the condition to respect quality standards and to be competitive on the external markets.

Milk Export/Import ratio

This ration between milk export and import is small and has a subunit level. If in 2014, its level was 0.40, in 2021, it declined to 0.24, which reflects that the imported milk quantity is higher than the exported amounts, and in consequence, it reflects a non efficient milk trade of the country (Fig. 8).

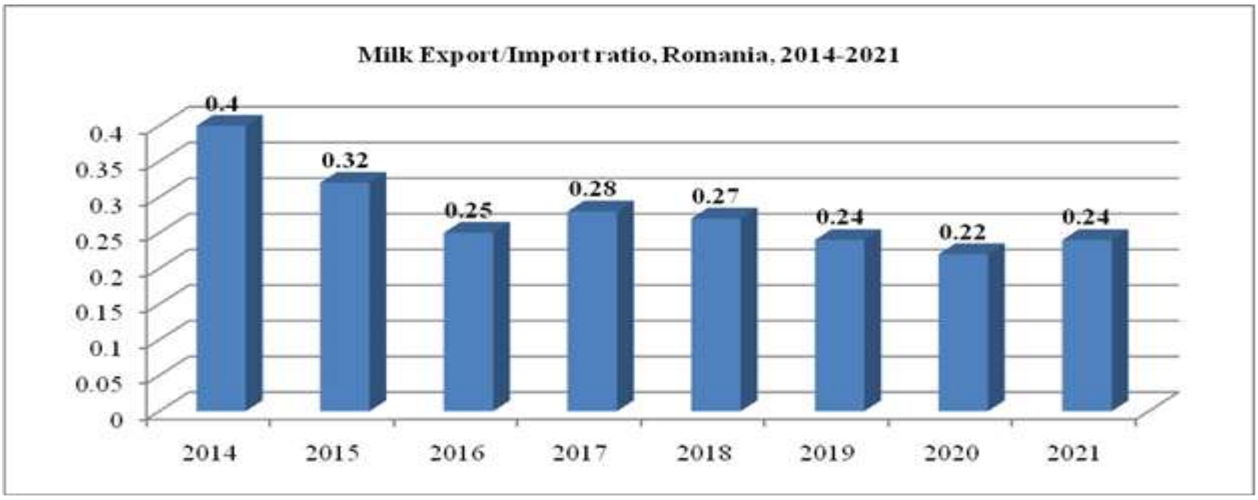

Fig. 8. Dynamics of Milk Export/Import ratio, Romania, 2014-2021
Source: Own design and calculation based on the data from NIS, 2023[8].

Dynamics of average annual Milk consumption per inhabitant

Milk consumption per capita increased year by year so that in 2021 it accounted for 255.6 kg/inhabitant being by 4.66% higher than in 2014 when it was 244.2 kg. This is a positive aspect (Fig. 9).

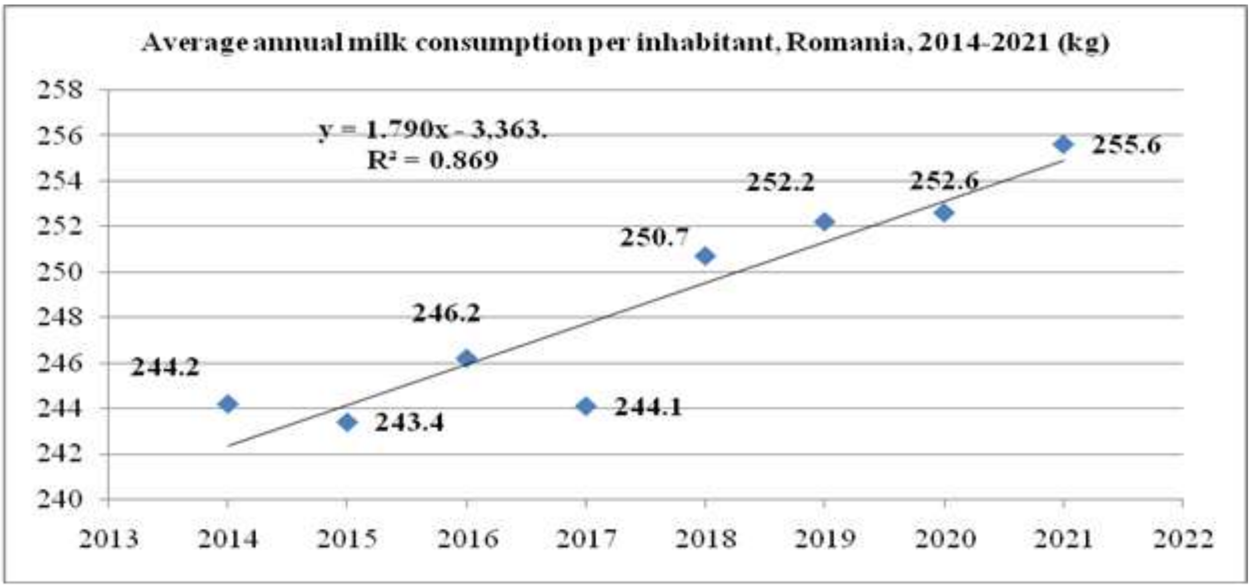

Fig. 9. Dynamics of average annual milk consumption per inhabitant, Romania, 2014-2021 (kg/capita)
Source: Own design and calculation based on the data from NIS, 2023 [8].

Dynamics of average daily milk consumption per inhabitant

Taking into account the milk consumption per year and capita, the average daily milk consumption increased by 4.67% from 689.1 g in 2014 to 721.3 g in 2021 (Fig. 10).

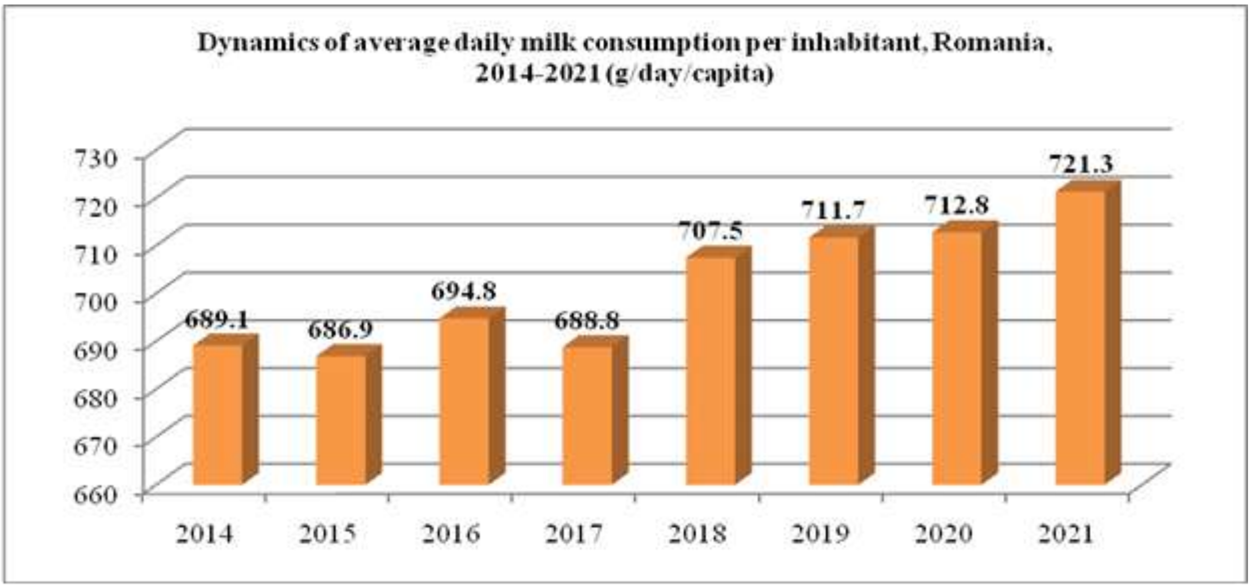

Fig. 10. Dynamics of average daily milk consumption per inhabitant, Romania, 2014-2021 (g/capita)
Source: Own design and calculation based on the data from NIS, 2023 [8].

Dynamics of milk self-sufficiency rate (SSR)

Self-sufficiency rate was determined according to the formula:

$SSR_{\%}$ = Milk delivery (C)/ (Milk delivery C + Import I - Export E)

In this case, milk delivery (C) was considered Utilizable milk production. The self-sufficiency rate registered a descending trend from 95% in the year 2014 to 84.02 % in the year 2021. This situation is explained by the decline in the utilizable milk production, increased imports and also increased exports. But, the main factor is the lower utilizable milk production, caused by the factors mention before (Fig. 11).

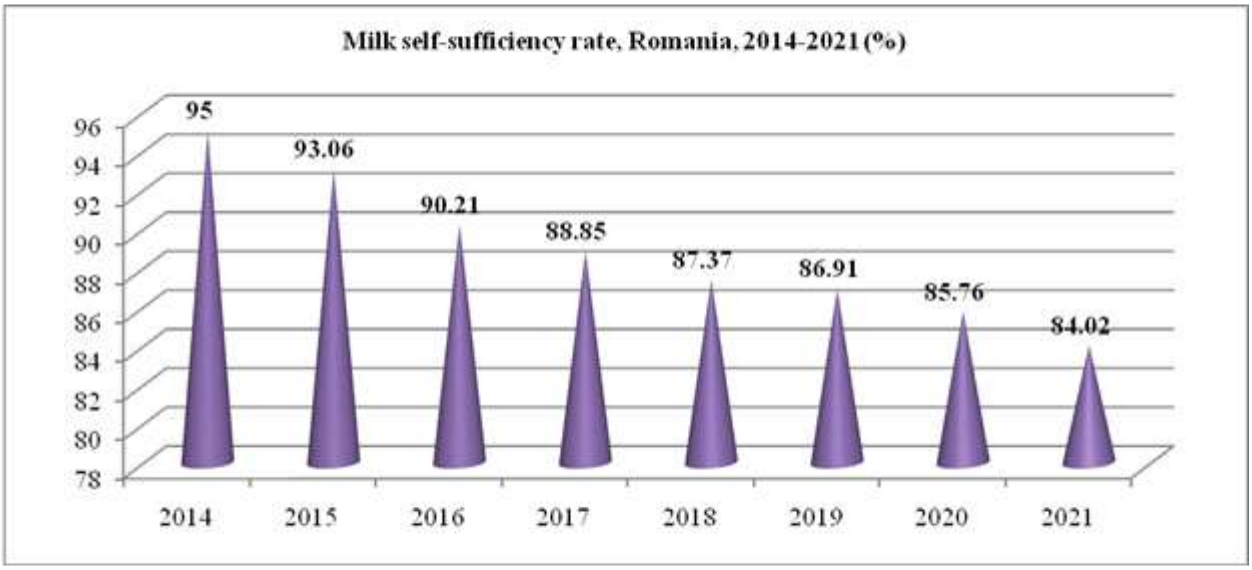

Fig. 11. Dynamics of milk self-sufficiency rate in Romania, 2014-2021 (%)
Source: Own design and calculation based on the data from NIS, 2023 [8].

CONCLUSIONS

The analysis allowed to draw the main conclusions on how milk balance reflects milk crisis in Romania.

First of all, utilizable internal milk production was in a continuous decline, from 57,055 thousand hl in 2014 to 51,750 thousand hl in 2021, recording a loss by 9.3%

Availabilities for human consumption remained relatively stable, in 2021 accounting for 48,881 thousand hl, being by only 0.53% higher.

The weight of availability of milk for human consumption in utilizable internal milk production increased from 85.21 % in the year 2014 to 94.45% in the year 2021.

Milk import registered an upward reaching 12,988 thousand hl in 2021, being 2.58 times higher than in 2014

As a consequence, the share of import in availability for human consumption increased by +16.28 percentage points, accounting for 26.57% in 2021 versus 2014, when it accounted for 10.29%.

Milk export registered an ascending trend from 2,004 thousand hl in 2014 to 3,152 thousand hl in 2021 (+ 57.28%). As a result, the share of export in utilizable production (UIP) went up from 3.51% in 2014 to 6.09% in 2021,

Export/import ratio declined from 0.40 in 2014 to 0.24 in 2021, reflecting that imports exceeds exports, which led to a negative milk trade balance.

Milk consumption per capita reached 255.6 kg in 2021, being by 4.66% higher than in 2014 when it was 244.2 kg.

The average daily milk consumption increased by 4.67% from 689.1 g in 2014 to 721.3 g in 2021.

The self-sufficiency rate decreased from 95% in the year 2014 to 84.02 % in the year 2021, because of the descending trend of utilized internal production.

In consequence this analysis led to the following recommendations:

-More subsidies for sustaining dairy farming are compulsory to diminish the decline in the number of dairy cows, milk production and

milk delivery on the internal market and to reduce imports.
-Processors have to offer a similar price with the one they provide in other EU countries, it is about Euro 0.5 per milk kilogram compared to Euro 0.2 - 0.3 they offer in Romania.
-Imports have to be reduced not to discourage Romanian farmers, who have to deliver their milk to dairies.
-Milk export have to be encouraged but after assuring the market requirements by internal production.
In this way, both self-sufficiency rate could be improved and also the efficiency in milk trade could grow.

REFERENCES

[1]Clal.it., 2023, EU-27: Milk Balance of self-sufficiency 2022, https://www.clal.it/en/?section=bilancio_approv_ue, Accessed on November 22, 2023.
[2]Eurostat, 2023, EU livestock population continued to decline in 2022, https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20230322-1#:~:text=The%20EU%20has%20a%20sizeable,million%20goats%20(%2D3%25). https://ec.europa.eu/eurostat/databrowser/view/APRO_MT_LSCATL__custom_5410182/bookmark/table?lang=en&bookmarkId=ec36805d-35df-4b0a-80eb-98a94069eafa, https://ec.europa.eu/eurostat/databrowser/view/apro_mt_lscatl/default/table?lang=en, Accessed on November 20, 2023.
[3]Eurostat Statistics Explained, 2023, Milk and milk product statistics, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Milk_and_milk_product_statistics&oldid=617758, Accessed on November 20, 2023.
[4]FAO, 2023, Food security and nutrition around the world, https://www.fao.org/3/cc3017en/online/state-food-security-and-nutrition-2023/food-security-nutrition-indicators.html, Accessed on November 20, 2023.
[5]Harvard T.H.Chan, School of Public Health, 2023, The nutrition source, Milk, https://www.hsph.harvard.edu/nutritionsource/milk/, Accessed on November 22, 2023.
[6]Milkmeansmore.org, 2023, Why milk?, https://www.milkmeansmore.org/why-milk/, Accessed on November 22, 2023.
US Department, of Agriculture, Agriculture Research Service, 2019, Food Data Central, fdc.nal.usda.gov
[7]National Institute of Statistics, 2023, Food balance methodology.
[8]NIS, 2023,Tempo Online database, Accessed on November 2, 2023
[9]Pirvutoiu, I., Popescu, A., 2012, Research concerning standard gross margin depending on milk yield in dairy farming, Scientific Papers Animal Science and Biotechnologies, 45(2):339-342
[10]Popescu, A., 2006a, Gross margin- a barometer of profitability in agriculture, International Symposium "Durable Agriculture–the agriculture of the future ", Craiova, pp.23-24.
[11]Popescu, A., 2006b, Study upon milk market in the EU countries, Bulletin of the University of Agricultural Sciences and Veterinary Medicine, Vol. 62, pp.214, 2006: Animal Husbandry and Biotechnologies, Symposium on Prospects for the 3rd Millenium Agriculture, Oct..5-6, 2006, Cluj-Napoca.
[12]Popescu, A., 2010, Home and foreign trade, Dominor Rawex Coms Publishing House, 176-244.
[13]Popescu Agatha, 2014a, Research on milk cost, return and profitability in dairy farming, Scientific Papers Series Management, Economic Engineering and Rural Development, Vol.14(2):219-223.
[14]Popescu, A., 2014b, Research on profit variation depending on the marketed milk and production cost in dairy farming, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.14(2): 223-230.
[15]Popescu, A., 2015a, Research on the trends in milk production and consumption in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.15(1), 387-392.
[16]Popescu, A., 2015b, Research on the trends in Romania's milk and dairy products foreign trade, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.15(10, 391-398.
[17]Popescu, A, 2015c, Research on the trends in milking livestock and milk production in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 15(10, 366-385.
[18]Popescu, A., 2016, The milk market concentration and competition thresholds in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.16(2), 247-253.
[19]Popescu, A, 2017, Trends in milk market and milk crisis impact in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 17(1), 366-385.
[20]Popescu, A., 2018, Discrepancies in dairy farms structure between Romania and the EU-28 top countries raising cows in the period 2010-2017, Annals of Academy of Romanian Scientists, Annals of the Academy of Romanian Scientists Series Agriculture, Silviculture and Veterinary Medicine Sciences, Vol. 7, No. 2,/2018, pp.22-33.

[21]Popescu, A., Condei, R., 2014, Study on the average marketed milk as a measure of profitableness threshold in dairy farms, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.14(4):219-222.
[22]Popescu, A, Angel, E., 2019, Cow raw milk quality and its factors of influence in relationship with milk price, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.19(1): 421-440.
[23]Popescu, A., Stoian, E., Serban, V., 2019, The EU-28 milk sector trends in the period 2009-2018, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 19(4), 249-263.
[24]Popescu, A., Caratus-Stanciu, M., 2021, Farm structure in animal sector of Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 21(4), 445-458.
[25]Statista, 2023, Annual consumption of fluid cow milk worldwide in 2023, by country (in 1,000 metric tons)**,** https://www.statista.com/statistics/272003/global-annual-consumption-of-milk-by-region/**,** Accessed on November 22, 2023.
[26]World Food Programme, 2023, A global crisis, 2023, Another year of extreme jeopardy for those struggling to feed their families, https://www.wfp.org/global-hunger-crisis, Accessed on November 20, 2023.

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DYNAMICS OF ROMANIA'S GROSS DOMESTIC PRODUCT, EXPORT AN IMPORT. A STUDY CASE IN AGRO-FOOD SECTOR, 2013-2022

Agatha POPESCU[1,2,3]

[1]University of Agronomic Sciences and Veterinary Medicine Bucharest, 59 Marasti Blvd, District 1, 011464, Bucharest Romania, Phone: +40213182564, Fax: +40213182888, E-mail: agatha_popescu@yahoo.com
[2]Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu-Sisesti", 61 Marasti Blvd, District 1, 011464, Bucharest Romania, E-mail: agatha_popescu@yahoo.com
[3]Academy of the Romanian Scientists, 1 Ilfov Street, Bucharest, 030167, Romania,
E-mail: agatha_popescu@yahoo.com

Corresponding author: agatha_popescu@yahoo.com

Abstract

The purpose of this study was to analyze the dynamics of Gross Domestic Product (GDP), Export (E) and Import (I) in Romania and also in its agro-food sector in the last decade 2013-2022 and to quantify the relationships between these macroeconomic indicators using the data provided by National Institute of Statistics. The methodology used in this study included; fixed basis and structural indices, growth rate, statistical econometric modeling using regression equations, coefficient of correlations, coefficient of determination, comparison and illustrative methods. In 2022 versus 2013, Romania's GDP accounted for Euro 285,884.8 Million (doubled), export raised by 85.51% and reached Euro 91,944 Million, imports accounted for Euro 126,034.07 Million (2.27 times higher) and the deficit of trade balance reached Euro -34,101 Million, being 5.92 times higher. The regression equations quantified the impact of the determinants on GDP as follows: an increase in E value by one unit will determine an increase by 3.5086 units of GDP; an increase by one unit of I will determine a growth by 2.1058 units of GDP; an increase by one unit of NE will shrink GDP by 5.10849 units. In agro-food sector, the situation was the following in 2022 versus 2013: GDP_A reached Euro 12,864.81 Million (+66%). E_A accounted for Euro 11,959.97 Million (2.26 times higher), I_A reached Euro 13,248.61 Million (2.7 times higher), NE_A attained Euro -1,288.64 Million (9.4 times higher compared to 2015 level). The regression assessed the impact of the determinants on GDP as follows: an increase in E_A will raise GDP_A by 0.8668 units; an increase by one unit of I_A will determine a growth by 0.7034 units of GDP_A; an increase by one unit of NE_A will shrunk GDP_A by - 1.2343 units. To balance the ratio between E and I with a beneficial impact on NE and GDP, Romania has to intensify exports and diminish imports, to increase production and quality of the exported products, to identify the products which should be purchased from abroad to cover the needs on the domestic market, to offer more subsidies to producers, to extend its commercial partners on the external market and better negotiate the trade transactions.

Key words*: *Gross Domestic Product, Export, Import, agro-food sector, dynamics and relationships, Romania

INTRODUCTION

Gross Domestic Product (GDP) characterizes the economy of a country, as it measures the monetary value of all the final commodities and services carried out within the borders of a country by the resident enterprises and bought by consumers in a given period.
GDP is important to be studied as it reflects the size and health of the country's economy and of the global economies as well [1].
GDP at market price could be determined by two methods:
-*Production method* which supposes that GDP is calculated summing "the value added" GVA at each stage of production and taxes on products (TP) and subtracting subsidies per product (SP), according to the formula: GDP = GVA + TP - SP, where: GVA represents total sales minus intermediate inputs into the production process.
-*Expenditures method*, according to which GDP is determined summing Final consumption (FC), Gross capital formation (GCF), export of commodities and services (E) and subtracting Import of goods and

services (I), as reflected by the formula: GDP = FC + GCF + E - I, where: FC is the final effective consumption in terms of the value of purchases of goods and services made by the final users: households, the government and foreigners; GFC represents the investments in fixed assets (machinery etc) by various companies [9].

The growth of GDP is a good sign showing that the economy is developing under the condition that inflation to be small and relatively stable.

When GDP is used for comparisons among countries, it needs to be adjusted taking into account price changes and using the so called "price deflator" which transform "the nominal GDP" (GDP at market prices) into "the real GDP" (GDP at constant prices or inflation-corrected GDP).

In its dynamics, GDP could grow or decrease. When it is growing, the status of the economy is good, we may talk about a "healthy economy", and employment could increase. But, when GDP is going down it is a sign that the economy is "not healthy" and employment declines [5].

Even though GDP increases, it does not tell anything about the social and environment status of an economy. To counteract this aspect, United Nations established the so called Human development index", OECD set a "Better life index" and Eurostat the so called "GDP and beyond".

A special situation is in the case when national entities earn income outside of the country's economy, of which the income earned by foreign nationals in the domestic economy are subtracted. The result is known as Gross National Income (GNI) which is another GDP variant.

GDP is used as a term of reference for many studies, researches and also it is important in the establishment of strategies and policies by Government, and other authorities. Usually, it is utilized in forecasting the development of the economy.

GDP is achieved by various economic branches of the economy whose contributions to GDP is different as volume and share.

In case of agriculture, for example, GDP is used in many analyses regarding the efficiency of various support mechanisms for increasing agricultural production and rural development.

To have a comprehensive and valuable image on the main drivers of the economic activity, we must study the components of GDP and related indicators: output, exports, imports, final consumption, investments as well as income and savings, all these are useful in setting up policies and strategies for economic development [4].

As mentioned above, GDP is influenced by many factors, among which export is a special component with a positive impact on the economic growth and GDP.

Export is a component of international trade which favors the flow of foreign currency into the payment balance of a country by selling its products and goods on the external markets. For this reason, it could strengthen the economic development and increase GDP.

The economic development of a country imposes commercial exchanges with other nations, which means to participate in the international trade [11].

For this reason, when GDP is analyzed, export and import of goods and services must also be taken into consideration as shown in its formula of calculation based on the expenditure method, besides other influencing factors like: final consumption, foreign investments, gross capital formation, employment, unemployment, inflation rate.

Export is another measure of the power of a country economy reflecting its capacity to achieve such a production to cover the demand in the domestic market and to produce supplementary amounts to be sold on various external markets.

An increasing export value shows that a country has a good economy and its products are of high quality and competitiveness in the international market. Export creates employment, investments, production and revenues. It contributes to the expand of the geographical area of influence in the international market and potential customers at the global level. It also is beneficial for the trade companies stimulating sales and increasing their profits and the life cycle of their products. Market diversification could be of much help to spread business risk. More than this, exports valorize the domestic production surplus on foreign markets, bringing foreign currency in the payment balance of a country. A trade surplus could grow the price of the commercialized goods and services and strengthen the domestic currency [11].

Import has a great importance for a country economy when it brings raw materials and finished products and services which that country has not and cannot produce or produce in a small amount than needed or when the production costs for carrying out those products are higher than in other countries, and obviously the purchase price from those suppliers is smaller.

Imports could have a beneficial effect in a growing economy, because they are a source of technology and capital goods which could increase productivity for a long run and also diversify consumers' choice for higher quality products and services. But, imports also generates a flow of currency spent for purchasing goods and services from other countries, diminishing the payment balance.

For this reason, any country desire is to export more and import less to have a high efficiency of its foreign trade, reflected by an import coverage by export higher than 1, meaning that export value exceeds import value, and the trade balance is positive [11, 32].

GDP and its relationships with its factors of influence have been studied by many researchers.

An interesting approach had Wolla (2018), who commented GDP formula: GDP = C + I +G + (X-M), where: C is personal consumption, I is gross private investments, G is government purchase, X is export and M is import, and pointed out that apparently import subtracted from GDP has a negative impact on it. The author affirmed that import has not a negative impact, because imported goods are produced abroad and cannot be subtracted from GDP which represent the value of the goods produced in the country. The author considers that "imports variable is an *accounting variable* and not an expenditure variable like C, I and G, because most domestically produced goods include some foreign parts or components and also while C, I, and G measure spending on only *final* goods and services, exports (X) and imports (M) also include *intermediate* goods". The author concluded that "the imports variable (M) corrects the value of imports that have already been counted as (C), (I), and (G). Therefore, the purchase of imported goods and services should have *no direct impact* on GDP" [35].

Other authors [33] studied the impact of foreign direct investments, import, export, growth rate, unemployment and inflation on GDP using a multiple linear regression model and affirmed that the effect on GDP is not always a positive one.

The relationship between GDP and employment and unemployment was approached by [14, 15] and in connection with the number of employees and export by [6].

The influence of the determinant factors on GDP was studied by [12] and the influence of fixed assets and employment using Cobb-Douglas production function was researched by [13].

The link between GDP and its resources was highlighted by [23]. GDP concentration and its convergence in rural development was studies by [17, 28].

Final consumption has a high influence on GDP as found [19] and also a positive and strong impact of final consumption and gross investment, but a very small impact of net exports on Romania's GDP was confirmed by [34].

Studying the relationship between export and GDP in five top exporting nations: USA, Germany, India, Japan and Singapore, Chauhan (2021) found that export had a beneficial impact on their economy [2].

A positive correlation between Export and GDP, but a negative connection of a negative trade balance on the economic growth was found by [3].

Other researchers highlighted the positive impact of export on GDP [7], and the positive impact of import on GDP was found by [8].

The contribution of agriculture to GDP was studied by [22].

In the last decade, it was noticed a controversial situation regarding the evolution of external trade and also in external agro-food trade of Romania [16]. At national level, both export and import of goods and services registered an upward trend, and the agro-food export and import as well [18]. The problem is that the imports value exceeded the export value resulting a negative trade balance, and the deficit is increasing year by year, reflecting that Romania is a net importing country [31].

In this context, the goal of the paper is to analyze the dynamics of Romania's GDP and the impact of Export and Import on its level, and also the evolution of GDP created in agriculture and the impact of export and import of agro-food products on it in the last decade 2013-2022 in order to quantify the measure of influences of these factors using econometric modelling based on regression equations.

MATERIALS AND METHODS

To set up this research, the data provided by National Institute of Statistics for the period 2013-2022 were used and processed utilizing varied methods: fixed index, structural index, descriptive statistics, regression equations, correlation coefficient, coefficient of determination, variance analysis, comparison method.

The main macroeconomic indicators approached in this study were: GDP, Export value (E), Import value (I) and Net export(NE) at the national level and also: GDP created in agriculture (GDP_A), Agro-food export value (E_A), Agro-food import value (I_A), and Net export in agro-food industry (NE_A).

Considering GDP as Y- dependent variable and the determinant factors one by one X-independent variable, there were constructed econometric regression models which were solved by Least squares method and using Excel facilities.

The results were illustrated in graphics and tables and were correspondingly interpreted.

RESULTS AND DISCUSSIONS

Analysis of GDP, Export value, Import value, Net export value at the national level

Dynamics of Romania's GDP

GDP doubled its value in the last decade from Euro 142,928.9 Million in 2013 to Euro 285,884.8 Million in 2022. The peak of GDP was attained in 2022, while the lowest one was registered in 2013. The general trend reflected growths from a year to another, except the year 2020, when the economy was affected by the measures taken by the authorities during the Covid-19 pandemic (Fig. 1).

To GDP formation, an important contribution has been brought by the following economic sectors: services, industry, constructions and agro-food sector.

As the growth rate ranged from an economic branch to another, some changes have appeared in the GDP structure by source. In 2022, services contributed by 57.7%, industry by 22.5%, constructions by 6.3%, agriculture by 4.5% and 1.3% others [10].

Dynamics of Export value

Export is one of the key factors which contributes to the increase of GDP. Romania's export value for all the commercialized goods and services raised by 85.51% in the analyzed interval from Euro 49,562.14 Million in 2013 to Euro 91,944 Million in 2022. The ascending trend was disturbed by a syncope only in the year 2020, when trade was affected by the Covid-19 pandemic, but in 2021, export has recovered and continued to grow till present (Fig. 2).

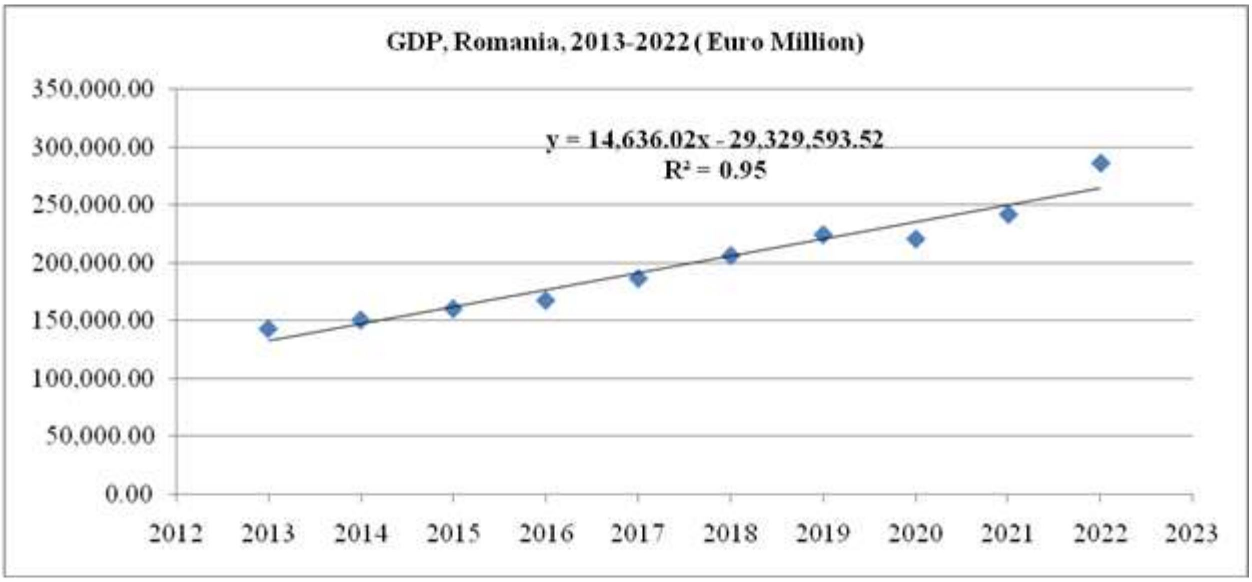

Fig. 1. Dynamics of Romania's GDP, 2013-2022 (Euro Million)
Source: Own design based on the data from National Institute of Statistics [10].

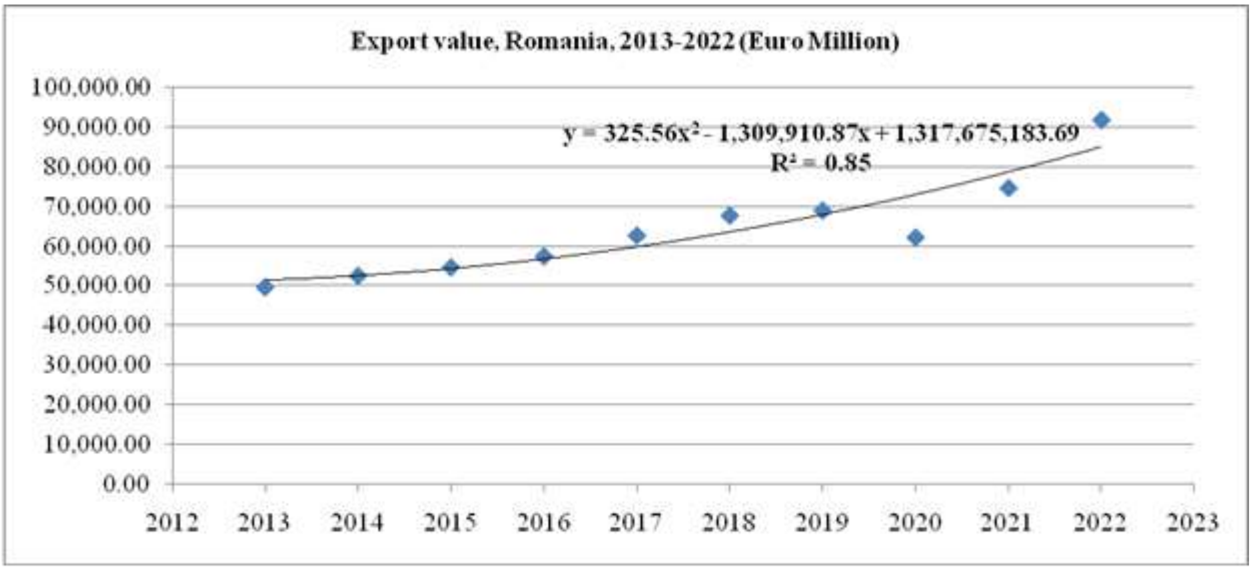

Fig. 2. Dynamics of Romania's export value, 2013-2022 (Euro Million)
Source: Own design based on the data from National Institute of Statistics [10].

Romania's export consists of many groups of commodities which are required on the international market. But, export value is conditioned by the sold quantity and export price. Sometimes, export price for some specific goods could be not satisfactory due to the volume of value added incorporated in that product and quality which is not as competitive as similar products commercialized by other countries, both on the EU and extra EU market.

Dynamics of import value

Imports had an ascending trend, in 2022, their value accounting for Euro 126,034.07 Million being 2.27 times higher than Euro 55,317.36 Million in 2013 (Fig. 3).

Romania's imports consist of a large category of goods and services, whose amount differs and import price as well.

During the last decade imports raised in a high proportion on the internal market even more than necessary in some cases and, in other cases, they were justified to better satisfy consumers' requirements.

Dynamics of trade balance or net export value

Taking into account the evolution of export and import, net export value was negative in each year of the studied period and, more than this, the deficit was higher and higher as the growth rate of imports exceeded the growth rate of exports. In 2022, the net export accounted for Euro -34,101 Million, being 5.92 times higher than in 2013 when it accounted for -5,755.22 (Fig. 4).

This had a negative impact on the coverage rate of imports by exports which registered a very small and subunit level. This reflects that Romania's economy is not balanced and that there are still disturbances in production regarding quantity, structure and quality.

Importing more than exporting involves more expenditures to purchase the imported goods and services which spoil the payment balance of exchangeable currency.

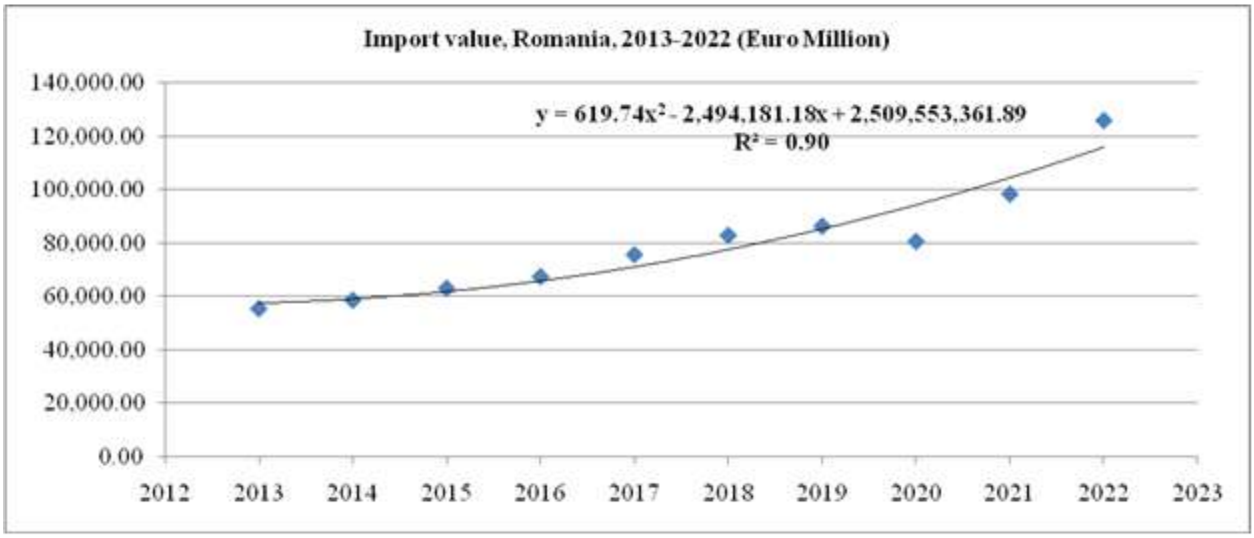

Fig. 3. Dynamics of Romania's import value, 2013-2022 (Euro Million)
Source: Own design based on the data from National Institute of Statistics [10].

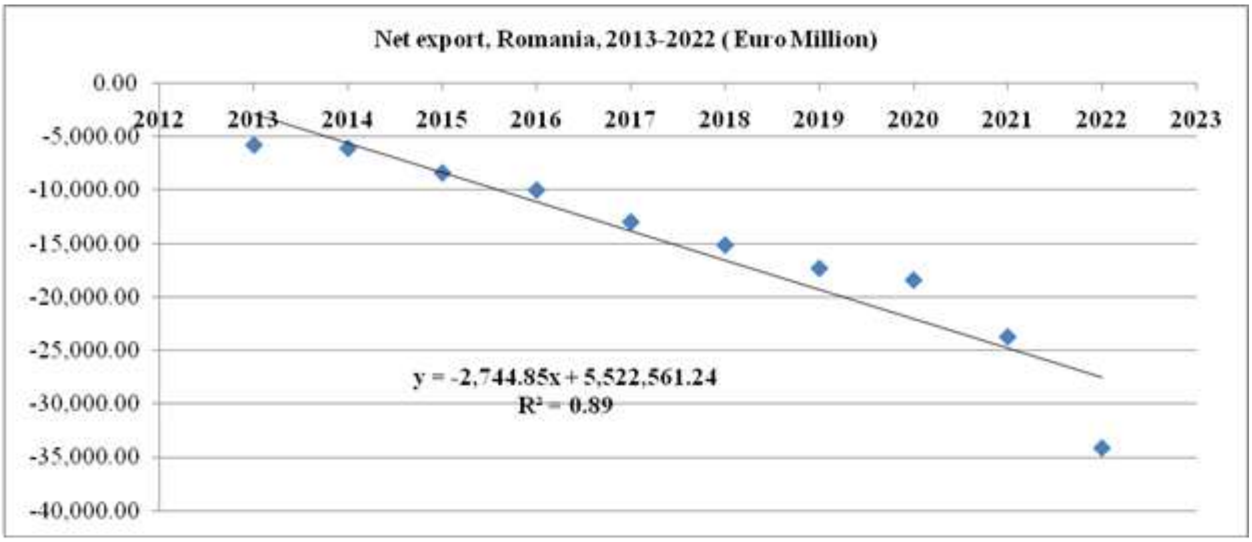

Fig. 4. Dynamics of Romania's net export value, 2013-2022 (Euro Million)
Source: Own design based on the data from National Institute of Statistics [10].

Descriptive statistics for GDP, export value, import value and net export value is shown in Table 1.

Table 1. Descriptive statistics for Romania's GDP, export value, import value and net export value, 2013-2022, n=10

	GDP	E	I	NE
Mean	198,516.61	64,222.30	79,389.92	-15,170.82
St. Error	14,396.24	3,961.46	6,7--.53	2,780.91
Median	196,235.7	62,408.81	78,087.08	-14,038
St. Dev.	45,524.93	12,527.26	21,188.96	8,794.01
Kurtosis	-0.263	1.681	1.599	1.1895
Skewness	0.590	1.173	1.159	-1.100
Min	142,928.9	49,562.14	55,317.36	-34,101
Max	285,884.8	91,944.57	126,034.07	-5,755.22

Source: Own calculations based on the data from NIS [10].

Regression statistics for GDP and its factors of influence: Export, Import, Net export

GDP was considered Y- dependent variable and Export, Import and Net export, were considered, one by one, X-independent variable. The regression equations set up separately for each pair of Y and X variables was solved using the Least square method and Excel facilities. The results regarding the regression analysis are shown in Table 2.

Table 2. Regression statistics for GDP depending on E, I and NE

Variable	Coefficient	St. Error	t - stat	Prob.
Regression analysis for Y- GDP and X- E				
C-constant	-26.745.0501	21,858.2543	-1.2235	0.2559
X - Export	3.5086	0.3346	10.4837	5.96-E
R squared	0.9321	Mean of dependent var.Y	198,586.61	
Adjusted R squared	0.9236	St. Dev. of dependent var.	45,524.93	
St. Error of regression	12,577.5385			
Sum squared residuals	1,265,555,797			
Regression equation: GDP = -26,745.05 + 3.5086 E				
Regression analysis for Y- GDP and X- I				
C-constant	31,406.0468	12,341.624	2,5447	0.0344
X - Import	2.1058	0.1507	13.9735	6.67-E
R squared	0.9606	Mean of dependent var. Y	198,586.61	
Adjusted R squared	0.9557	St. Dev. of dependent var.	45,524.93	
St. Error of regression	9,579.535			
Sum squared residuals	734,140,000.3			
Regression equation: GDP = 31,406.0468 + 2.1058 I				
Regression analysis for Y- GDP and X- NE				
C-constant	121,086.602	5,131.151	23.5983	1.11-E
X - Net export	-5.10849	0.2963	-17.2369	1.31-E
R squared	0.9737	Mean of dependent var. Y	198,586.61	
Adjusted R squared	0.9705	St. Dev. of dependent var.	45,524.93	
St. Error of regression	7,818.798			
Sum squared residuals	489,068,932.7			
Regression equation: GDP = 121,086.602 - 5.10849 NE				

Source: Own results.

The regression equation GDP = -26,745.05 + 3.5086 E reflects that an increase in Export value by one unit will determine an increase by 3.5086 units of GDP. The determination coefficient, $R^2 = 0.9606$ tells us that 96.06% of the variation of GDP is caused by the variation of Export value.

The regression equation GDP = 31,406.0468 + 2.1058 I shows that an increase by one unit of Import will determine a growth by 2.1058 units of GDP. The $R^2 = 0.9737$ highlights that

97.37% of GDP variation is determined by the variation of Import.

However, this result does not suit the GDP formula used when it is applied the expenditure method, GDP = FC + GCF + E - I, but it could much better fit the comments made by [35], who affirmed that "the purchase of imported goods and services should have *no direct impact* on GDP".

But, this result is similar with the one found by Marinescu et al (2016) who affirmed that it was a positive relationship between GDP and Import in the interval 1990-2015 in Romania, according to the following regression equation: PIB=8,916.779+2.248633*Import, which tells us that an increase by one unit of import will determine an increase of GDP by 2.248633 units [8].

The regression equation: GDP = 121,086.602 - 5.10849 NE reflects that, if Net export will increase by one unit, GDP will decrease by 5.10849 units. The determination coefficient $R^2 = 0.9797$ reflects that 97.97% of the variation of GDP is caused by the variation of net export.

The correlation coefficients between GDP and Export, Import an Net export are presented in Table 3. The value of the correlation coefficients are very high reflecting a strong and positive relationship between GDP and these factors of influence.

Table 3. The correlation coefficients between GDP and Export, Import an Net export, Romania, 2013-2022

	Export value	Import value	Net export value
GDP	0.965	0.980	0.986

Source: Own results.

Analysis of GDP, Export value, Import value, Net export value in the agro-food industry

Dynamics of GDP created in agro-food industry

Agro-food sector is very important in the economy of any country as it is called to sustain the coverage of the population needs in food products, which emphasize its role in assuring food security and also raw materials for other economic sectors.

The sum of the value of all the agro-food products in a year in the country forms GDP created by agro-food sector.

Agro-food products are of a large variety, depending on various criteria such as: origin, technological processing degree, packaging type, purpose of use and nutritional function. From a commercial point of view, they are classified in four groups: I Live animals and products of animal origin, II. Vegetal products, III. Animal and vegetal fats and oils and IV. Food products, beverages and tobacco [16, 18].

Also, the Combined Nomenclator is used for assessing the performance in international trade [10].

GDP created in agriculture followed a general increasing trend from Euro 7,718.16 Million in 2013 to Euro 12,864.81 Million in 2022, which means a level by 66% higher than in the previous year of the study (Fig. 5).

If we compare with the doubled value of Romania's GDP in 2022, we may affirm that the volume and the growth rate of GDP created in agro-food sector is much smaller.

In the year 2020, the year of the Covid-19 pandemic, GDP formed in agro-food field was only Euro 8,598.97 Million, being even lower than the level achieved in 2018 and which accounted for Euro 8,861.09 Million.

In 2022, agriculture and food industry contributed to Romania's GDP by 4.5%, compared to 5.4% in 2013. If we compared these figures with the share of other economic sector to GDP, we may notice that agro-food sector comes the fourth in this hierarchy, after services, industry and constructions. The lowest share of agro-food industry in GDP was 3.9% recorded in ten years 2016 and 2020.

The gap between agro-food sector and other economic branches is caused by the specificity of conditions in which agriculture is running its activity: soil and climate conditions which differ on the map of Romania from a region to another, climate changes which have started to affect more and more the production performance in agriculture (high temperatures, droughts, floods, hail etc), the existence of very small subsistence and semi-subsistence farms with an average physical size of 4.2 ha/farm, a standard output of Euro 4,029/farm, the smallest among the EU countries, the low training level of the farmers, the lack of modern technologies and equipment, the low productivity compared to the EU member states [20, 21, 27], the aging of the farmers and rural population, and more intense migration [24, 25, 26, 30], low subsidies, and discriminatory subsidies among the vegetal and animal sector which led to an unbalanced ratio between these two sectors: 65.5 % vegetal and 21% animal in the agricultural output value.

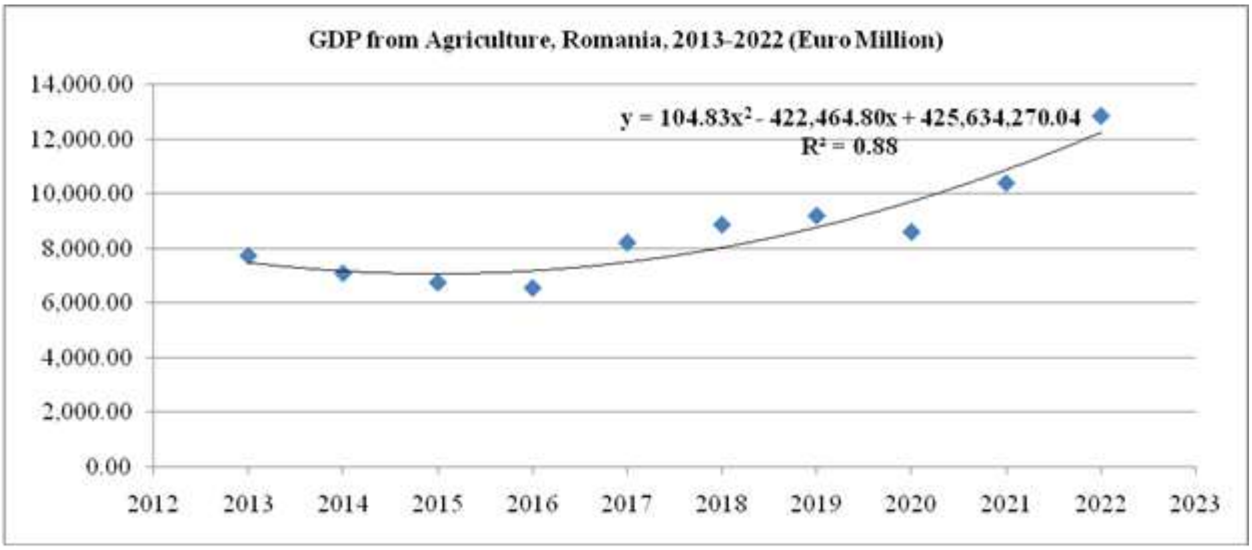

Fig. 5. Dynamics of GDP created in agro-food sector, Romania, 2013-2022 (Euro Million)
Source: Own design based and calculation based on the data from NIS [10].

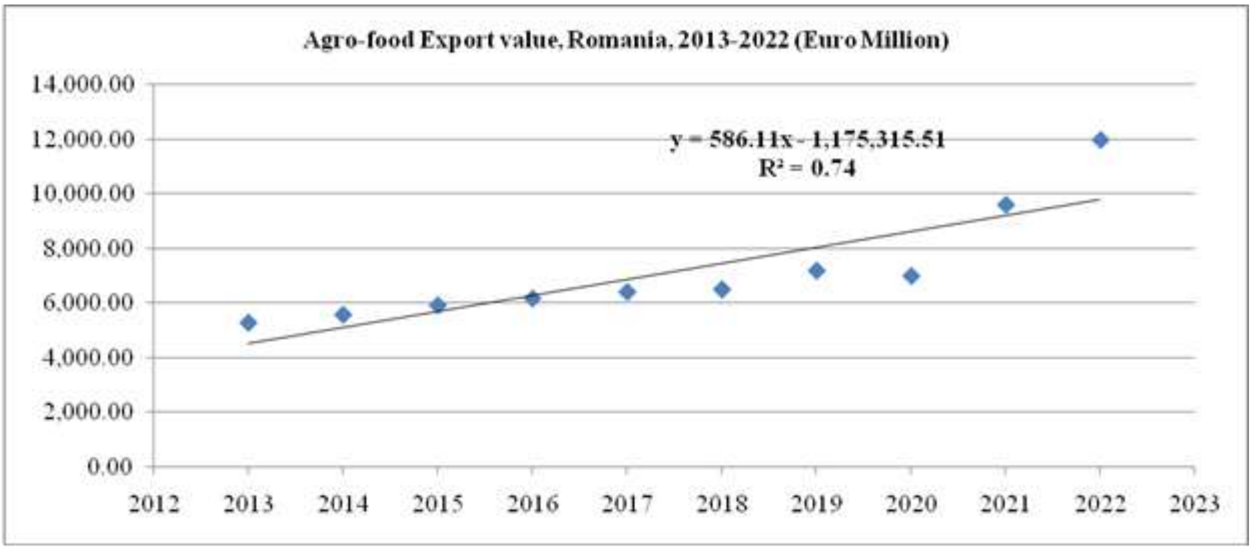

Fig. 6. Dynamics of Export value of agro-food products, Romania, 2013-2022 (Euro Million)
Source: Own design based and calculation based on the data from NIS [10].

Dynamics of Export value of agro-food products

Romania has intensified its external trade with agro-food products, but there is still a huge difference between export and import value regarding their levels and growth rates.

The export value of agro-food products increased from Euro 5,284.41 Million in 2013 to Euro 11,959.97 Million in 2022, which means 2.26 times. In 2020, an inflexion was noticed when the export value declined to Euro 6,994.05 Millions due to the restrictions imposed by the authorities during the Covid-19 pandemic (Fig. 6).

The increased export is a positive aspect in the economy, but it depends on the sold amount and also on the export price got on the external market.

In general, Romanian export of agro-food products is dominated by less processed products like cereals, sunflower seeds, and just a small part of food products, for which the export price is small and directly connected with the quality of the products.

Dynamics of import value of agro-food products

In case of the import value of agro-food products, it was noticed also an ascending tendency from Euro 4,902.04 Million in 2013 to Euro 13,248.61 Million in 2022, a figure 2.7 times higher (Fig. 7).

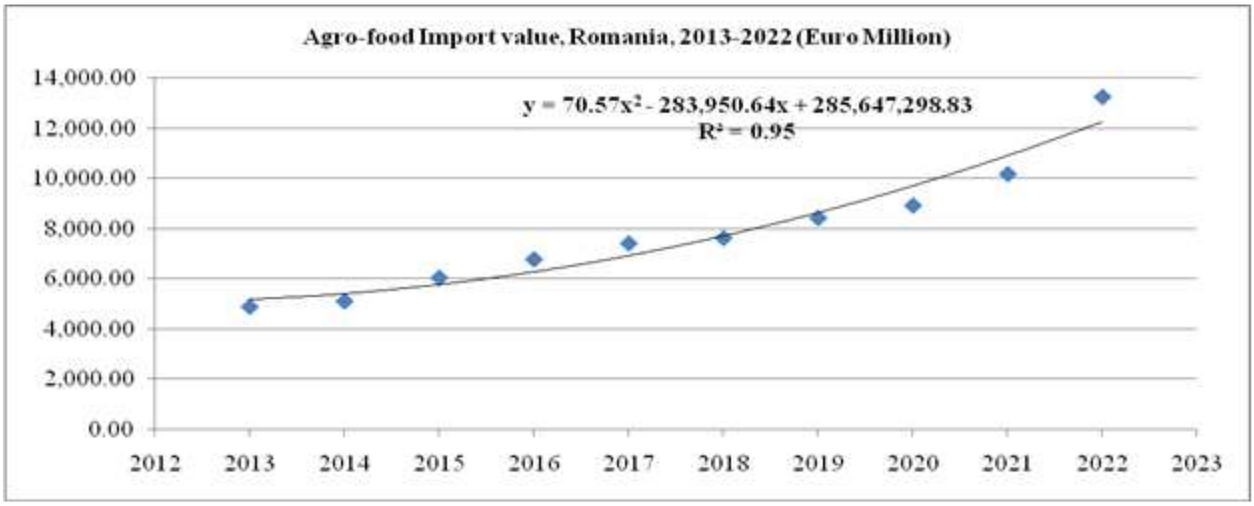

Fig. 7. Dynamics of Import value of agro-food products, Romania, 2013-2022 (Euro Million)
Source: Own design based and calculation based on the data from NIS [10].

Comparing import with export value of agro-food products, we may notice that import value is much higher than export value. In 2022, this surplus was 10.77% compared to the year 2013, when it accounted for only 7.24%.

If in 2013 and 2014, Romania was a net exporting country of agro-food products, starting from 2015, it has become a net importing country, as the import value exceeded the export value.

High imports on the domestic market are justified to diversify the offer and cover much better the demand, as long as production is not able to ensure the necessary for certain products. But, too many imports have disadvantaged the local producers and also have produced a flow of currency to the external suppliers [29].

Dynamics of the net export value of agro-food products

Taking into account the evolution of export and import value of agro-food products, we may easily notice that agro-food trade balance was positive just in the years 2013 and 2014, and since 2015, it became negative with a higher and higher deficit year by year.

in 2022, the deficit accounted for Euro -1,288.64 Million compared to Euro -137 Million in the year 2015, being 9.4 times higher, and compared to the positive net export in 2013, which was Euro +382.37 Million, the gap is much larger (Fig. 8).

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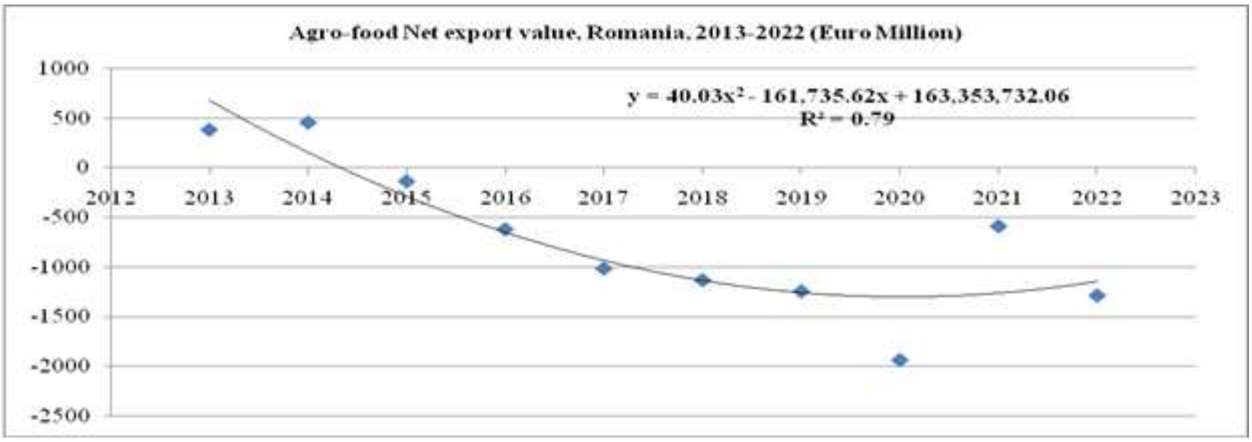

Fig. 8. Dynamics of Net export value of agro-food products, Romania, 2013-2022 (Euro Million)
Source: Own design based and calculation based on the data from NIS [10].

Descriptive statistics for GDP, Export, Import, Net export of agro-food products

Descriptive statistics for GDP, export value, import value and net export value is shown in Table 4.

Table 4. Descriptive statistics for Romania's GDP, export value, import value and net export value, 2013-2022, n=10

	GDP_A	E_A	I_A	NE_A
Mean	8,616.193	7,158.846	7,871.99	-713.153
St. Error	604.0063	654.303	794.428	242.8608
Median	8,399.28	6,454.01	7,529.08	-818.205
St. Dev.	1,910.035	2,069.15	2,512.204	767.99
Kurtosis	1,7874	2,6719	1.2108	-0.6356
Skewness	1,2411	1,639	1,0051	0.2523
Min	6,532.08	5,284.41	4,902.04	-1,938.44
Max	12,864.81	11,959.97	13,248.61	455.99

Source: Own calculations based on the data from NIS [10].

Regression statistics for GDP in agro-food sector and its factors of influence: Export, Import, Net export

GDP_A was considered Y- dependent variable and $Export_A$, $Import_A$ and Net $export_A$, were considered, one by one, X-independent variable. The regression equations set up separately for each pair of Y and X variables was solved using the Least square method and Excel facilities. The results regarding the regression analysis are shown in Table 5.

The regression equation GDP_A = 2,410.198 + 0.8668 E_A reflects that an increase in Export value of agro-food products by one unit will determine an increase by 0.8668 units GDP_A. The determination coefficient, R^2 = 0.8560 tells us that 85.6% of the variation of GDP_A is caused by the variation of Export value of agro-food products, and the difference by other factors.

The regression equation GDP_A = 3,078.62 + 0.7034 I_A shows that an increase by one unit of Import of agro-food products will determine a growth by 0.7034 units of GDP_A. The R^2 = 0.8560 highlights that 85.6% of GDP_A variation is determined by the variation of Import $_A$.

This result does not suit to the formula of GDP calculation, which shows a negative influence of import, but it suits to the comments made by [35]. who affirmed that "the purchase of imported goods and services should have *no direct impact* on GDP".

The regression equation: GDP_A = 7,735.88 - 1.2343 NE_A reflects that, if Net export of agro-food products will increase by one unit, GDP_A will decrease by - 1.2343 units. The determination coefficient R^2 =0.2463 reflects that only 24.63% of the variation of GDP is caused by the variation of NE_A and the remaining of 75.27% is caused by other factors.

The correlation coefficients between GDP_A and $Export_A$, $Import_A$ an Net $export_A$ are presented in Table 6.

The value of the correlation coefficients are very high reflecting a strong and positive relationship between GDP_A and Export $value_A$ and Import $value_A$, but a moderate and positive connection with Net export $value_A$.

Table 5. Regression statistics for GDP_A depending on E_A, I_A and NE_A

Variable	Coefficient	St. Error	t - stat	Prob.
Regression analysis for Y- GDP_A and X- E_A				
C-constant	2,410.198	832.4154	2.8954	0.0200
X - $Export_A$	0.8668	0.112139	7.7306	5.58-E
R squared	0.8819	Mean of dependent var. Y	8,616.193	
Adjusted R squared	0.8771	St. Dev. of dependent var.	1,910.035	
St. Error of regression	686.0959			
Sum squared residuals	3,876,395			
Regression equation: GDP_A = 2,410.198 + 0.8668 E_A				
Regression analysis for Y- GDP_A and X- I_A				
C-constant	3,078.6296	838.862	3,6700	0.0063
X - $Import_A$	0.7034	0.1019	8.8971	0.00012
R squared	0.8560	Mean of dependent var. Y	8,616.193	
Adjusted R squared	0.8380	St. Dev. of dependent var.	1,910.035	
St. Error of regression	768.666			
Sum squared residuals	4,726,790			
Regression equation: GDP_A = 3,078.62 + 0.7034 I_A				
Regression analysis for Y- GDP_A and X- NE_A				
C-constant	7,735.883	778.2547	9.8400	8.88-E
X - Net $export_A$	-1.2343	0.7633	-1.6170	0.1445
R squared	0.2463	Mean of dependent var. Y	198,586.61	
Adjusted R squared	0.1521	St. Dev. of dependent var.	45,524.93	
St. Error of regression	1,758.75			
Sum squared residuals	24,745.720			
Regression equation: GDP_A = 7,735.88 - 1.2343 NE_A				

Source: Own results.

Table 6. The correlation coefficients between GDP_A and $Export_A$, $Import_A$ and Net $export_a$, Romania, 2013-2022

	Export $value_A$	**Import $value_A$**	**Net export $value_A$**
GDP	0.939	0.925	0.496

Source: Own results.

CONCLUSIONS

This study analyzed the GDP and foreign trade dynamics in terms of Export, Import and Net export in the last decade 2013-2022 in Romania.

The results proved that, in 2022 versus 2013, Romania's GDP accounted for Euro 285,884.8 Million, meaning a double value.

Export raised by 85.51% and reached Euro 91,944 Million, while imports accounted for Euro 126,034.07 Million, being 2.27 times higher.

Romania's trade balance registered a higher and higher deficit which reached Euro -34,101 Million, being 5.92 times higher.

Studying the impact of Export, import and Net export on Romania's GDP it was found that: an increase in Export value by one unit will determine an increase by 3.5086 units of GDP; an increase by one unit of Import will determine a growth by 2.1058 units of GDP; an increase by one unit of Net export will shrink GDP by 5.10849 units.

Compared to 2013, in 2022, agro-food sector contributed by 4.5% to Romania's GDP. GDP produced in this sector had also an ascending trend and reached Euro 12,864.81 Million (+66%). agro-food export accounted for Euro 11,959.97 Million, being 2.26 times higher; agro-food import reached Euro 13,248.61 Million in 2022, being 2.7 times higher; the deficit of Net export attained Euro -1,288.64 Million being 9.4 times higher compared to 2015 level.

The regression equations quantified the impact of each determinant on GDP created in agro-food sector as follows: an increase in Export value of agro-food products by one unit will determine an increase by 0.8668 units GDP_A; an increase by one unit of Import of agro-food products will determine a growth by 0.7034 units of GDP_A; an increase by one unit of Net export $_A$ will shrunk GDP_A by -1.2343 units.

These results confirm the existence of relationships between diverse economic factors and GDP both at the national level, and in this study case regarding agro-food industry.

They also proved that there are still gaps and disturbances which could unbalance the economy, and this has to continue in more details to identify the aspects which have to be improved.

Multiple regressions could be more useful than simple regression to quantify the joined effect of many factors of influence on GDP.

The results allow to draw some main recommendations to balance the ratio between export and imports with a beneficial impact on GDP and trade balance as well.

Romania's export has to be intensified on a larger international market and with a higher efficiency. In this respect, producers oriented to exports have to increase production of the products highly requested on the external market and also to improve product quality for getting a better export price.

Imports have to be analyzed and restructured in the sense to purchase from abroad mainly products which could not be carried out or are produced in a small quantity in Romania. High imports are not justified, because they affect the domestic producers and diminish the currency in the payment balance.

Subsidies have to continue to sustain the internal producers in a higher amount to enable them to increase production and its quality and stimulate the export of the Romanian products.

The small export/import ratio reflects a non corroborated development of the commercial transactions which increased the deficit in the trade balance of Romania and also in the agro-food sector.

The Romanian products destined to be exported needs to have more value added and higher quality to be competitive on the external market.

REFERENCES

[1]Callen, T., Groos Domestic Product: An economy's all. International Monetary Fund, https://www.imf.org/en/Publications/fandd/issues/Series/Back-to-Basics/gross-domestic-product-GDP#:~:text=GDP%20measures%20the%20monetary%20value,the%20borders%20of%20a%20country. Accessed on November 30, 2023

[2]Chauhan, V., 2021, Relationship between exports and gross domestic product (GDP), International Journal of Creative Research Thoughts (IJCRT), Vol.8(4), 2697-2702.

[3]Eric, O., Popovic, G., Popovic, S., 2019, Foreign trade liberalisation and economic growth: The case of the Republic of Srpska. Economics, Vol.7(2), 99-108.

[4]Eurostat Statistics Explained, 2023, National accounts and GDP, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=National_accounts_and_GDP, Accessed on November 20, 2023.

[5]Eurostat Statitics explained, Beginners:GDP - What is gross domestic product (GDP)? https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Beginners:GDP_-_What_is_gross_domestic_product_(GDP)?, Accessed on November 20, 2023.

[6]Grigorescu, L., Marinescu, A.I., 2020, The economic-social content of the indicators used in the analyses of the macroeconomic proportions and correlations, Romanian Statistical Review, Suppl. 2, 51-73.

[7]Manole, A., Anghelache, C., SJ Jweida, I.J., Nita, G., Marinescu, A.-I., 2016, A regression model utilized for analyzing the correlation between GDP and export, Romanian Statistical Review, Suppl. 10, 85-88.

[8]Marinescu, R.T., Diaconu, A., Badiu, A., Bodo, G., 2016, Analysis of the correlation between GDP and import using a statistic-econometric model, Romanian Statistical Review, Suppl. 10, 93-97.

[9]National Institute of Statistics, 2023, Methodology for calculating GDP.

[10]National Institute of Statistics, 2023, Tempo online, www.insse.ro, Accessed on November 20, 2023.
[11]Popescu, A., 2010, Home and foreign trade, Dominor Rawex Coms Publishing House, 176-244.
[12]Popescu, A., 2015, Analysis of the dynamics of Gross Domestic Product and of its main factors of influence in Romania's agriculture, Proceedings of 25th IBIMA International Conference Innovation Vision 2020: from Regional Development Sustainability to Global Economic Growth, Amsterdam, The Netherlands, May 7-8, 2015, pp.1379-1393.
[13]Popescu, A., David, L., 2015, The use of the Cobb-Douglas production function to analyze the relationship between GDP, Fixed assets and Employment in Romania's Agriculture, Proceedings of 25th IBIMA International Conference Innovation Vision 2020: from Regional Development Sustainability to Global Economic Growth, Amsterdam, The Netherlands, May 7-8, 2015, pp. 1366-1378.
[14]Popescu, A., 2016a, Research on the Relationship between GDP, Unemployment and Employment in the EU-28, Proceedings of 27th IBIMA International Conference Innovation Management and Education Excellence Vision 2020: from Regional Development Sustainability to Global Economic Growth, Milan, Italy, May 4-5, 2016, pp.686-695.
[15]Popescu, A., 2016b, Research on the Correlation between Economic Growth, Unemployment and Employment. A case study-Romania, Proceedings of 27th IBIMA Conference Innovation Management and Education Excellence Vision 2020: from Regional Development Sustainability to Global Economic Growth, Milan, Italy, May 4-5, 2016,606-706.
[16]Popescu, A., 2017a, The Intra-Industry Trade in Agro-Food Products - The Case of Romania, Proceedings of 29th IBIMA International Conference on Education Excellence and Innovation Managmenet through Vision 2020: from Regional Development Sustainability to Global Economic Growth, Vienna, Austria, May 4-5, 2017, pp.1261-1278.
[17]Popescu, A., 2017b, Convergence of Regional Development in Romania in Terms of Gross Domestic Product, Proceedings of 29th IBIMA International Conference on Education Excellence and Innovation Managmenet through Vision 2020: from Regional Development Sustainability to Global Economic Growth, Vienna, Austria, May 4-5, 2017, pp.1279-1293.
[18]Popescu, A., 2017c, Trends and correlations in Romania's agro-food foreign trade in the period 2007-2016, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development,Vol.17(4)293-304.
[19]Popescu, A., 2018, The Influence of Final consumption on Gross Domestic Product in Romania, Proceedings of 31st IBIMA International Conference on Vision 2020: Education Excellence and Management of Innovations through Sustainable Economic Competitive Advantage, Milan, April 25-26, 2018, pp.2411-2423
[20]Popescu, A., 2019, Trends in Labour Productivity in Romania's Agriculture, Proceedings of 34th IBIMA International Conference on Vision 2025: Education Excellence and Management of Innovations through Sustainable Economic Competitive Advantage, 13-14 Nov.2019, Madrid, Spain, pp.9999-10016.
[21]Popescu, A., 2019, Trends in Labour Productivity in the European Union's Agriculture, Proceedings of 34th IBIMA International Conference on Vision 2025: Education Excellence and Management of Innovations through Sustainable Economic Competitive Advantage, 13-14 Nov.2019, Madrid, Spain, pp.9982-9998.
[22]Popescu, A., 2020, Contribution of Agriculture to Romania's Gross Domestic Product, Proceedings of 36th IBIMA International Conference on Vision 2025: Education Excellence and Management of Innovations through Sustainable Economic Competitive Advantage, November 4-5, 2020, Granada, Spain, pp.2207-2220.
[23]Popescu, A., David, L., 2017, The Relationship between GDP and its Resources in Romania's Economy, Proceedings of 30th IBIMA International Conference, Madrid, November 8-9, 2017, pp.449-468
[24]Popescu, A., Dinu, T.A., Stoian, E., 2018, Demographic and economic changes characterizing the rural population in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.18(2), 333-346.
[25]Popescu, A., Tindeche, C., Marcuta, A., Marcuta, L., Hontus, A., Angelescu, C., 2021, Labor force in the European Union agriculture - Traits and tendencies, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.21(2), 475-486.
[26]Popescu, A., Dinu, T., A., Stoian, E., Şerban, V., 2021, Efficiency of labor force use in the European Union's agriculture in the period 2011-2020, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.21(3), 659-672.
[27]Popescu, A., Tindeche, C., Marcuta, A., Marcuta, L., Hontus, A., 2021, Labor productivity in Romania's agriculture in the period 2011-2020 and its forecast for 2021-2015, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.21(3), 673-678.
[28]Popescu, A., Serban, V., 2021, Dynamics of Concentration in Gross Domestic Product achieved in Romania's Agriculture, Proceedings of 38th IBIMA International Conference, Sevilla, Spain, November 23-24, 2021, pp.6972-6981.
[29]Popescu, A., 2022, The importance of production and import for ensuring food availability in Romania, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.22(1), 533-548.

[30]Popescu, A., Dinu, T.A, Stoian, E., Serban, V., 2022, Population occupied in agriculture and agricultural production value in Romania, 2008-2020, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.22(1), 503-514.

[31]Popescu, A., Dinu, T.A, Stoian, E., Serban, V., 2022, Romania's agro-food foreign trade concentration with the European Union countries, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.22(2), 565-578.

[32]Sangho, K., Lim, H., Park, D., 2009, Imports, Exports and Total Factor Productivity in Korea. Applied Economics 41 (14): 1819-1834. https://doi.org/10.1080/00036840601032243.

[33]Stanic, S., Racic, Z.V., 2019, Analysis of macroeconomic factors effect to Gross Domestic Product of Bosnia and Herzegovina using the multiple linear regression model, Economics, Vol.7(2), 91-97.

[34]Villanueva, A., 2020, Analyzing Romania GDP: Final consumption, gross investment, and net exports influence compared to previously published models, Theoretical and Applied Economics, Vol. XXVII, No. 4(625), Winter, pp. 169-176.

[35]Wolla, S.A., 2018, How Do Imports Affect GDP? Page One Economics, 1-6. https://research.stlouisfed.org/publications/page1-econ/2018/09/04/how-do-imports-affect-gdp, Accessed on November 25, 2023.

ANALYSIS OF INTERNAL AUDIT EFFECTIVENESS: AN INTERDISCIPLINARY GLOBAL RESEARCH PERSPECTIVE. A BIBLIOMETRIC APPROACH

Andrei Bogdan POPESCU-GRĂDIȘTEANU, Dorina MOCUȚA

University of Agricultural Sciences and Veterinary Medicine Bucharest, 59 Marasti, District 1, 11464, Bucharest, Romania, Email: popescu.andrei_bogdan@yahoo.ro, dorinamocuta@yahoo.com

Corresponding author: popescu.andrei_bogdan@yahoo.ro

Abstract

Internal audit has become globally recognized as a vital component of corporate governance, contributing to transparency, accountability, and organizational performance. The aim of the study is to provide an understanding of developments and trends related to internal audit at an interdisciplinary level, thus bibliometric analysis was used to examine 648 scientific articles, published between 1990 and 2022, which had the keyword "internal audit effectiveness". The study suggests that continued research and development in this area is essential, given the constant changes in the business environment and the need to continuously improve the quality, effectiveness and performance of internal audit.

Key words**:** *audit, economic efficiency, bibliometric analysis*

INTRODUCTION

Internal audit as a concept and practice has evolved over time in response to changes in the economic and social context [2]. Although there are references to audit activities and control of financial transactions in ancient societies, such as Egyptian civilization or the Roman Empire, the modern concept of internal audit began to take shape more clearly in the 20th century [3].

It was first defined in the United States, where the twentieth century brought a number of significant changes in corporate and governmental settings, including the increasing complexity of business operations, the growth of the service sector, and the emergence of new information technologies [4, 6]. These changes have increased the need for tighter and more effective control of internal operations, leading to the development and institutionalization of internal audit.

During the 1940s, the Institute of Internal Auditors (IIA) was established in the United States, marking a crucial moment in the formal recognition and establishment of internal auditing as a profession [8]. This pivotal milestone was instrumental in shaping and legitimizing the field of internal auditing, providing a structured framework to define the responsibilities, roles, and ethical benchmarks for internal auditors [10].

Over the years, internal auditing has evolved in response to shifting business landscapes, embracing change and innovation. Yet, at its core, the fundamental role of providing unbiased and autonomous evaluations of internal control, risk management, and governance effectiveness has remained constant. [11, 12].

The 1970s and 1980s were a period of expansion and consolidation for internal audit, following a series of major financial scandals that highlighted the need for stronger internal control [14]. Against this backdrop, the Foreign Corrupt Practices Act was passed in the United States in 1977, requiring companies to implement effective internal control systems [15].

Internationally, the importance of internal audit has been emphasized by professional standards issued by the IIA. These have been updated over the years to respond to changes in business practices and the increasing complexity of the corporate environment. Thus, in 1999, the IIA introduced a new model for defining internal audit, emphasizing its role in assessing and improving risk management, control, and governance processes [17].

Consequently, internal audit has garnered global recognition as an indispensable element of corporate governance, fostering transparency, accountability, and enhancing organizational performance [21]. Key milestones defining the inception of internal audit encompass the contributions of industry trailblazers, the imperative for control and accountability, and the evolution of the internal audit profession; the evolution of requirements and regulations [22, 24].

Auditing is the systematic process of examining, evaluating and verifying financial information and the various operations and even practices of an enterprise to ensure the reliability and compliance of an entity's operations [16,18].

Auditing in agriculture is the process that helps to effectively manage agricultural businesses, which have specific characteristics due to the nature and complexity of the sector [19, 26]. A significant feature of agricultural auditing is its dependence on natural factors that directly influence yields. Agriculture relies on various investments, which require control and evaluation of assets, which are set with government regulations of subsidies, food safety and even environmental protection [13, 20].

Thus arises the need for auditing in agriculture which must ensure compliance with industry standards, and financial performance management.

The defining characteristics of auditing in agriculture are weather factors such as natural resources, soil, water, which affect yields and make auditing to be essential for Agricultural business [9].

Audit also has a role in sustainable land planning, the most efficient use of resources and in maintaining the sustainability of agricultural activities.

Auditing in agriculture can also be a tool to promote transparency in good agricultural governance, thus through a detailed examination of an entity's operations and processes, it can prevent fraud, abuse and errors that may occur, so that the integrity of financial data and information is maintained.

Auditing in agriculture and economics are two interlinked areas that have a significant influence on the agricultural sector. Agriculture is vital to the global economy, and agricultural auditing has evolved over time to become an indispensable tool for agricultural business [5].

Today, the global economy faces various challenges, such as the environment, which requires resource management to protect it, as well as agricultural waste and overproduction.

From an economic point of view, auditing needs to correctly assess expenses and assets in order to maintain financial stability of farms, and auditing helps to identify risks and promote financial management.

In this case, the audit has to assess the right farming practices in order to comply with environmental regulations and have a positive impact on the environment. From the point of view of technologies, an assessment of the systems and monitoring of the agricultural machinery is aimed at achieving a better risk management, as well as optimizing the technologies used [20, 28].

On the other hand, auditing also has a direct impact on society by ensuring food safety through the verification of conformity and quality of agricultural products.

Theoretical Background

In the ever-changing world of internal audit, emerging trends and technological innovations are leaving their mark on the way research is conducted. In a fascinating study by Appelbaum, Kogan, Vasarhelyi, and Yan (2017) [2], the authors investigated the impact of business analytics and enterprise systems on managerial accounting. They explored how technology can change internal audit processes, leading to developments in practices that can transform the way organizations manage risk and improve efficiency.

Conversely, there is a rising apprehension regarding the function of internal audit in the prevention and detection of fraud. In a compelling investigation conducted by Năstase and Ionescu in 2012 [17], this matter is thoroughly examined. The authors propose that internal audit assumes a pivotal function in averting and identifying fraud, underscoring the significance of this role in upholding the ethical standards and transparency within organizations. Each of these scholarly papers constitutes a significant addition to the collective wisdom in the realm of internal audit, imparting valuable insights into the hurdles and prospects confronted by professionals in this field under the current circumstances.

They help to provide a snapshot of the current state of internal audit research globally and in Europe, highlighting the continuing importance of the field in promoting efficiency, accountability and corporate governance in organizations.

Over time, the need for innovation and adaptability in internal audit has become clear, especially in the face of contemporary challenges such as digitalization and globalization. The strong focus on digitization and big data has fundamentally changed the way internal audit is approached and conducted. For example, KPMG (2020) has released a report titled "Internal Audit 2020: a vision of the future", which looks at how technology is set to transform internal audit and how internal auditors need to adapt to remain relevant.

In another landmark study by Alles (2015) [1], research focused on how information technology is transforming internal audit. His results reveal that the appropriate use of information technology can help improve the efficiency and effectiveness of internal audit processes. This research not only highlights the importance of technology in internal audit, but also highlights the need for continuous adaptation and learning in the field.

The European context is also no stranger to these trends and changes. For example, Cohen, Krishnamoorthy and Wright's (2017) [7] study explores the various challenges facing internal audit in the European Union and the importance of internal audit in maintaining effective corporate governance and addressing emerging challenges such as changing regulations and digitalization.

In Romania, internal audit research work has followed global trends, with a specific focus on local applicability and in line with national regulations. For example, the paper [14] entitled "Fair Value Accounting and Its Implications for Corporate Governance: a Comparative Analysis" (2014) is a significant contribution to the study delves into the intersection of internal audit and corporate governance, specifically examining the impact of fair value accounting within the Romanian context. Moreover, the paper titled "Retailers' Audit Strategies for Green Agriculture Based on Dynamic Evolutionary Game" aims to explore retailers' audit approaches concerning sustainable agriculture. Additionally, it utilizes principles from evolutionary game theory to scrutinize the dynamics between retailers and agricultural suppliers. The authors explore the cooperative and conflicting dynamics between retailers and agricultural suppliers concerning the adoption and promotion of environmentally sustainable farming methods. Their approach involves utilizing evolutionary game theory to understand these dynamics and depict the evolving nature of these engagements, considering the shifts over time in the approaches adopted by both entities.

The results of the paper show that auditing plays a key role in promoting green agriculture by providing assurance and assessments of compliance with environmental and sustainability standards. The authors stress the importance of collaboration and cooperation between retailers and agricultural suppliers to promote these sustainable practices [27].

Saad et al.'s scientific publication in 2016 centers on conducting energy audits within an agricultural system that includes maize, wheat, and green bean crops situated in the northwestern area of the Indo-Gangetic Plains, which is characterized by irrigation. The main aim of the study is to assess energy efficiency and compare the conventional farming system with conservation agriculture from the perspective of energy consumption.

The authors carry out detailed analyses to quantify the energy required and consumed at various stages of the farming system, such as land preparation, sowing, irrigation, harvesting and crop processing. The findings from the research reveal a considerable disparity in energy consumption, with the conventional agricultural system exhibiting notably higher energy usage, particularly in the context of irrigation and mechanical operations. In contrast, the practice of conservation agriculture, characterized by its soil preservation and resource-efficient techniques, demonstrates a significant reduction in energy consumption. These outcomes underscore the significance of transitioning towards farming practices that are both more sustainable and energy-efficient. Conservation agriculture proves to be a more environmentally friendly and energy-efficient option compared to conventional agriculture.

The aim of the paper is to evaluate existing research in this field and the impact it has on the effectiveness of internal audit.

MATERIALS AND METHODS

The term "bibliometrics" was first used by Alan Pritchaed as early as 1969 and is considered a statistical and mathematical method that focusses on books and publications. Utilizing the Web of Science database, a collection of scientific articles concerning internal audit effectiveness was obtained in text format. The data, retrieved through an advanced search mode spanning from 1990 to 2022, encompass diverse publication types within the Web of Science database. [23]. The second step consisted of processing the extracted data and maps were generated on the topics of interest for which conclusions were formulated in the third step. To produce the figures, the VOSviewer software was used for creating, visualizing and exploring network-based maps [20].

RESULTS AND DISCUSSIONS

According to the Web Of Science database, 648 scientific papers were identified by searching the keyword ,,internal audit effectiveness". The main topics in which papers were included are: business finance (191 papers), management (121 papers), business (71 papers), economics (68 papers), information system (37 papers), general internal medicine (30 papers), public administration (19 papers), health care services and science (30 papers), interdisciplinary social science (21 papers) and educational research (17 papers) (Figure 1). The main representative keywords interlinked with the topic of ”internal audit effectiveness" are: corporate governance, internal audit, impact, quality, determination, cost, decision making, quality manager, fraud, trust, risk management. These words are divided into 5 clusters (Figure 2).

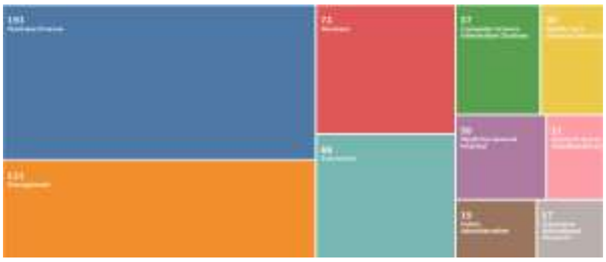

Fig. 1. Tree diagram of Web of Science publications on ”internal audit effectiveness".
Source: in-house development.

The first blue cluster, called ,,corporate governance", includes: agency theory, firm, audit committee, board, directors, audit committee characteristics, agency, ownership, agency issues, regulation, internal audit function, efficiency, compensation, firm performance. The second green cluster, called ,,quality", includes: audit quality, services, association, audit committees, control deficiencies, material weakness, independence, association, consequences, engagement quality.

The third yellow cluster, called ,,internal audit", includes: management, risk management, internal auditor, trust, internal audit, corruption, fraud, organizations, incentives, avoidance, standards.

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The fourth red cluster, called ,,impact", includes: information, audit, design, guidance, women, health, care, quality improvement, sustainability, strategies, doctors, design, risk, banks.

The fifth purple cluster, called ,,decision-making", comprises adoption, size, cost, organization, sustainability, audit fees, financial reporting, committee (Figure 3).

For keywords used by researchers over the years 2012-2014, the authors studied expertise, rest, audit committees, experience, weakness, material weakness, knowledge, internal medicine, improvement, feedback, program, control, guidelines, audit, services.

From 2015-2019, researchers focused on quality, impatience, management, internal audit, audit engagement, corporate governance, directors, disclosure, public sector, risk management, ownership, association, firm, revenue management, external audit, health, system, methodology.

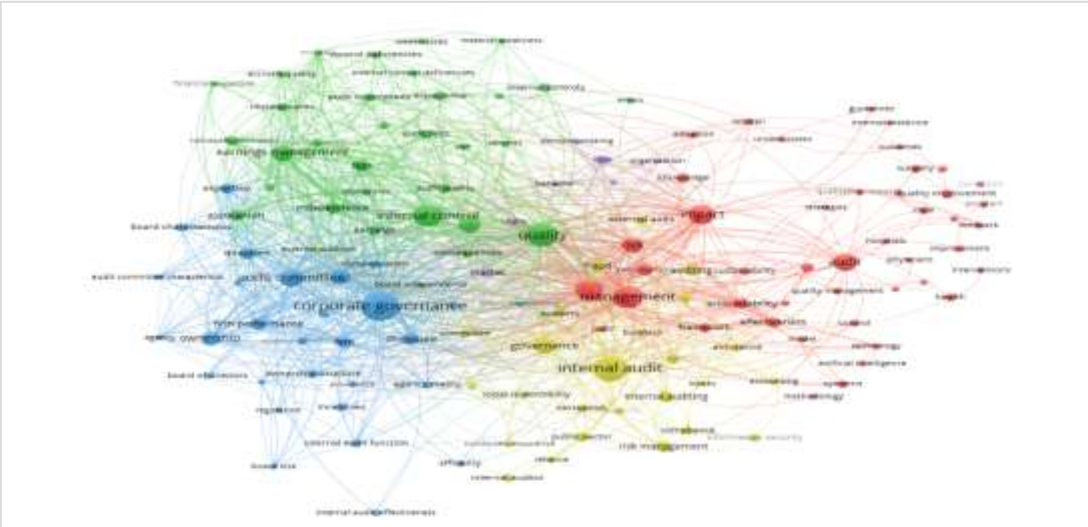

Fig. 2. Keyword connectivity (internal audit effectiveness).
Source: in-house development.

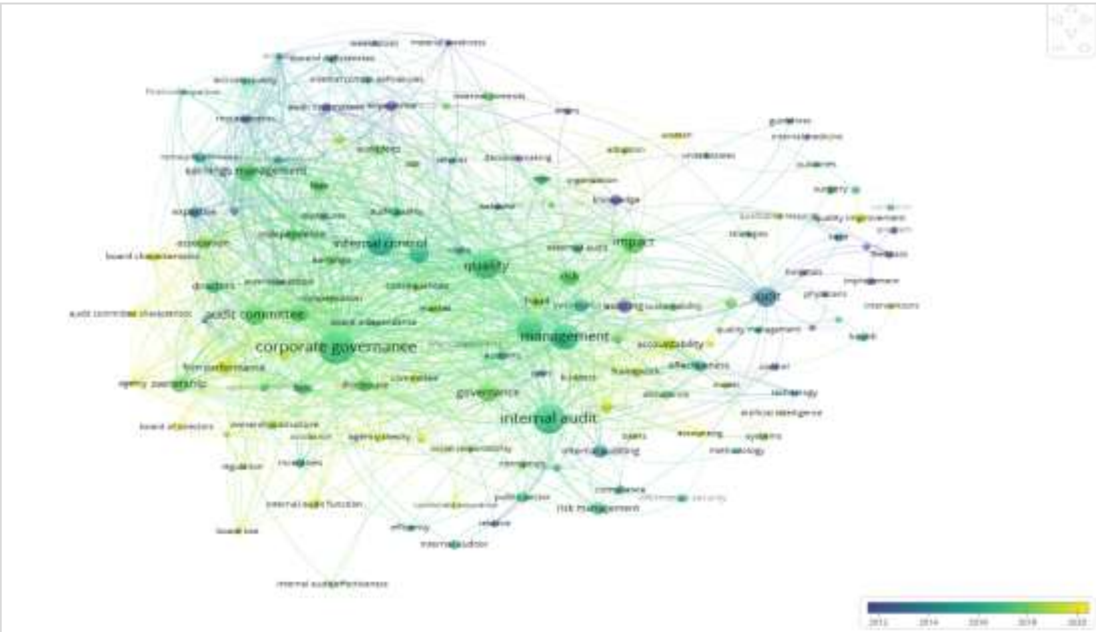

Fig. 3. Keyword connectivity (internal audit effectiveness) by year.
Source: in-house development.

In 2019-2020, the most important topics were adoption, accountability,. firm performance, agency theory, board of directors, board characteristics, framework, business, banks, woman, internal audit function (Figure 3).

In terms of countries that have taken a particular interest in the chosen topic, we note that the United States of America, China, England, Austria and Malaysia are concerned by the size of the node on the map.

Also, the colours present on the map indicate the research directions, so that 8 research directions can be observed, and European Union countries such as Ukraine, Germany, Russia and France are also identified as having the same research direction. Moreover, these countries are closely related according to the degree of interlinkage (Figure 4).

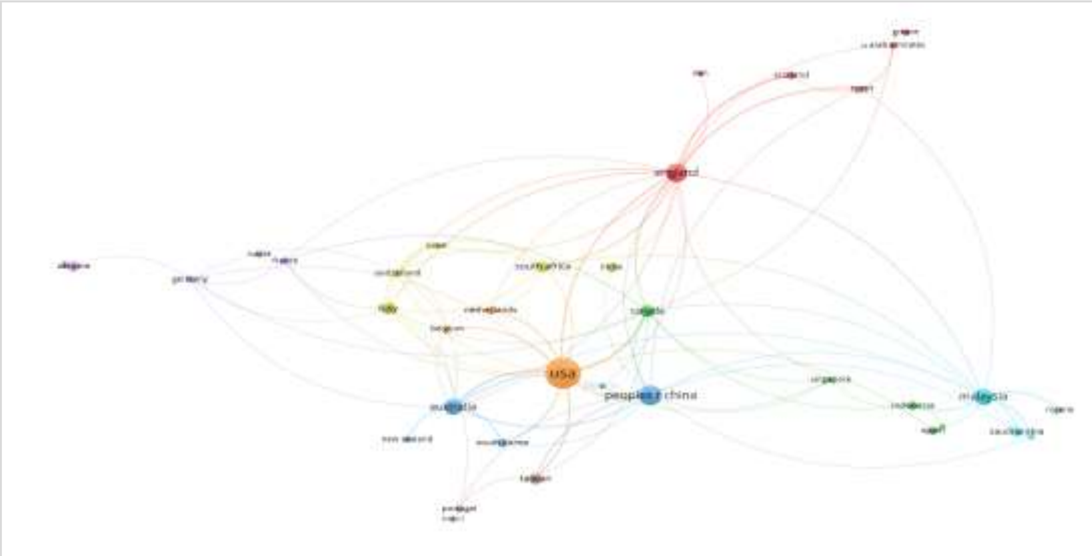

Fig. 4. Graphical representation of the co-authoring countries.
Source: in-house development.

CONCLUSIONS

The bibliometric analysis conducted using the Web of Science database identified 648 scientific papers dedicated to exploring the effectiveness of internal audit. A notable concentration of these papers is found within the fields of business finance and management, emphasizing the significance and extensive application of internal audit within these domains. The primary keywords interconnected with the effectiveness of internal audits include: corporate governance, quality, impact, internal audit, and risk management, highlight the central themes of research in this area. The results also reveal a clustered structure of topics, suggesting the existence of specific sub-areas of interest within internal audit research.

The temporal trends identified indicate a continued interest in topics such as quality, management and corporate governance, with a recent increase in interest in topics such as adoption and firm performance. This suggests an evolution of research from technical and quality issues towards strategic and performance issues.

Geographical analysis reveals a global concern for internal audit effectiveness, with particular interest in the United States, China, England, Austria, and Malaysia.

There is also a tendency for researchers from the same country or region to collaborate, which may indicate the formation of regional research communities or collaborative networks.

REFERENCES

[1]Alles, M., 2015. Drivers of the Use and Facilitators and Obstacles of the Evolution of Big Data by the Audit Profession. Accounting Horizons, 29(2), pp.439-449.

[2]Alles, M., Kogan, A., Vasarhelyi, M.A., 2008. Putting Continuous Auditing Theory into Practice: Lessons from Two Pilot Implementations. Journal of Information Systems, 22(2), pp.195-214.

[3]Appelbaum, D., Kogan, A., Vasarhelyi, M.A. and Yan, Z., 2017. Impact of business analytics and enterprise systems on managerial accounting. International Journal of Accounting Information Systems, 25, pp.29-44.
[4]Arena, M., Azzone, G., 2009, Identifying organizational drivers of internal audit effectiveness. International Journal of Auditing, 13(1), pp.43-60.
[5]Benson, T. (2014). Building good management practices in Ethiopian agricultural cooperatives through regular financial audits. Journal of Co-operative Organization and Management, 2(2), 72-82.
[6]Birkett, W.P., 2006, The History and Development of Internal Auditing. Managerial Auditing Journal, 21(5), pp.505-523. doi: 10.1108/02686900610667009
[7]Cohen, J., Krishnamoorthy, G., Wright, A., 2017, Enterprise Risk Management and the Financial Reporting Process: The Experiences of Audit Committee Members, CFOs, and External Auditors. Contemporary Accounting Research, 34(2), pp.1178-1209.
[8]Forster, M., 2013, Evolution of Internal Audit: From Traditional to Emerging Roles. Journal of Modern Accounting and Auditing, 9(4), pp.487-498.
[9]Golova, E. E., Gapon, M. N., & Baranova, I. V. (2021). Analytical procedures in the audit of finished products in agricultural enterprises. In The Challenge of Sustainability in Agricultural Systems: Volume 2 (pp. 371-377). Cham: Springer International Publishing.
[10]Gramling, A.A., Maletta, M.J., Schneider, A. and Church, B.K., 2004, The role of the internal audit function in corporate governance: A synthesis of the extant internal auditing literature and directions for future research. Journal of Accounting Literature, 23, pp.194.
[11]Jääskeläinen, J., Pellinen, J., 2018, Internal Auditing: A Literature Review and Research Agenda. Journal of Accounting Literature, 40, pp.75-101. doi: 10.1016/j.acclit.2018.01.003
[12]Karapetrovic, S., 2011, Audit strategies vs. QA standardized systems. International Journal of Quality & Reliability Management, 28(1), pp.46-61.
[13]Klychova, G. S., Zakirova, A. R., Kamilova, E. R., 2016, The methodological instruments of social audit in the agricultural companies development. International Business Management, 10(22), 5254-5260.
[14]Matis, D., Vladu, A.B., Robu, I.-B., 2014, Fair Value Accounting and Its Implications for Corporate Governance: a Comparative Analysis. Journal of Economic Surveys.
[15]Mock, T.J., Turner, J.L., 2010, Internal Audit Functions. In: Corporate Governance: A Synthesis of Theory, Research, and Practice, pp.375-398.
[16]Mocuta, D., Spiridon, N., 2013, The audit of reception process, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 13(2), pp.247-250.
[17]Năstase, P., Ionescu, I., 2012, The Role of Internal Audit in Fraud Prevention and Detection. Procedia Economics and Finance, 3, pp.487-493.
[18]Nicola, M.D., Mocuta, D., 2019, Methods to increase efficiency of management and audit instruments to control animal diseases in crisis situations, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 19(2), pp.281-292.
[19]Ruliana, T., Indrawati, A., Febrina Lubis, S., 2017, Audit electronic (e-Audit) to the financial statements, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 17(3), pp.363-367.
[20]Saad, A. A., Das, T. K., Rana, D. S., Sharma, A. R., Bhattacharyya, R., Lal, K., 2016, Energy auditing of a maize–wheat–greengram cropping system under conventional and conservation agriculture in irrigated north-western Indo-Gangetic Plains. Energy, 116, 293-305.
[21]Sarens, G., De Beelde, I., Everaert, P., 2009, Internal Audit: A Comfort Provider to the Audit Committee. The British Accounting Review, 41(2), pp.90-106.
[22]Sawyer, L.B., Dittenhofer, M.A., 2012, Sawyer's Guide for Internal Auditors (6th ed.). The Institute of Internal Auditors Research Foundation.
[23]Sterie, C.M., Tarhini, M., Dumitru, E.A., 2022, Fair Food Trade - Bibliometric Analysis. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(1), 637-641.
[24]Stewart, J., Subramaniam, N., 2010, Internal Audit Independence and Objectivity: Emerging Research Opportunities. Managerial Auditing Journal, 25(4), pp.328-360.
[25]Stoica, G.D., Giuca, A.D., Sterie, C.M., 2022. Digitalization Of Agriculture – A Bibliometric Analysis. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(4), 707-712.
[26]Sysoieva, I., Zagorodniy, A., Pylypenko, L., Tomilin, O., Balaziuk, O., Pohrishchuk, O., 2021, Analysis of potential risks of audit of agricultural enterprises. Agricultural and Resource Economics: International Scientific E-Journal, 7(1), 164-191.
[27]Yang, X., Dai, X., Liu, Z., 2023, Retailers' Audit Strategies for Green Agriculture Based on Dynamic Evolutionary Game. Sustainability, 15(4), 3261.
[28]Zakariyeva, A. U., Serikova, M. A., 2021, Compliance Audit With The Use Of Budget Funds In The Field Of Agriculture.

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CHANGE OF WEEDINESS IN A FIVE-FIELD CROP ROTATION BY MINIMIZING THE MAIN TILLAGE OF THE SOIL AND DIFFERENT LEVELS OF FERTILIZER AND ITS IMPACT ON CROP PRODUCTIVITY

Ivan PRYMAK, Mykola GRABOVSKYI, Yriy FEDORUK, Igor POKOTYLO, Mykola LOZINSKYI, Taras PANCHENKO, Lyudmyla YEZERKOVSKA, Vitalina KARAULNA, Leonid KOZAK, Serhii OBRAZHYI, Nataliia PRYSIAZHNIUK, Nataliia FEDORUK

Bila Tserkva National Agrarian University, Bila Tserkva, Kyiv Region, Ukraine, 8/1, Sobornaya pl., Bila Tserkva, Kyiv region, 09117, Ukraine, Phone/Fax:021/3182411, E-mails: zemlerodstvo_@ukr.net, nikgr1977@gmail.com, fedoruky_4@ukr.net, pokotuloi@ukr.net, lozinskk@ukr.net, panchenko.taras@gmail.com, liudmilabc89@gmail.com, karaulnav@ukr.net, kla59@ukr.net, zemlerodstvo_@ukr.net, natasha.prisjazhnjuk@ukr.net, natalifedoruk44@gmail.com

Corresponding author: nikgr1977@gmail.com

Abstract

This researchwas carried out in a stationary field trial on a typical deep low-humus black soil at the experimental field of Bila Tserkva National Agrarian University. The aim of the research was to assess the productivity of a crop rotation using the main tillage of the soil, which included mouldboard for sunflower (25-27 cm), mouldboardless for corn (25-27 cm) and for soybeans (16-18 cm) and disking for winter wheat, spring barley and white mustard (10-12 cm). The results proved that in this crop rotation the productivity was the highest. Cenotic resistance to weeds was highest in winter wheat and lowest in corn. During the period of the experiment (2012-2021) the potential weediness on unfertilized plots was unchanged and the annual application of 12 tons of manure + $N_{95}P_{82}K_{72}$ *and 16 tons of manure +* $N_{112}P_{100}K_{86}$ *per hectare of crop rotation increased this indicator by 2.4 and 6.0%, respectively. The used for the main cultivation of the soil mouldboardless and disking (continuous shallow) causes the spread of rhizomatous and root rhizomes and the localization weeds and an increase the number of seeds of other species in the upper soil layer (0-10 cm). In the weed component of agrophytocenoses of crop rotation the increases of dicot species under mouldboard tillage and monocots - under mouldboardless tillage. Productivity of crop rotation on fertilized and unfertilized plots is almost at the same level for mouldboard and mouldboard & mouldboardless tillage but it is significantly lower for mouldboardless and disking tillage. The highest efficiency in crop rotation provided by differentiated cultivation with used of 12 tons of manure +* $N_{95}P_{82}K_{72}$.

Key words: *main tillage, fertilizers, soil, weeds, agrophytocenoses, crop rotation, yield, productivity.*

INTRODUCTION

The primary tasks of resource-saving mechanical tillage are weediness control and effective use of soil moisture. The main tillage of the soil is aimed at ensuring its optimal structure and regulating the number of weeds [34, 36]. Tillage, herbicides and weeds-interaction can have definite implications for crop growth and yield [1]. In Ukraine a lot of results scientific research were obtained regarding the influence of mechanical tillage on weediness of agrophytocenoses but these data are quite contradictory [24, 26, 47, 48].

Modern agrarian production for successful operation requires for arable land the development and implementation of a system of complex measures for the gradual reduction of the level of potential soil debris by seeds and bodies of vegetative reproduction of weeds, taking into account the specifics of each field [17].

Weeds are recognized to hold a key role within agroecosystems; they are the greatest contributor to plant diversity, they represent crucial resources for other taxa and they may provide crops with important ecosystem services [27]. Since reducing the intensity of tillage, on the one hand, has a positive effect, but, on the other hand, is associated with a possible undesirable effect on weeds and productivity it is necessary to develop strategies that can combine weed control and conservation tillage [15].

According to Sizov A.I. et al. [43] the main place of accumulation and preservation of weed seeds is the arable layer of the soil. The use of man on arable lands of different systems of the main cultivation of the arable layer promotes the penetration of the weed seeds in different horizons of the soil. Modern arable land, which has been used for growing crops for a long time, has significant reserves of weed seeds in all horizons of the arable layer. Therefore, the use of plowing only partially reduces the reserves of unwanted vegetation - weeds in the upper soil horizons.

Crop rotation such as diversification with legume crops is an alternative strategy to maintain soil quality and crop productivity when compared with monocultural cropping patterns [45]. Long-term field experiments provide reliable information on the sustainability of agriculture, where large amounts of fertilizer are used each year. Also, soil microbial properties and crop yields depend on time and the influence of plant diversity [49].

Farming systems have different effects on soil physical properties and crop yields [37]. A conservation tillage system is thought to have more weed problems due to their higher number of seedlings [4]. Therefore, it is needed to adopt such practices, which help to eliminate or at least reduce the weed problem in conservation agriculture.

A direct relationship has been established between the duration of rotation and the productivity of crop rotation: the shorter the rotation period than lower the yield of agricultural crops. This especially applies to 2-3 field crop rotations [5]. In such crop rotations with a share of grain crops of 70-100%, continuous shallow and sometimes No-till is quite often used. Annual use of herbicides with the same active ingredient causes resistance in weeds. As a result of many years of activity in the arable land of our country in the arable layer of soil, significant reserves of seeds and organs of vegetative reproduction of weeds of various species have been formed. The size of such depot is an important indicator of the level of agronomic culture of farming in regions or specific farms and fields [19].

The level of potential littering of arable land by seeds and organs of vegetative reproduction of weeds (0-30 cm) in the main soil-climatic zones is very high and makes up from 114 thousand pcs./m^2 (Steppe zone) to 171 thousand pcs./m^2 (Forest-steppe zone). Virtually all soil-climatic zones are present on arable lands and form the most important parts in the structure of the stock of seeds in the soil, the representatives of the botanical families of Chenopodeaceae 51.8-62.7%, Amaranthaceae 12.8-21.6%, Poaceae 6.4-11.2%, Polygonaceae 4.5-5.3%, Brassicaceae 1.6-6.2%, Asteraceae 1.1-2.6%. The average indices of the ability of ground-weed seeds of weeds of different species to germination are: Polissya zone – 7.7%, Forest-steppe zone – 8.2%, Steppe zone – 5.9%. On arable land are able to germinate on average: Polissya - 1,887 sq/m^2, Forest-step - 4,674 sq/m^2, Steppe – 2,242 sq/m^2 [17, 18].

According to forecasts, the average annual air temperature in Ukraine will increase by 0.4°C every ten years, which will cause an increase in the frequency of droughts. Aridization of the climate exacerbates the problem of water supply for agrophytocenoses. As a result of these negative climate changes, the area of very dry and dry zones of Ukraine increased by 7% and covers more than 29.5% of the territory or 11.6 million (37%) of arable land [3].

It was found that in the Right Bank Forest-Steppe of Ukraine, weediness of agrophytocenoses in short crop rotation was practically the same for plowing and mouldboardless and for shallow tillage it was 6-25% higher. Therefore, it is recommended to carry out shallow tillage (10-12 cm) with simultaneous slitting to a depth of 40 cm [21].

In the tillering phase of winter wheat and spring barley, mouldboard-mouldboardless tillage had the advantage of arable layer moistening. When sowing white mustard, the most moisturized soil layers were under differentiated tillage, the least moisturized – under mouldboardless tillage [32].

Research in the fight against weeds has been aimed at increasing the effectiveness of herbicides or replacing them with other measures, such as, for example, mechanical control. To increase the sustainability of agricultural systems, a paradigm shift in the control of segetal plants is necessary: from a single tactic and approach to a comprehensive control of weeds in crops [40].

According to the results of field experiments at the Sumy Agrarian University, it was established that green manure made from oilseed radish significantly decreased weed infestations and weed weight, especially of early weeds and winter weeds. The method of tillage had a greater influence on the weed infestation-34 and 46% compared with the application of green manure-29 and 39%. The sweep ploughing at a depth of 28-30 cm with green manure application reduces the effect of potato overgrowth with weeds and helps to get the largest crop yield-up to 30.3 t ha^{-1} [25].

Weediness of agrophytocenoses of grain-row crop rotation under direct sowing was 57% higher than under ploughing. At the same time, in the first year of using direct-seeding, this indicator was at the level of plowing, and in the third crop of the crop rotation, it exceeded the control by 50% [8]. A significant decrease in yield under direct-seeding was noted in corn in the third year of crop rotation, in winter wheat - in the fourth year, sunflower and spring barley - in the fifth year [9].

Integrating preventive and interventional methods of weed control remains essential in managing weed communities in direct-seeding of rice to prohibit the evolution of herbicide resistance and to maximize the relative contributions of individual components where herbicides are not widely used. There remains a need to further develop understanding of the mechanisms and dynamics of rice weed competition and of the community dynamics of weed populations in direct-seeding of rice to underpin sustainable weed management practices [38].

In terms of seeds as a source for weeds, the change in primary tillage means a change in depth where weed seeds are shifted or not to deep layers by tillage operations [39]. Considering the ability of most types of weeds to germinate from a depth of up to 5 cm, and some types up to 10 cm, surface treatment only ensures reliable storage of their seeds in the soil. Such processing stimulates the germination of weed seeds and, first of all, annual species [18]. Seeds with a comparatively low dormancy and seed persistence for instance of graminoid weeds or volunteers would not survive for a longer period [13].

Previous studies have established that the highest yields of winter wheat, soybeans and corn obtained with mouldboard tillage, and spring barley and sunflower with mouldboardless tillage in crop rotation. Under disc and systematic mouldboardless tillage in crop rotation the yield of all crops decreased significantly and with an increase in the rates of mineral fertilizers the difference between the control and these tillage options grew [30, 31].

With zero tillage in the rotation of fallow-wheat or mungbean-wheat more spread of weeds was observed (total dry biomass of weeds 72.4-109.6 and 105.6-112.1 g/m^{-2} in the first and second year respectively). On the contrary, disturbed soils (deep tillage, bed sowing and conventional tillage) in any of the crop rotations had lower weed infestation (weed biomass 0.4–7.1 and 1.1–5.4 g/m^{-2} in the first and second year, respectively). The sorghum-wheat rotation had a strong suppressing effect on weediness in all tillage systems. At the same time, the effect of the crop rotation factor was more noticeable in the second year of the experiment [41].

In Ukraine 13 million hectares of arable land are technologically suitable for minimal tillage and 5.5 million hectares can be used for No-till [33]. During the transition from the traditional tillage technology to the No-till system an increase in weediness of agrophytocenoses was noted, especially in the first 3-4 years of its implementation [28].

No-tillage reduced weed density and dry biomass and resulted more grain yield even in weedy control relative to the rest of the tillage practices. Highest grain yield (4.52 t ha^{-1}) was obtained with label herbicide dose followed by its 50% reduced dose tank mixed with Sorgaab (4.28 t ha^{-1}) under zero tillage system [20].

Some scientists note the deterioration of the phytosanitary condition and agrophysical properties of the soil (density, hardness, water permeability) under No-till systems [16]. They note that the transition period from direct sowing to the No-till system should be up to four years and the system itself originates from the creation of a 3-4 cm layer of plant residues on the surface of the field [6]. The application of mulching allows you to regulate the density of weeds in agrophytocenoses under No-till systems. To control the growth of annual and perennial weed species the layer of straw mulch should be more than 5 cm [17].

According to other data No-till can help weed management because weed seeds do not survive as long lying on the soil surface compared with burial in soil. Integrating no-till with diverse crop rotations has enabled producers in the semiarid steppe of the USA to manage weeds with 50% less cost compared to tilled rotations with less crop diversity [2].

Crop rotation diversification can be achieved through perennial and cover crops and no-till practices which may be an effective strategy for increasing soil carbon and nitrogen storage in the long-term, but uncertainty remains regarding the relationship between crop performance and health soil. Crop rotation diversification increases surface soil organic carbon sequestration, soil microbial activity and long-term crop productivity [7].

According to the results of the conducted research under rainfed Mediterranean conditions it is established that wheat yield was greater with conventional tillage than with no tillage. Wheat yield showed no additional response to N fertilizer rates above 100 kg ha^{-1}. N use efficiency and N uptake efficiency were greater with conventional tillage than with no tillage [23].

The response of wheat to fertilizer N rates in drought years (with rainfall below 450 mm in the growing season) to be low or nonexistent. However, wheat responded to N fertilizer in years where rainfall during the vegetative growth period exceeded 500 mm, but the response depended on the rotation. Under these conditions a small N rate (50 kg N ha^{-1}) could be used at seeding, and additional N fertilizer could be applied as a top dressing at the end of tillering or the beginning of stem elongation depending on the winter rainfall [22].

Nutrient availability and plant diversity are two important factors determining crop productivity in agricultural ecosystems. Long-term inorganic or organic fertilization significantly increased soil total N by 27% – 77% and crop yield by 237%–419% and decreased soil pH by an average of 0.4 units when compared with non-fertilized control [50].

The application of fertilizers significantly increased the productivity of agricultural crops and also influenced the structure of soil bacterial and fungal communities. The application of mineral fertilizers together with manure can reduce the influence of environmental factors on the structure of the soil bacterial community, mineral fertilizer alone or the application of wheat straw in combination with mineral fertilizers [14].

The use of macronutrients (NPK) leads to an increase in maize fresh mass productivity by 11.4-21.0%, DM productivity by 11.4-17.0% and an increase in CH_4 output potential by 11.2-30.9%, compared to options without their application [10]. It is recommended to cultivate compatible crops of corn and sweet sorghum against the background of $N_{120}P_{80}K_{80}$ and mouldboard [11].

In accordance, Soon Y. K. & Clayton G. W. [44] no influence of the interaction of tillage with crop rotation on changes in wheat productivity or grain quality indicators.

Tillage treatments also did not affect the yield of other crops in the crop rotation and the concentration of nutrients. During the second cycle of crop rotation the yield of wheat was 22% higher under no-tillage compared to conventional tillage and N fertilizer requirement decreased.

The purpose of the research was to establish the influence of the main tillage and fertilizer systems on the yield of crops and the productivity of grain-row crop rotation.

MATERIALS AND METHODS

The research was carried out on the experimental field of the Bila Tserkva National Agrarian University on a typical deep, low-humus, medium-loam black soil during 2012-2021 in a stationary five field crop rotation, where four systems of basic tillage (Table 1) and four fertilizer systems were studied: 0 - without fertilizers, 1 - 8 t/ha of manure + $N_{76}P_{64}K_{57}$, 2 - 12 t/ha of manure + $N_{95}P_{82}K_{72}$, 3 – 16 t/ha of manure + $N_{112}P_{100}K_{86}$.

Crop rotation fields were fully deployed in space and time. The experiment options were replicated three times, the plots of the first order (tillage system) were placed sequentially in one tier, and the plots of the second (fertilizer doses) were sequentially placed in four tiers.

Table 1. Systems of basic tillage in crop rotation

№ field	Crop	Tillage*			
		mouldboard (control)	mouldboardless	mouldboard & mouldboardless (differentiated)	disking (continuous shallow)
		Depth (cm) and cultivation			
1	Soybean	16-18 (p.)	16-18 (d.t.)	16-18 (r)	10-12 (d.h.)
2	Winter wheat + white mustard on green manure	10-12 (d.h.)	10-12 (d.t.)	10-12 (d.h.)	10-12 (d.h.)
3	Sunflower	25-27 (p.)	25-27 (d.t.)	25-27 (p.)	10-12 (d.h.)
4	Spring barley + white mustard on green manure	10-12 (d.h.)	10-12 (d.t.)	10-12 (d.h.)	10-12 (d.h.)
5	Maize	25-27 (p.)	25-27 (d.t.)	25-27 (d.t.)	10-12 (d.h.)

*Note: p. – plowing, d.h. – disc harrow, d.t. – deep tiller.
Source: Authors own results.

The sown area of the elementary plot was 171 m^2 (9 x 19 m) and the accounting area was 112 m^2 (7 x 16 m). The area under the experiment was 3.7 ha.

Cattle manure, ammonium nitrate, simple granulated superphosphate, and potassium salt were used as fertilizers. Weediness on the date of harvesting of crops was determined: actual by the quantitative-weight method, and potential by the method of washing soil samples on sieves with a hole diameter of 0.25 mm (Kalentyev method) [29].

RESULTS AND DISCUSSIONS

The highest weediness of soybean agrophytocenoses was under disk cultivation (continuous shallow). The actual and potential weediness with was under mouldboard 84 pcs./m^2 and 88.7 million pcs./ha, mouldboardless – 143.0 and 117.4, mouldboard & mouldboardless (differentiated) – 77.0 and 76.3, disking (continuous shallow) – 98 pcs./m^2 and 98.7 million pcs./ha for crop rotation (Table 2). These indicators of weediness are higher for mouldboardless by 70.2 and 32.4%, disking – 16.7 and 11.3%, and lower for mouldboard & mouldboardless by 8.3 and 14.0% than for the control (mouldboard). The raw mass of weeds under mouldboardless and disking is 1.5 times higher than the control and under differentiated (mouldboard & mouldboardless) 24.3% less. Although the raw mass of weeds is almost at the same level for tillage with a mouldboardless and a disking, both actual and potential weediness are higher by 46.8 and 19.4%, respectively, for the second than for the fourth tillage option.

The actual and potential weediness of winter wheat was 52 pcs./m^2 and 100.6 million pcs./ha under mouldboard in crop rotation, mouldboardless – 89 and 127.7, mouldboard & mouldboardless – 47 and 86.0, continuous shallow – 66 pcs./m^2 and 109.2 million pcs./ha. When tilling the soil with a mouldboardless and disking the actual weediness was 74.0 and 28.0% and the potential weediness is 27.5% and 8.7% higher compared to the control. These indicators are, respectively, 10.0 and 8.7% lower for differentiated than mouldboard tillage. The highest number of weeds in winter wheat crops was under continuous shallow – 199.1 g/m^2, which is 80.2; 23.6 and 105.6 g/m^2 more than, respectively, for the first, second and third variants of tillage. This indicator for mouldboardless and disking tillage exceeded the control by 48.5 and 68.7%, respectively and for mouldboard & mouldboardless tillage it was inferior to it by 21.8%.

In the agrophytocenoses of sunflower the lowest number of weeds was obtained under mouldboard & mouldboardless tillage, the indicators of actual, potential weediness and the raw mass of weeds were 69.0 pcs./m^2, 97.3 million pcs./ha and 141.8 g/m^2, which by 11.8, 11.9% and 24.6% less compared to the control.

For soil cultivation with a disk harrow (continuous shallow) these indicators were 1.26, 1.23 and 1.49 and a mouldboardless tillage – 1.61, 1.41 and 1.55 times higher than in the control options.

Table 2. Weediness of agrophytocenoses of crop rotation under different systems of main tillage and fertilization (2017-2021)

Cultures of crop rotation	Fertilizer levels in crop rotation	Potential weediness of arable (0-30 cm) soil layer, million pcs/ha				Actual weediness of agrophytocenoses							
						pcs./m^2				raw mass, g/m^2			
		The main tillage in crop rotation											
		1	2	3	4	1	2	3	4	1	2	3	4
Soybean	0	94.3	122.4	81.0	104.0	87	150	81	102	193.2	295.9	171.2	285.1
	1	90.6	118.9	77.9	100.5	85	139	78	99	185.2	277.4	169.7	273.9
	2	85.9	115.8	74.3	96.4	82	135	76	96	179.0	269.1	163.9	266.8
	3	84.1	112.5	72.0	93.8	78	128	73	94	168.7	260.3	157.0	259.6
Winter wheat	0	105.5	138.9	90.7	114.4	55	87	51	71	118.0	174.1	92.5	200.6
	1	101.9	131.9	87.4	109.8	52	92	48	67	119.8	175.4	93.9	200.8
	2	99.1	122.5	83.9	107.1	50	75	46	63	119.5	176.7	93.8	198.5
	3	95.7	117.5	81.8	105.5	48	70	42	60	118.1	175.6	93.5	196.5
Sunflower	0	105.2	139.5	91.7	122.2	68	108	64	81	177.1	275.4	161.6	267.1
	1	109.2	148.4	97.0	130.2	79	120	72	95	188.1	289.4	162.5	278.3
	2	110.6	157.2	98.4	138.5	81	129	78	102	190.3	293.5	164.8	280.6
	3	115.5	171.9	101.9	147.8	84	137	81	115	194.2	295.9	168.2	284.1
Spring barley	0	99.5	127.2	84.7	120.1	65	99	61	80	154.8	239.4	128.2	245.6
	1	95.2	124.3	80.1	110.1	61	93	58	76	139.2	213.2	114.3	230.9
	2	92.0	120.1	75.8	105.6	58	88	54	71	132.5	197.2	106.6	222.8
	3	88.9	116.2	71.8	102.1	56	82	52	70	127.3	186.1	101.8	218.6
Corn	0	106.3	135.9	91.6	106.6	94	142	85	110	300.1	530.2	280.8	392.4
	1	119.5	148.0	104.2	119.2	107	154	98	122	311.0	504.8	298.5	394.0
	2	134.3	160.7	116.4	131.6	121	164	112	133	318.2	475.7	297.0	402.5
	3	149.9	176.9	132.4	147.5	129	170	122	140	322.3	458.7	277.5	410.5
SD_{05}	A	8.3				12.0				30.0			
	B	8.9				9.0				17.4			
	AB	8.6				10.0				23.2			

Source: Authors own results.

In the agrophytocenoses of spring barley the indicators of actual, potential weediness and the raw mass of weeds were for mouldboard tillage 60 pcs./m^2, 93.9 million pcs./ha and 138.5 g/m^2, mouldboardless tillage – 101.0, 122.0 and 209.0, differentiated tillage – 58, 78.1 and 112.8, continuous shallow tillage – 74 pcs./m^2, 109.5 million pcs./ha and 229.5 g/m^2. They were the lowest in plots of mouldboard & mouldboardless tillage, which was 96.6, 82.8 and 81.1% less than the control. Actual and potential weediness were the mouldboardless tillage which is higher than the control by 70.7 and 30.6%. Raw weed mass was 166.8% greater in disking compared to mouldboard tillage.

In the agrophytocenoses of corn for the first, second, third and fourth tillage options actual weediness was 113.0, 163.0, 104.0 and 126.0 pcs./m^2, potential – 127.5, 155.2, 111.2 and 126.2 million pcs./ha, and the raw mass of weeds – 312.9, 492.4, 271.9 and 399.0 g/m^2.

The number and raw mass of weeds for disking were higher by 11.2 and 28.0% compared to the control. The lowest indicators of active, potential weediness and raw mass of weeds were under differentiated tillage, which is 8.1, 13.0 and 13.2% less than mouldboard.

In the crop rotation for the first, second, third and fourth tillage variants, the actual weediness was 77, 124, 71 and 92 pcs./m^2 the potential weediness was 104.3, 135.3, 96.1 and 115.7 million pcs./ha and the raw mass of weeds – 187.8, 288.2, 151.6 and 275.5 g/m^2. Of the four systems of basic tillage in crop rotation the highest anti-weed efficiency is characteristic of differentiated tillage, for which the above-mentioned indicators are respectively 7.8, 7.9 and 19.3% less, compared to the control options.

It was established that mouldboard and mouldboardless tillage have different effects on soil fertility. Therefore, it is important to more effectively use their positive influence on the soil and agrophytocenoses, reducing their negative effect [35].

The long-term experimental data obtained by us in a stationary field experiment confirm the conclusion of other scientists that the highest anti-weed efficiency can be achieved with differentiated main tillage, which includes plowing once every 4-5 years and in the rest of the time period various depths mouldboardless and disking tillage. Such a system of main tillage ensures not only the natural destruction of weed seeds but also increases biological activity and improves the nutrient regime of the soil [26, 42].

With the increase in fertilizer rates, there was a decrease in soil weediness in crops soybean, winter wheat, and spring barley and an increase in crops corn and sunflower, which is associated with the application of manure to these crops. The application of the maximum rate of fertilizers ensured a decrease in weediness of crops winter wheat, soybeans and spring barley by an average of 6, 10 and 12% and an increase in crops of sunflower and corn by 18 and 37%, compared to unfertilized options.

Actual weediness in agrophytocenoses of sunflower and corn increased by 25 and 27 % when applying the highest rate of fertilizers (16 t/ha of manure +$N_{112}P_{100}K_{86}$), compared to unfertilized options. In the agrophytocenoses of soybean, winter wheat and spring barley crops the opposite trend was observed: in the unfertilized variants this indicator was in crops soybean 105 pcs./m^2, in crops winter wheat – 66 and in crops spring barley – 76 pcs./m^2 and at the plots with maximum rate of fertilizers – 93.3, 65.5 and 65.0 pcs./m^2.

The raw mass of weeds during the harvesting period of winter wheat was almost at the same level in both fertilized and unfertilized variants (146-148 g/m^2). Before harvesting soybeans and spring barley this indicator on unfertilized plots was 237 and 192 g/m^2, while the maximum level of fertilization was 217 and 172 g/m^2. In the agrophytocenoses of sunflower the raw mass of weeds on the unfertilized variants was 220 g/m^2 and on the plots with the maximum rate of fertilizers – 235 g/m^2. In the agrophytocenoses of corn there were no changes in the raw mass of weeds depending of the fertilizer.

The average indicators of actual and potential weediness and raw mass of weeds by crop rotation were in soybean 100 pcs./m^2, 95 million pcs./ha and 217 g/m^2, winter wheat – 64, 106 and 199, sunflower – 92 , 124 and 278, spring barley – 73, 101 and 230, corn – 127 pcs./m^2, 130 million pcs./ha and 400 g/m^2.

Due to the well-developed root system and leaf surface, sunflower shades the soil and has a high competitiveness against weeds, in contrast to corn, which grows slowly in the initial growing period. In terms of cenotic resistance to weeds corn is significantly inferior to winter wheat, which is confirmed by the results of experiments and other scientists [46].

In our research, the number of weeds and their raw mass had the lowest indicators in the agrophytocenoses of winter wheat, while in crops soybean they were 1.56 and 1.09 times higher, in crops sunflower – 1.44 and 1.40, in crops spring barley – 1.14 and 1.16, in crops corn at 1.98 and 2.01.

Table 3. Change in weediness during two rotations of crop rotation under different systems of main tillage and fertilization (2011-2021)

The main tillage in crop rotation	Fertilizer levels in crop rotation			
	without fertilizers	8 t/ha of manure + $N_{76}P_{64}K_{57}$	12 t/ha of manure + $N_{95}P_{82}K_{72}$	16 t/ha of manure + $N_{112}P_{100}K_{86}$
Potential weediness of the arable soil layer in August 2011, million pcs/ha				
mouldboard (control)	103.3	104.0	103.6	103.8
mouldboardless (chisel)	105.0	102.8	102.7	104.6
mouldboard &mouldboardless (differentiated)	104.0	103.6	104.3	102.2
disking (continuous shallow)	102.5	105.2	105.2	102.9
Potential weediness of the arable soil layer in August 2021, million pcs/ha				
mouldboard (control)	95.0	96.7	98.5	101.5
mouldboardless (chisel)	123.3	125.5	127.0	129.5
mouldboard &mouldboardless (differentiated)	86.2	88.0	91.0	92.6
disking (continuous shallow)	110.1	112.6	114.6	116.7
Actual weediness in July 2012, pcs./m^2				
mouldboard (control)	85.0	107.0	123.0	135.0
mouldboardless (chisel)	94.0	129.0	162.0	194.0
mouldboard &mouldboardless (differentiated)	80.0	97.0	108.0	114.0
disking (continuous shallow)	90.0	117.0	138.0	156.0
Actual weediness in July 2021, pcs./ m^2				
mouldboard (control)	70.0	74.0	76.0	78.0
mouldboardless (chisel)	110.0	118.0	124.0	132.0
mouldboard &mouldboardless (differentiated)	65.0	68.0	69.0	70.0
disking (continuous shallow)	83.0	92.0	98.0	103.0
Raw mass of weeds in July 2012, g/m^2				
mouldboard (control)	270.5	326.2	352.5	366.5
mouldboardless (chisel)	328.5	438.6	516.2	604.4
mouldboard &mouldboardless (differentiated)	257.1	301.7	314.0	319.9
disking (continuous shallow)	331.0	419.2	466.3	506.6
Raw mass of weeds in July 2021, g/m2				
mouldboard (control)	214.5	219.2	211.2	209.6
mouldboardless (chisel)	359.8	375.1	370.4	383.6
mouldboard &mouldboardless (differentiated)	191.3	193.9	184.1	179.0
disking (continuous shallow)	307.9	333.6	337.5	345.3

Source: Authors own results.

In 2011, on average, according to the experiment, the potential weediness of the arable layer was 105 million pcs./ha, varying from 103.5 to 104.0 million pcs./ha according to the tillage options (Table 3). At the end of the second crop rotation the potential weediness increased by 3.1% and amounted to 106.9 million pcs./ha and the difference between the tillage options was insignificant.

In 2021 the number of weed seeds in the arable layer of the soil decreased by 6 and 14 million pcs./ha (6 and 13%) under mouldboard and mouldboard & mouldboardless tillage. This indicator increased by 23 and 10 million pcs./ha (22 and 9%) when the soil was cultivated with a mouldboardless and a disking tillage.

In 2021 the potential weediness of the arable soil layer under mouldboardless and continuous shallow (disking) tillage increased by 29 and 16%, respectively and under differentiated tillage it decreased by almost 9%, compared to mouldboard tillage.

Over ten years of research on crop rotation this indicator increased by 3 million pcs./ha (3%).

In 2011 significant differences were observed in the number and mass of weeds in agrophytocenoses of crop rotation under different tillage systems. Thus, these indicators for mouldboardless and disking tillage were 145 and 125 pcs./m^2, 472 and 431 g/m^2 which exceeded the control by 28 and 11% and 43 and 31%, respectively. The number and raw mass of weeds decreased in 2021 compared to 2012 for mouldboard tillage by 33 and 35%, mouldboardless by 16 and 21, differentiated by 32 and disking tillage by 37 and 23% and in general by crop rotation by 26 and 28%.

Similar research results were obtained at the Institute of Agriculture of the Steppe Zone of Ukraine the number of weeds decreased the most when using plowing (25-27 cm) compared to mouldboardless tillage (25-27 and 10-12 cm) [46].

In 2021 the number and mass of weeds using mouldboard tillage amounted to 75 pcs./m^2 and 213 g/m^2, mouldboardless – 121 and 372, mouldboard & mouldboardless – 68 and 187, disking tillage – 94 pcs./m^2 and 331 g/m^2. Thus the increase in the number and raw mass of weeds when using a mouldboardless tillage was 60 and 73%, and with a disking tillage – 25 and 54%, respectively. When using the mouldboard & mouldboardless tillage these indicators decreased by 9 and 12%, compared to the control. On average the number of weeds decreased by 26% and their weight by 3% during the two crop rotation periods.

The application in 2021 of the first, second and third rates of fertilizers caused an increase in the number of weeds by 7, 12 and 17%, compared to unfertilized plots.

Over the ten-year period of research the potential weediness on unfertilized variants did not change and with the used of fertilizers it increased by an average of 4.8%.

With mouldboard tillage weed seeds in the plow layer are distributed more evenly than with other variants of the main soil tillage. Thus, in 2021, after plowing the green mass of white mustard (predecessor - winter wheat) into the soil, weed seeds were distributed in the soil layers of 0-10, 10-20 and 20-30 cm for mouldboard tillage – 39, 34 and 27%, mouldboardless – 67, 23 and 10%, mouldboard & mouldboardless – 49, 31 and 20%, disking tillage – 78, 17 and 5%. This indicates a well-defined localization of weed seeds in the upper layer of the soil after cultivation with a deep mouldboardless and a disk harrow tillage. Cultivation of the soil with these tools caused an increase in the number of perennial weed species, such as Cirsium arvense L., Convolvulus arvensis and Elymus repens L.

In the destruction of annual weeds and Cirsium arvense L. the double-layer plough was not inferior to the deep plough and is suitable for controlling weeds in organic farming. Shallow cultivation of stubble after harvest can significantly contribute to weed control in organic farming, in particular by reducing Cirsium arvense L. If there are no perennial weeds and the main tillage is done by soil inversion an omission of stubble tillage can be taken into consideration [12].

The yield of dry matter at the zero, first, second and third levels of fertilization in the crop rotation was under mouldboard tillage 2.12, 3.57, 4.64 and 5.66 t/ha; mouldboardless – 1.80, 3.14, 4.14 and 5.09; mouldboard & mouldboardless – 2.11, 3.54, 4.58 and 5.59; for continuous shallow (disking) tillage – 1.80, 3.15, 4.14 and 5.10 t/ha (Fig.1).

Without taking into account the straw of cereal grain crops the collection of fodder units was under mouldboard tillage 2.97, 5.00, 6.46 and 7.87 t/ha; mouldboardless – 2.54, 4.42, 5.77 and 7.09 t/ha; differentiated (mouldboard & mouldboardless) – 2.94, 4.92, 6.35 and 7.74; disking tillage – 2.55, 4.43, 5.79 and 7.11 t/ha, respectively at four levels of fertilization in crop rotation.

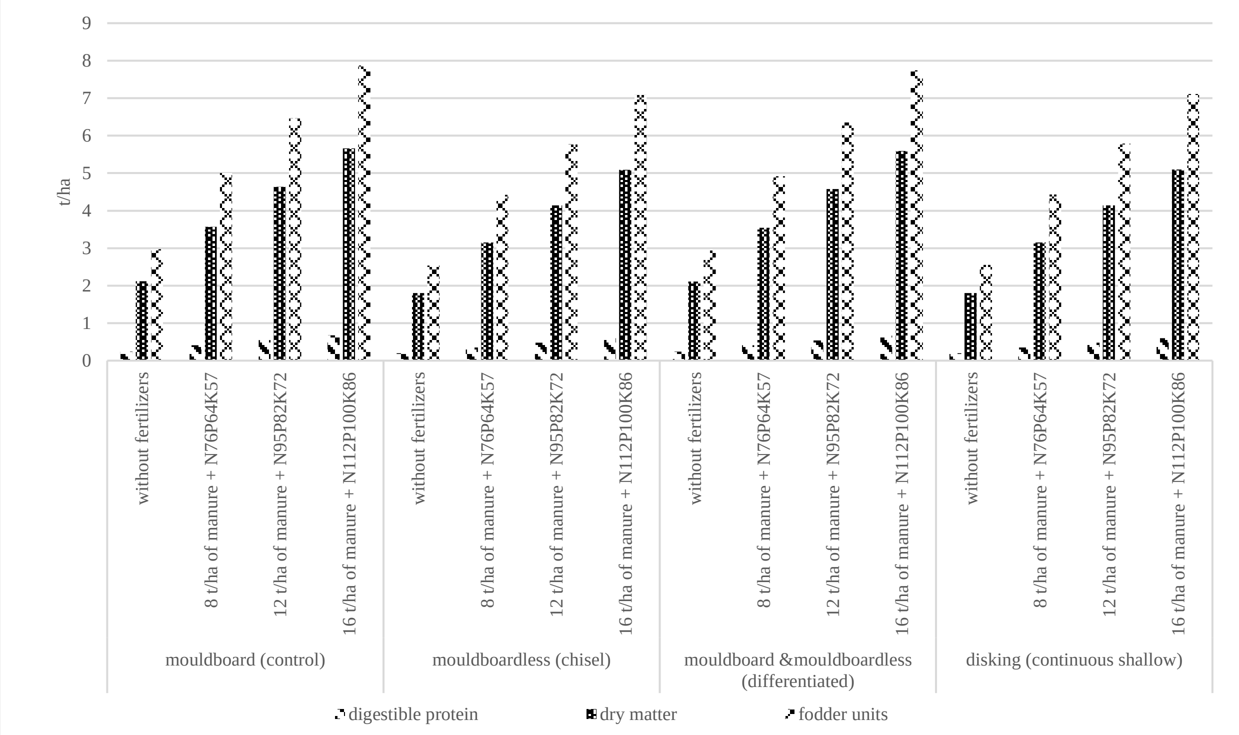

Fig. 1. Productivity of crop rotation under different systems of main tillage and fertilization (average for 2012-2021), t/ha
Source: Authors own results.

The collection of digestible protein was under mouldboard tillage 0.237, 0.409, 0.546 and 0.675 t/ha; chisel (mouldboardless) – 0.194, 0.354, 0.478 and 0.577 t/ha; mouldboard & mouldboardless – 0.237, 0.407, 0.542 and 0.669 t/ha; disking tillage – 0.195; 0.354; 0.481 and 0.599 t/ha (SD_{05}=0.033 t/ha).

CONCLUSIONS

The use for the main cultivation of the soil mouldboardless and disking tillage affects the appearance and spread in the crop rotation of rhizomatous and root rhizomes weeds (*Cirsium arvense L., Convolvulus arvensis*) and an increase the number of seeds of other species in the upper soil layer (0-10 cm). Cenotic resistance to weeds was highest in winter wheat and the lowest in corn. In the weed component of agrophytocenoses of crop rotation the increases of dicot species under mouldboard tillage and monocots under mouldboardless tillage. The minimum mass and number of weeds in the crop rotation was under differentiated tillage. At the same time, the actual and potential weediness was 8%, and the raw mass of weeds was 18% less, compared to the control. On unfertilized plots, potential weediness did not change, and the application of 12 tons of manure + $N_{95}P_{82}K_{72}$ and 16 tons of manure + $N_{112}P_{100}K_{86}$ per hectare of crop rotation contributed to the growth of this indicator by 2.4 and 6.0%.

Productivity of crop rotation on fertilized and unfertilized plots is almost at the same level for mouldboard and mouldboard & mouldboardless tillage but it is significantly lower for mouldboardless and disking tillage. The highest efficiency in crop rotation provided by differentiated cultivation with used of 12 tons of manure + $N_{95}P_{82}K_{72}$.

REFERENCES

[1]Acciaresi, H.A., Balbi, H.V., Bravo, M.L., Chidichimo, H.O., 2003, Response of weed populations to tillage, reduced herbicide and fertilizer rates in wheat (*Triticum aestivum*) production. Planta Daninha, 21, 105-110.

[2]Anderson, R. L., 2010, Weed community response to no-till in North America. Quarantine and Protection of Plants, 12, 345-357.

[3]Balyuk, S. A., Vorotyntseva, L. I., Zakharova, M. A., Drozd, O. M., Nosonenko, O. A., 2017, Protection and reproduction of the resource potential of soils under conditions of climate change. Bulletin of Agrarian Science, 12, 10-13 [in Ukrainian]

[4]Barberi, P., Lo Cascio, B., 2001, Long-term tillage and crop rotation effects on weed seedbank size and composition. Weed research, 41(4), 325-340.

[5]Boyko, P. I., Litvinov, D. V., Demydenko, O. V., Shapoval, I. S., Kovalenko, N. P., 2016, Productivity of agricultural crops in multi-rotational crop rotations on typical chernozems. Bulletin of Agrarian Science, 12, 11-14 [in Ukrainian]

[6]Bulygin, S. Yu., Vitvitskyi, S. V., Antonyuk, D. O., 2019, Direct sowing - No-till: agrophysical examination of the transition stage. Bulletin of Agrarian Science, 6, 13-20 [in Ukrainian].

[7] Chahal, I., Hooker, D. C., Deen, B., Janovicek, K., Van Eerd, L. L., 2021, Long-term effects of crop rotation, tillage, and fertilizer nitrogen on soil health indicators and crop productivity in a temperate climate. Soil and Tillage Research, 213, 105121.

[8]Cheryachukin, M. I., Grigor'eva, O. M., 2019, Effectiveness of direct seeding on chernozem of ordinary heavy loam of the Right Bank Steppe. Bulletin of Agrarian Science, 10, 5-11 [in Ukrainian]

[9]Grabak, N. Kh., 2003, Improvement of soil cultivation in the Steppe. Bulletin of Agrarian Science, 3, 12-14 [in Ukrainian]

[10]Grabovskyi, M., Kucheruk, P., Pavlichenko, K., Roubík, H., 2023, Influence of macronutrients and micronutrients on maize hybrids for biogas production. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-023-27235-3

[11]Grabovskyi, M., Lozinskyi, M., Grabovska, T., Roubík H., 2023, Green mass to biogas in Ukraine – bioenergy potential of corn and sweet sorghum. Biomass Conversion and Biorefinery, 13, 3309–3317.

[12]Gruber, S., Claupein, W., 2009, Effect of tillage intensity on weed infestation in organic farming. Soil and Tillage Research, 105(1), 104-111.

[13]Gruber, S., Carola, C., 2005, Life cycle and potential gene flow of volunteer oilseed rape in different tillage systems. Weed Research, 45, 83-93.

[14]Guo, Z., Wan, S., Hua, K., Yin, Y., Chu, H., Wang, D., Guo, X., 2020, Fertilization regime has a greater effect on soil microbial community structure than crop rotation and growth stage in an agroecosystem. Applied Soil Ecology, 149, 103510.

[15]Herencia, J.F., 2015, Enzymatic activities under different cover crop management in a Mediterranean olive orchard. Biological Agriculture & Horticulture, 31:1, 45-52.

[16]Ilchenko, V. Yu., Ponomarenko, N. O., Ponomarenko, R. G., Butenko, D. M., 2013, Advantages and disadvantages of the No-till system. Design, production and operation of agricultural machines, 2(43), 101-108 [in Ukrainian].

[17]Ivaschenko, O., Remeniuk, S., 2018, Problems of potential weediness of soil in Ukraine. Bulletin of agricultural science, 8, 58-68.

[18]Ivashchenko, O. O., 2019, General Herbology: Monograph. Kyiv, 358 p. [in Ukrainian]

[19]Ivashchenko, O.O., 2001, Weeds in agrophytocenoses. Problems of practical herbology. Kyiv, 234 p. [in Ukrainian]

[20]Khaliq, A., Shakeel, M., Matloob, A., Hussain, S., Tanveer, A., Murtaza, G., 2013, Influence of tillage and weed control practices on growth and yield of wheat. Philippine Journal of Crop Science (PJCS), 38(3), 00-00.

[21]Kolomiets, L.P., Shevchenko, I.P., Tereshchenko, O.M., 2019, Agro-ecological effectiveness of soil protection technologies in the system of contour-ameliorative organization of land use. Bulletin of Agrarian Science, 12, 3-12 [in Ukrainian]

[22]López-Bellido, L., Fuentes, M., Castillo, J. E., López-Garrido, F. J., Fernández, E. J.,1996, Long-term tillage, crop rotation, and nitrogen fertilizer effects on wheat yield under rainfed Mediterranean conditions. Agronomy Journal, 88(5), 783-791.

[23]López-Bellido, R. J., López-Bellido, L., 2001. Efficiency of nitrogen in wheat under Mediterranean conditions: effect of tillage, crop rotation and N fertilization. Field Crops Research, 71(1), 31-46.

[24]Maliarchuk, M., Maliarchuk, A., Tomnytskyi, A., Maliarchuk, V., Lykhovyd, P., 2021, Influence of basic tillage systems and fertilization on productivity and economic efficiency of irrigated crop rotation. Scientific Papers Series Management, Economic Engineering in Agriculture and rural development, Vol. 21(4), 345-354.

[25]Mishchenko, Y. G., Zakharchenko, E. A., Berdin, S. I., Kharchenko, O. V., Ermantraut, E. R., Masyk, I. M., Tokman, V. S., 2019, Herbological monitoring of efficiency of tillage practice and green manure in potato agrocenosis. Ukrainian Journal of Ecology, 9(1), 210-219.

[26]Panchenko, O.B., 2016, Reproduction of fertility of typical chernozem depending on the systems of basic tillage and fertilizer in grain crop rotation of the Right-Bank Forest-Steppe of Ukraine. Thesis PhD dissertation, Kyiv. 22 p. [in Ukrainian].

[27]Plaza, E. H., Navarrete, L., González-Andújar, J. L., 2015, Intensity of soil disturbance shapes response trait diversity of weed communities: The long-term

effects of different tillage systems. Agriculture, Ecosystems & Environment, 207, 101-108.
[28]Pogromska, Ya., 2020, To act outside the norm. Farmer, 12, 11-12 [in Ukrainian].
[29]Primak, I.D., Kosolap, M.P., Martyniuk, I.V., 2021, Scientific basis of management of the weed component of agrophytocenoses of Ukraine. Vinnytsia, 358 p.
[30]Prymak, I., Fedoruk, Y., Grabovskyi, M., Lozinskyi, M., Lozinska, T., Prysiazhniuk, N., Pokotylo, I., Fedoruk, N., Panchenko, I., Panchenko, T., 2022, Productivity, economic and energy efficiency of short crop rotation under different systems of basic tillage and fertilization in the right bank forest steppe of Ukraine. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22(4), 617-626.
[31]Prymak, I., Fedoruk, Y., Karaulna, V., Yezerkovska, L., Panchenko, O., Pokotylo, I., Hornovska, S., Panchenko, I., Fedoruk, N., Obrazhyy, S., 2021, Impact of basic tillage systems and fertilization on agrochemical indices of soil fertility in the right bank of the Forest-Steppe of Ukraine. Vestsi Natsyyanal'nay akademii navuk Belarusi. Seryya agrarnykh navuk Proceedings of the National Academy of Sciences of Belarus. Agrarian series, 59(1), 41-50.
[32]Prymak, I., Grabovskyi, M., Fedoruk, Y., Lozinskyi, M., Panchenko, T., Yezerkovska, L., Panchenko, A., Karaulna, V., Pokotylo, I., Prysiazhniuk, N., Hornovska, S., Shubenko, L., 2023, Productivity of grain ear crops and post-harvest white mustard on green fertilizer depending on the systems of soil basic tillage in the forest steppe of Ukraine. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 23(1), 669-681.
[33]Prymak, I.D., 2017, Agronomic soil science. Vinnytsia, 289 p [in Ukrainian].
[34]Prymak, I.D., 2019, Mechanical tillage: history, theory, practice. Vinnytsia, 262 p. [in Ukrainian].
[35]Prymak, I.D., Yakovenko, O.M., Voytovyk, M.V., Karaulna, V.M., Yezerkovska, L.V., Panchenko, O.B., Fedoruk, Yu.V., Pokotylo, I.A., Panchenko, I.A., 2020, Effect of soil treatments on pests contamination and crop disease distribution in black soil fields with short rotation crops. Ukrainian Journal of Ecology, 10(1), 127-132.
[36]Prymak, I.D., Yezerkovska, L.V., Fedoruk, Yu.V., 2020, Agriculture. Vinnytsia, 345 p [in Ukrainian].
[37]Ranamukhaarachchi, S. L., Begum, M. M. R. S. N., 2005, Soil fertility and land productivity under different cropping systems in highlands and medium highlands of Chandina sub-district, Bangladesh. Asia-Pacific Journal of Rural Development, 15(1), 63-76.
[38]Rao, A. N., Johnson, D. E., Sivaprasad, B., Ladha, J. K., Mortimer, A. M., 2007. Weed management in direct-seeded rice. Advances in agronomy, 93, 153-255.
[39]Riemens, M. M., Van Der Weide, R. Y., Bleeker, P. O., Lotz, L. A. P., 2007, Effect of stale seedbed preparations and subsequent weed control in lettuce (cv. Iceboll) on weed densities. Weed Research, 47(2), 149-156.
[40]Riemens, M., Sønderskov, M., Moonen, A. C., Storkey, J., Kudsk, P., 2022, An integrated weed management framework: a pan-European perspective. European Journal of Agronomy, 133, 126443.
[41]Shahzad, M., Farooq, M., Jabran, K., Hussain, M., 2016, Impact of different crop rotations and tillage systems on weed infestation and productivity of bread wheat. Crop protection, 89, 161-169.
[42]Shevchenko, M.V., 2019, Scientific bases of tillage systems in conditions of unstable and insufficient moisture, Kharkiv, 234 p [in Ukrainian]
[43]Sizov, A.I., Lunev, I.I., Jakovchenko, V.P., 1989, Intensive technologies and soil protection from pesticide pollution. Agriculture, 9, 40-42. [in Russian]
[44]Soon, Y. K., Clayton, G. W., 2002, Eight years of crop rotation and tillage effects on crop production and N fertilizer use. Canadian journal of soil science, 82(2), 165-172.
[45]Tiemann, L. K., Grandy, A. S., Atkinson, E. E., Marin-Spiotta, E., McDaniel, M. D., 2015, Crop rotational diversity enhances belowground communities and functions in an agroecosystem. Ecology letters, 18(8), 761-771.
[46]Tkalich, Y.A., 2013, Agrotechnical and biological measures to increase yield and control weediness of corn, sunflower, and winter wheat in the Northern Steppe of Ukraine. Thesis dissertation of the Doctor of Agricultural Sciences, Dnipropetrovs′k, 44 p. [in Ukrainian].
[47]Tsentylo, L. V., 2020, Agroecological bases of reproduction of fertility of typical chernozem and increase of productivity of agrocenoses of the Right-bank Forest-steppe of Ukraine. Thesis dissertation doctor in agricultural science, Kyiv, 41 p [in Ukrainian].
[48]Tsyliuryk, O.I., 2014, Scientific substantiation of efficiency of systems of the basic cultivation of soil in short-rotation crop rotations of the Northern Steppe of Ukraine. Thesis dissertation doctor agricultural science, Kyiv, 41 p [in Ukrainian].
[49]Yang, L., Song, M., Zhu, A. X., Qin, C., Zhou, C., Qi, F., Gao, B., 2019, Predicting soil organic carbon content in croplands using crop rotation and Fourier transform decomposed variables. Geoderma, 340, 289-302
[50]Zhang, Ai, C., Zhang, S., Guo, X., Zhou, D., Huang, W., 2018, Distinct responses of soil bacterial and fungal communities to changes in fertilization regime and crop rotation. Geoderma, 319, 156-166.

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RISKS OF IMPLEMENTING ORGANIC FARMING PROJECTS IN RURAL TERRITORIES

Evgeniy RUDOY, Marina PETUKHOVA

Federal State Budgetary Educational Institution of Higher Education Novosibirsk State Agrarian University, 160, Dobrolyubov street, Novosibirsk, 630039, Phone: +7 (383) 267-38-11, Mobile: +79231061280, E-mails:rector@nsau.edu.ru,russian_basket11@mail.ru

Corresponding author: russian_basket11@mail.ru

Abstract

The relevance of the study is due to the increasing role of organic farming as a driver of sustainable development of rural territories. The purpose of the article is to develop methodological approaches to the identification of factors that restrain the implementation of organic farming projects and the development of methods and instruments of management of organic products. Methodological aspects of sustainability are developed, including environmental, economic and social. The analysis of the regulatory support of the implementation of projects of organic farming was carried out. An assessment of the structure of the organic production market and the demand for organic products is given. Systematization and classification of restraining and accelerating factors in the implementation of organic farming projects. The need to diversify agricultural production as a conditions for reducing risks and the growth of the yield of agricultural producers is justified. The study has developed directions for increasing the effectiveness of the institutional interaction of the main stakeholders of the organic farming process at the federal and regional levels based on the communication, coordination and cooperation system. The practical significance of the results of the study is to develop measures to improve the scientific and technological policy of the agro-industrial complex in the conditions of structural transformation.

Key words**:** *organic farming, risks, demand for organic products, certification, stakeholders, institutional development, state support*

INTRODUCTION

In modern conditions of sanctions policy, geopolitical challenges, environmental problems, the use of modern technologies for the effective use of natural resources that meet the sixth industrial revolution trends aimed at increasing the stability of agrosystems, taking into account economic, environmental and social aspects [24], is of particular relevance [24].

The economic component of sustainable development implies the effective use of resources [2, 26, 34].

The state actively supports entrepreneurship in the field of research and development focused on economic priorities. At the new stage of technological development, environmental aspects are of particular relevance [1,6].

Technological innovations with new approaches change the structure of production, increasing efficiency and eliminating environmental risks. Russia has high potential for the development of organic production. The formation of the organizational and economic mechanism of the development of organic farming, taking into account institutional conditions and financial instruments is a priority task at both the federal and regional levels [27]. This approach is aimed at predicting possible negative consequences for the ecosystem and minimizing the risks of transition to a new technological structure [4,10].

Organic farming is one of the priority areas of scientific and technological progress in agriculture. It is based on the use of agricultural biotechnologies and organic fertilizers for growing agricultural crops [16]

In recent years, the demand for organic products has significantly increased in the world market [31]. In 2020, the capacity of the global market for organic products amounted to $ 145 billion. It is expected that by 2025 the global market for organic products will expand by 10-15%.

The market of organic agriculture of European countries is characterized by dynamic development, which is largely associated with the presence of favorable natural-economic conditions.

According to Popescu, A. [21] the increase in demand for organic fuel predetermined positive dynamic shifts in the production and trade of organic products, including exports to the market of European countries. The development strategy of organic production in Romania involves a further expansion of agricultural space under organic cultures, improving the quality of products, increasing consumption of these products by the population and increasing exports.

The improvement of legislation in the field of organic production in Russia also contributed to positive shifts in the production and consumption of these products. It should be noted that the demand for environmentally friendly products in Russia is developing quite high pace. Experts evaluate the annual increase in organic products in the amount of 20-23 %. Russian environmental products occupy one of the most important export positions in international trade with European countries [14].

The undoubted competitive advantage of Russia is the presence of a significant array of unused land, the area of which is 20 million hectares. The introduction of these lands into organic agricultural circulation will ensure the production of environmentally friendly products. Currently, the global agricultural market has an increased demand for organic cultures such as soy and corn, despite higher prices. According to experts, the cost of organic products exceeds the cost of standard products by 1.5-2 times [19].

Among the directions of development of organic farming, the formation of a network of interested parties is distinguished [9,35].

The authorities of various levels play an important role in supporting the stability of organic agriculture, promoting processes with the participation of many interested parties at various stages of development [11, 36].

Nevertheless, the development of organic agriculture is faced with a number of problems requiring an immediate solution, among which: market difficulties, interest and consumers of organic products, the certification process, which small rural manufacturers consider it difficult [23].

Authorities must be able to interact with interested parties in the development of organic farming and stable food systems [22]

In addition, the institutional environment related to the development of organic agriculture should be fixed both by interested parties and legal conditions and the organizational structure of organic agricultural management institutions. The institutional aspect plays an important role in ensuring the sustainability of the functioning of the system [8]. If problems arise with the functioning of the system, it can be assumed that the institutional aspect itself experiences problems [13].

The mechanism will work if various interested parties are involved in the process related to the development program of organic agriculture.

Significant preferences of the development of organic agriculture in Russia are: expanding the possibilities of exporting organic products, strengthening the image of domestic organic products abroad, restoring soil fertility. At the same time, organic agriculture is associated with organizational, economic, technical, social and foreign trade risks, restraining an accelerated transition to large-scale production.

The purpose of the article is to develop methodological approaches to the identification of factors that restrain the implementation of organic farming projects and the development of methods and instruments of management of organic products.

MATERIALS AND METHODS

The methodological basis of the study was state legislative acts, decisions and decisions of the government, scientific works of domestic and foreign scientists-economists and agrarian specialists on the problem being studied. In the process of research, monographic, abstract-logical, analytical, economic-statistical, expert research methods were used. As an information base of the study, the materials and reports of Global Footprint Network Grand View Research, Fibl, Ifoam - Organics International, the development of organic production in the Russian Federation until 2030 as well as regulatory documents and materials of scientific literature and periodicals were used.

RESULTS AND DISCUSSIONS

An increase in the scale of food production in Russia is a vivid manifestation of a global concentration in agriculture. Thus, leading food companies seek to master the production of organic goods. Such aspirations receive support from the state, and its priorities have already received legislative consolidation.

Among countries with the greatest consumption of organic products per capita, European countries are absolute leaders. So, in Switzerland, this value was 425 euros per capita, in Denmark-384, in Luxembourg-313, in Austria and Sweden-268 and 266 euros per capita, respectively.

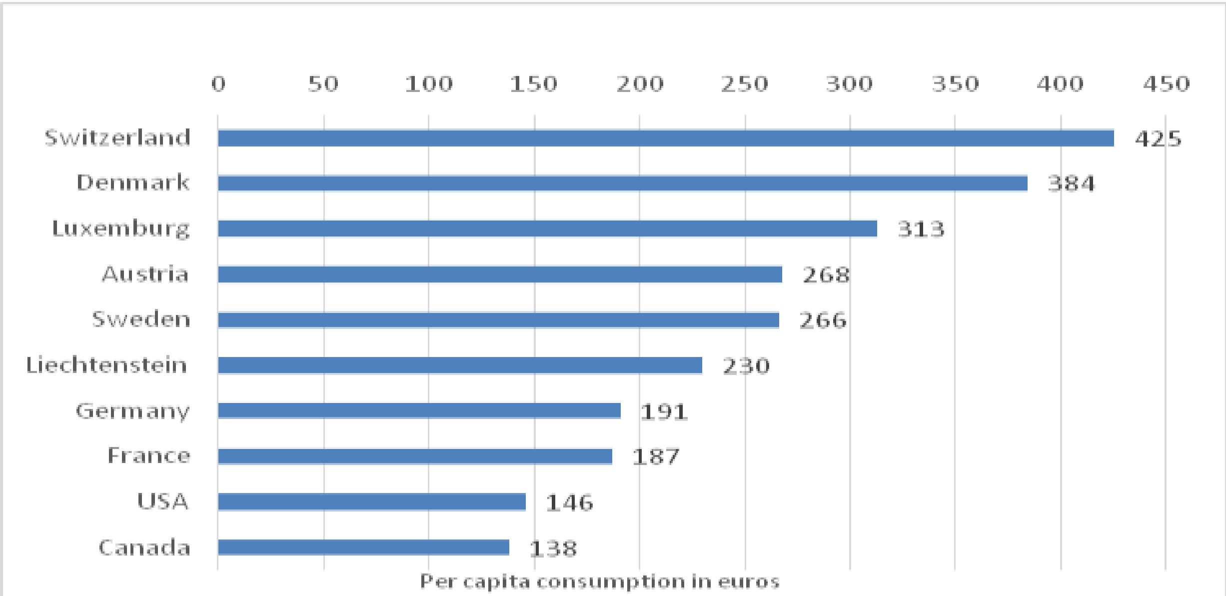

Fig. 1. Top 10 countries with the highest consumption of organic products per capita (in euros) (2021).
Source: Own calculations based on data [30].

Developing countries have significant potential for the production of organic products. The largest number of manufacturers of certified products fall on India, Uganda, Ethiopia and Tanzania (Fig. 2).

Considering that more than 3.1 million manufacturers of organic products are certified in the world, India ranks first (1,366,000), Uganda - the second (210,000) and Ethiopia - the third (204,000). Most small manufacturers undergo group certification based on the internal control system. It should be noted the small -special nature of organic agriculture in developing countries. The average size of enterprises is 3-4 hectares, while in Europe one enterprise may account for 20-25 hectares; In Russia and the USA - from 100 to several thousand hectares [17].

Some foreign scientists studied the consumer behavior of youth in relation to organic products in Romania using sociological research methods. The results of the survey showed a high degree of perception of organic products by young people of this category of the population. It was established that organic products consume 90.6%of the examined young people, and a large share of products is purchased in local markets (81.15%) or supermarkets (80%).

Respondents noted the most effective ways to popularize the consumption of organic products, including products tasting in hypermarkets or supermarkets, as well as specialized fairs of organic products.

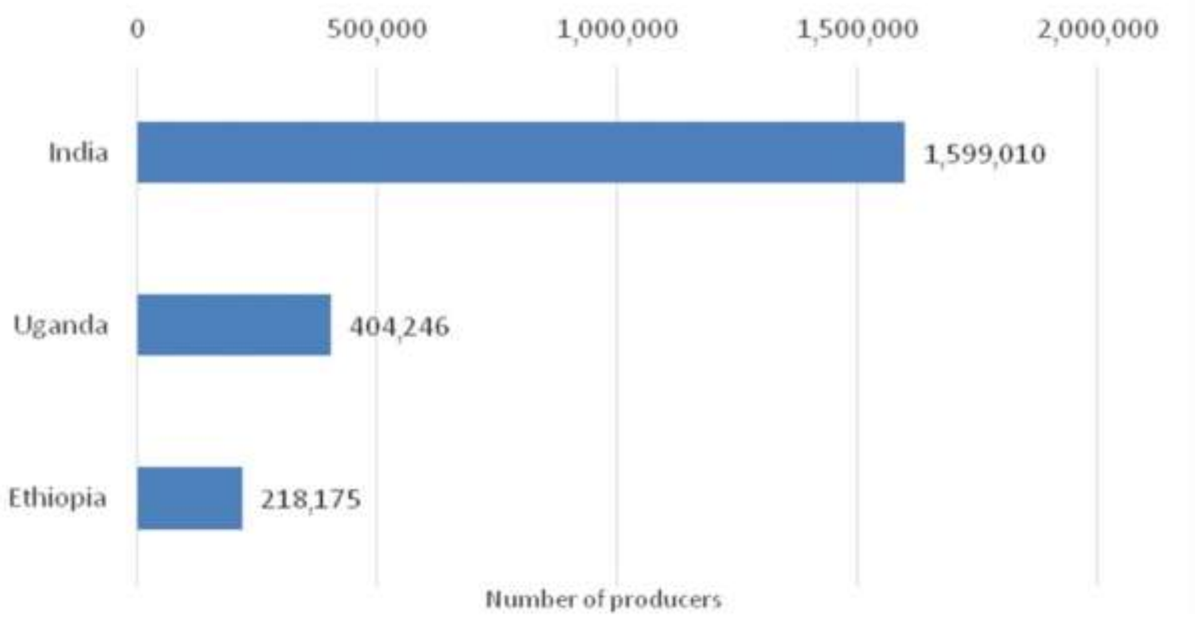

Fig. 2. Countries with the largest number of certified organic producers (2021).
Source: Own calculations based on data [30].

The sociological survey made it possible to establish the goodness of consumers, the ability to recognize organic products by labeling on the packaging. Usefulness (93.2%) are called as the main properties of organic products; taste (71.2%); less chemicals (61.8%); Lack of synthetic additives (48.7%). Many respondents noted such advantages of organic production as environmental protection (45%), support for family farms (40.3%), the development of the region's economy (40.3%) [5,20].

In continuation of the subject of the consumption of organic products M. Krejnus, K.P. Štofková, J. štofková studied consumer behavior in the Slovak market. Slovak organic agriculture covers the production of grain, legumes, vegetables, fruits, as well as individual sectors of livestock. As the main factors of consumption by the population of organic products are highlighted: health and safety, quality characteristics; Product price, product certification. The results of a sociological survey showed that they showed that respondents received information about organic products mainly via the Internet. Some respondents noted the lack of information about organic products. Most consumers of organic products are working women aged 26 to 40 years old, having secondary or higher education and income of Euro 500 - 900 [15].

In the global market, the growth rate of demand for organic products is ahead of the increase in its production by about an average of 10 percent [28], experts and analysts predict that world production of organic products will increase by 10-15 %by 2025. Almost 70 % of the consumption of organic farming products falls on the following countries: the United States - 43 %; Germany - 11 %; France - 9 %; China - 8 %; Canada - 3 %. At the same time, the highest consumption per capita was reached in European countries, which is explained by a high share of import of organic products. The share of imports in the consumption of organic products by the population of European countries is about 50 % [14].

In Russia, the organic production segment occupies only 0.2 % of the global volume, while in the USA - 40 %. The low scale of Russian organic production is explained by the long absence of the appropriate regulatory framework governing its development [33].

The developed organic production development strategy in the Russian Federation until 2030 involves an increase in the consumption of organic products by Russian citizens by 2030, compared with 2021, almost 8 times. The average annual level of consumption of organic products will increase from 147 rubles. in 2021 to 1,040 rubles. In 2030 per person. A significant increase in demand will be possible as a result of the expansion of consumer awareness about the advantages of a healthy diet, as well as increasing the price availability of domestic organic products for the general population [29].

It should also be noted that Russia has a significant scale of unused agricultural land, which can be intended for organic farming. Currently, the global agricultural market has an increased demand for organic cultures such as soy and corn, despite higher prices. The cost of environmentally friendly food of the agricultural industry intended for export exceeds the cost of standard agricultural products by 60–100 %. However, the growing demand in the world market for such crops as soy and corn, creates incentives for their cultivation using organic production technologies [19].

Manufacturers of organic products receive the right to financial support from the federal budget, but in the amount that is very much different from the amounts allocated to support industrial agriculture. It means compensation for organic certification costs, the right to free certification, subsidies for manufacturers of ordinary food products and other measures. However, having the right to support and really receive this support - things are completely different. A similar situation has developed in other countries, for example, in India, where the past years led to a high rate of development of organic production. State support and supervision (compliance with GOST standards, certification, inclusion in the register of manufacturers of organic products) can be explained not only by economic motives, but also by the desire to provide the population with reliable, safe and high -quality food, the production of which would impose a minimum possible agroecological harm. That is why, in fact, Russian organic certification, despite the optional nature, is not voluntary in fact.

On the territory of the country there is a branched sector of organic food products, which covers production, consumption and retail trade. The field of production is divided into informal, semi -formal and formal sectors.

However, the development of organic production in Russia is faced with certain obstacles that need to be overcome.

First of all, organic products have high retail prices, which makes them more expensive than inorganic analogues by an average of 1.5-3 times. This is due to the fact that organic production requires more labor, costs more and has low productivity. Low real incomes of the population and inflation also affect the choice of customers who are forced to reduce the consumption of more expensive goods, including organic food products.

The insufficient number of accreditation companies, inspectors and experts who can control the organic foods is equally important. At the same time, the presence of restrictions on the trade in imported organic products, insufficient financial support at the regional level and the lack of an effective certification system create additional difficulties for the development of this sector.

The problem of falsifications is also urgent and affects various aspects. Many companies represent incomplete or inaccurate data during certification, and also use organic labeling without passing this process. The lack of consumer confidence in what they buy, as well as the physical and economic accessibility of organic food products, also restrain the demand for them.

In general, the development of the formal organic sector in Russia is advisable taking into account state support and objective capabilities, however, overcoming these obstacles requires an integrated approach and cooperation by the state, business and population. Only in this case, the real development of organic food production in Russia will be achieved.

The development of organic agriculture in Russia is restrained by the presence of numerous risks associated with the absence of the necessary conditions for the transition to a new method of production. As international experience shows, the production of organic products should be ensured by the appropriate infrastructure; To expand the demand of the population for these products, it is necessary to increase the culture of organic production and popularize the advantages of organic products. Russian agriculture is lacking in qualified personnel and necessary technological solutions in the field of organic production. In the world market, the organic products of Russian producers are weak competitive due to lower production indicators, which also weakens the country's export capabilities. In many areas of organic agriculture, there are no cooperative ties of producers. It should also be noted the insufficient security of the proper infrastructure of organic agriculture and the lack of statistical tools for accounting for organic products. Low recognition of certified organic products by consumers and the presence of a significant number of falsifications in markets; Products prevents the formation of demand for organic products. The above problems, according to experts, will be preserved in the average and long term.The development strategy of organic production in the Russian Federation until 2030 identifies the main types of risks of conducting competitiveorganic agriculture: agroclimatic, technological, social, foreign trade (Table 1).

Table 1. The main risks of conducting competitiveorganic agriculture

Types of risks	Consequences and loss assessment
1.Agroclimatic	The unsatisfactory state of the country's agroclimatic resources, the gradual deterioration of weather and climatic conditions, a lack of water resources, soil degradation, and the deterioration of soil fertility. The costs of soil recovery reach 25 thousand rubles/ha. The prolongation of adverse trends until 2030 may cause a decrease in agricultural land using organic farming technologies by 2,000-4,000 thousand hectares. In addition, adverse changes in the natural and climatic conditions in the Russian Federation lead to an increase in production costs and a decrease in organic production.
2. Technological	The lag of the domestic production base from developed countries at the level of technological development. High technological import dependence. Lack of necessary technological solutions in the field of organic production. Given the prevailing conditions, losses from a decrease in the volume of production of organic products by 2030 can reach 100-150 billion rubles.
3. Personnel	Lack of the necessary competencies of personnelthe potential necessary in the implementation and use of organic production technologies
4.Social	The outflow of labor from rural areas leads to a shortage of personnel of organization and conducting organic production.
5. Consumer	The insufficient demand of the population for organic products is associated with the insufficient popularization of the advantages of organic products, the low recognition of certified organic products with consumers and the presence of a significant amount of falsified products in markets. While maintaining passive consumer behavior in 2030, it is possible to reduce the cost of organic products consumed by 2030 by 250-300 billion rubles.
6. Foreign trade	Tightening the requirements of the manufacturers for supplied products; sanctions on export-import operations; currency course changes; the volatility of world prices for agricultural goods, machines and equipment; low competitiveness of supplied products; Changing the conjuncture of the global market of organic products and reducing the volume of export supplies. Risky losses from reducing the export of organic products due to the above factors are estimated at 40-60 billion rubles.

Source: Own calculations based on data [29].

The presence of agroclimatic risks is associated with adverse climatic changes, the state of agroclimatic resources countries, worsening soil fertility. Analysis of the results of agroecological monitoring of 2021, showed the areas of arable land with a high degree of acidic soils: very strongly acidic (pH <4.0) are common on an area of 74.93 thousand ha, (0.7% of the surveyed areas); Strongly acidic (pH 4.1-4.54.1-4.5)-340.05 thousand ha (3.0%); Medium-term (pH 4.6-5.0)-1,594.97 thousand ha (14.3%). In addition, 1.3 million hectares (11.6% of the examined lands) fall on an area with low and very low potassium in the soil. Soils with a low humus content were detected on an area of 4.6 million hectares, which amounted to 41.7% of the examined land. The unsatisfactory state of soil is one of the most significant risks of using organic farming technology and the involvement of unused lands in agricultural circulation. A significant part of such lands is concentrated in the regions of the Russian Federation with adverse agroclimatic conditions and low soil fertility. In this regard, it seems quite justified proposals to introduce special measures to improve the quality of soils introduced into organic agricultural circulation [29].

The consequences of changing the natural and climatic conditions can be both an increase in the cost of manufactured products and the drop in the volume of production of organic products. The risks of a lack of water resources are also significant,

necessary for irrigation of agricultural lands, which is complicated by a shortage of funds for financing capital investments in the arrangement of reclamation facilities. Foreign trade risks affect the formation of the export potential of organic products. The most significant are the foreign trade restrictions and threats of a sanctions nature, as well as fluctuations in currency and prices for agricultural products and technologies.

The concept of sustainable development contains the tasks of achieving food safety and reducing food poverty in the context of preserving natural resources and compliance with environmental requirements for the organization and maintenance of agricultural production [25].

The use of traditional methods of agriculture leads to negative changes in ecosystems and environmental loads. Therefore, sustainable methods of agricultural management should include measures aimed at restoring degraded agricultural land and growing organic products [3].

State support for organic farming is carried out using various tools. Direct support includes regulation of market prices, including the establishment of targeted prices; Subsidizing and investment. Indirect support is related to financing research on this topic, as well as the provision of consulting services in order topopularize knowledge of organic production. Such measures of state support as the provision of subsidies to producers; preferential taxation; organization of disposal of organic products; Stimulating the organization and conduct of organic farming by farmers contribute to increasing the profitability of organic farms and an increase in product competitiveness [18].

The solution to the problem of restoration of soil fertility is possible as a result of the use of organic agriculture and biologization of agriculture. These methods represent a set of methods of production of agricultural products with specified characteristics based on the use of living organisms and biological processes. The main technologies include: the use of biological phytosanitary drugs; biological fertilizers; selection achievements and genetic engineering; waste processing, bioenergy. Currently, in the agriculture of Russia, only 2-3 % of agribiotechnologies are used, despite the presence of a scientific and production base in the country for their development and implementation. The problem is also a low investment of science and the lack of qualified specialists, as well as restrictions on commercialization of these technologies and implementation in agricultural production [32].

Thus, organic farming has high potential for realization in Russian agriculture, however, state support and stimulation are necessary for successful development manufacturers of agricultural products [12] are promising areas of development of domestic organic agriculture as follows:

1. The development of methods of organic agriculture and biologization of agriculture in order to restore and maintain the fertility of agricultural land. The use of agricultural manufacturers is not only traditional, but also modern management methods, including rational, scientifically based land use in order to preserve, maintain and expand fertile land [24].
2. The creation of a single center, including cooperation of knowledge and experimental experience based on coordination of stakeholders of the process of organic products: universities, research institutes, agribusiness, intermediary organizations [7].
3. Conducting research and development work on the creation of complex technologies of organic farming for various regions of the country with good natural-climatic conditions.

At the same time, the introduction of organic farming technologies borders on certain risks: in low internal demand for organic agricultural products compared to developed countries; difficulties in selling organic products due to significant financial investments for its certification; lack of domestic seeds for organic farming; disadvantage of qualified personnel; a decrease in the yield of cultivated plants grown using organic agricultural technologies

Catalysts of the growth of organic farming in our country are the internal demand for products with organic characteristics, as well as the demand of consumers of the world community. With the transition to organic agriculture, domestic manufacturers of agricultural products will have a prospect of entering the world market and receiving export income, which will significantly improve the financial and economic situation of agricultural enterprises. The export price of organic agricultural products is much higher than the price of inorganic analogues, which positively affects the effectiveness of the production process. Thus, for the effective development of organic agriculture, it is necessary to increase the level of commercialization of scientific research and development, to introduce complex technologies of organic farming, and stimulate this direction by the state and manufacturers of agricultural products

CONCLUSIONS

The article develops methodological approaches to the identification of factors restraining the implementation of organic farming projects and the development of methods and tools for managing organic products. The directions of increasing the efficiency of organic farming based on the coordination and coordination of interested parties have been investigated. An analysis of the regulatory support of the implementation of projects of organic farming, certification of organic products was carried out. Systematization and classification of deterrent factors for the implementation of projects of organic farming is shown. The directions of increasing the effectiveness of the institutional interaction of the main stakeholders of the organic farming process at the federal and regional levels based on planning and coordination were developed. The practical significance of the results of the study is to develop measures to improve the scientific and technological policy of the agro-industrial complex in the conditions of structural transformation.

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REFERENCES

[1]Barinov M.N., 2016, Value-based approach to project and program management, Economy and Society, Vol. 1(20):1280-1285.
[2]Barros, M. V., Salvador, R., do Prado, G. F., de Francisco, A. C., Piekarski, C. M., 2021, Circular economy as a driver to sustainable businesses, Cleaner Environmental System, Vol. 2:100006.
[3]Beckford, C., Campbell, D., Barker, D.,2011,Sustainable Food Production Systems and

Food Security: Economic and Environmental Imperatives in Yam Cultivation in Trelawny, Jamaica, Sustainability, Vol.3: 541–561.
[4]Bulanov, V.S., 2017, Methodologies of economic phenomena and processes, Prospekt, 2017:64
[5]Cărătuş Stanciu, M., Popescu, A., 2021, Research on Attitude and the behavior of the Romanian young generation in relation to the purchase and consumption of organic products, Scientific Papers: Management, Economic Engineering in Agriculture, Rural Development, Vol. 21 (4): 125-131.
[6]Degtyarev, D.S., 2016, Models and concepts of marketing in the evolution of the development of value-based marketing, Trends of modern science: 66-70.
[7]Derunova, E., 2021. Conditions for the development of the institutional structure of the scientific and intellectual potential of the agricultural food complex, Scientific Papers: Management, Economic Engineering in Agriculture, Rural Development, Vol. 21 (1): 197-205.
[8]Derunova, E., Kireeva, N., Pruschak, O., 2020, The level and quality of inclusive growth agri-food system in modern conditions. Scientific Papers Series «Management, Economic Engineering in Agriculture and Rural Development», Vol.20(3),193-206.
[9]Ferro, N.D., Camarotto, C., Piccoli, I., Berti, A., Mills, J., Morari, F.,2020, Stakeholder Perspectives to Prevent Soil Organic Matter Decline in Northeastern Italy, Sustainability, Vol.12: 378.
[10]Guryeva, M. A.,2014, The evolution of the concepts of “greening” and “green economy”, Perspectives on Science, Vol.10: 100-105.
[11]Halloran, A., Magid, J., 2013, The role of local government in promoting sustainable urban agriculture in Dar es Salaamand Copenhagen, GeografiskTidsskrift-Danish Journal of Geography,Vol.113 (2): 121–132.
[12]Ivanova, N. I., Levchenko, L. V.,2017, “Green” economy: essence, principles and prospects, Bulletin of Omsk University, Series "Economics", Vol. 2: 19–28.
[13]Jitareanu, A.F., Mihaila, M., Robu, A.D., Lips, F.D.,Costuleanu, C.L., 2022, Dynamic of Ecological Agriculture Certification in Romania Facing the EU Organic Action Plan, Sustainability, Vol.14: 11105.
[14]Kabir, L. S., Anosova, L. A., 2017, “Green” economy: new challenges and prospects for public administration, Economics and management, Vol. 11 (145):37–42.
[15]Krejnus, M., Štofková, K. R., Štofková, J., 2022, Consumer purchasing behaviour at the organic food market, Engineering Science and Production Management, 2022: 58.
[16]Oborin, M. S., 2022, Opportunities for the development of the agricultural sector when implementing the concept of “green” growth, Bulletin of NGIEI, Vol. 8 (135): 62–70.
[17]Organic market in the world and Russia, 2021, https://rosorganic.ru/files/Анализ%20органического%20рынка%202021%20г.pdf, Accessed on September 29, 2023.
[18]Orlund, K.,2003, Norwegian experience with conversion and support payments for organic farming, Organic Agriculture: Sustainability, Market and Policies: 337.
[19]Pavlova, E. A., Sangalova, E. D., Kanunnikova, K. I.,2021, Modern innovative solutions aimed at improving the environmental and economic situation in St. Petersburg, Scientific journal of NIU ITMO, Series: Economics and environmental management, Vol. 2 (45): 107–115.
[20]Popescu, A., Guresoaie, I., 2019, Consumer's behaviour towards honey purchase- A case study in Romania, Scientific Papers Series Management, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.19 (1): 451-470.
[21]Popescu, A., Pop, C., 2013,Considerations regarding the development of organic agriculture in the world, the EU-27 and Romania, Development, Vol. 13 (2) :323-329.
[22]Prasetyaningtyas, S.W., Sobir, Hermawan, A., Maarif, M.S.,2019, Utilizing stakeholders analysis on sustainable organic farming in West Java: The case of Cisarua organic farming. J. Manaj, Agribisnis, Vol.16: 56–65.
[23]Qiao, Y., Martin, F., He, X., Zhen, H., Pan, X., 2019, The changing role of local government in organic agriculture development in Wanzai County, China., Canadian Journal of Development Studies/Revue canadienned'études du développement, Vol.40 (1): 64–77.
[24]Rodionova, I. A., Lipina, S. A.,2015, “Green” economy in Russia: model and development forecasts, Fundamental Research,. Vol. 2(24): 5462–5466.
[25]Rudoy, E.V. Petukhova, M.S., Isaeva, G.V., Dobryanskaya, S.L, 2021, Organic farming as a promising direction of scientific and technological development of crop production in the Novosibirsk region. IOP Conference Series: Earth and Environmental Science. 723(3). 032031.
[26]Rudoy E.V., Petukhova, M.S., Dobryanskaya, S.L., Sadokhina, T.A., Kapustyanchik,S.Yu.,2020, Algorithm for the development of the strategy for scientific and technological development of the crop sector of the Novosibirsk region IOP Conference Series: Earth and Environmental Science. conference proceedings. Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations. P. 32032.
[27]Sandu, I., Butorin, S., Ryzhenkova, N.,2019, Scientific basis for forecasting the innovative development of the agricultural sector of the region's economy (on the materials of the Perm region). In Proceedings of International Scientific and Practical Conference on Agrarian Economy in the Era of Globalization and Integration.IOP Conference Series: Earth and Environmental Science, 274(1), 012016.
[28]Sorokina, Yu. V., 2017, Elimination of past environmental damage: theoretical aspect, Scientific

Bulletin of the WF RANHiGS, Series:Jurisprudence, Vol.2: 65–68.

[29]Strategy for the development of organic production in the Russian Federation until 2030, 2020, http://static.government.ru, Accessed on September 25, 2023.

[30]The World of Organic Agriculture Statistics and Emerging Trends 2023, https://www.fibl.org/fileadmin/documents/shop/1254-organic-world-2023.pdf, Accessed on September 29, 2023.

[31]Valkama, E., Kunypiyaeva G., Zhapayev, R., Karabayev, M., Zhusupbekov, E., Perego, A., Schillaci, C., Sacco, D., Moretti, B., Grignani, C., Acutis, M.,2020, Can conservation agriculture increase soil organic carbon? A modelling approach, Geoderma, Vol. 369:114298.

[32]Vasilchenko, M., Derunova, E., 2021, Assessment of the contribution of the investment potential to increasing the efficiency of agricultural production. Scientific Papers Series «Management, Economic Engineering in Agriculture and Rural Development», Vol.21(1), 805-816.

[33]Vypkhanova, G.V.,2020, Theoretical, legal and practical problems of eliminating accumulated harm to the environment, Environmental law, Vol. 1: 11–13.

[34]Yakovlev, I. A., Kabir, L. S., Nikulina, S. I., Rakov, I.D., 2017, Financing "green" economic growth: concepts, problems, approaches, Scientific Research Financial Institute, Financial Journal, Vol. 2: 9–21.

[35]Zagata, L., Uhnak, T., Hrabak, J., 2021, Moderately radical? Stakeholders' perspectives on societal roles and transformative potential of organic agriculture, Ecological Economic, Vol.190: 107208.

[36]Zanetti, L., Candiotto, P., 2018, Organic Products Policy in Brazil, Land Use Policy, Vol. 71: 422–430.

THE PERFORMANCE AND ECONOMIC EFFICIENCY OF NEW GENOTYPES OF ALFALFA (*MEDICAGO SATIVA*)

Călin SĂLCEANU, Mirela PARASCHIVU, Aurel Liviu OLARU

University of Craiova, Faculty of Agronomy, 19 Libertății Street, Craiova, Dolj county, Romania, Phone: +400251418475, Mobile: +40773818957; +40745577355; +40741272138, Emails: calin.salceanu@yahoo.com, paraschivumirela@yahoo.com, liviu.olaru.dtas@gmail.com

Corresponding authors: paraschivumirela@yahoo.com, liviu.olaru.dtas@gmail.com

Abstract

Alfalfa is the most widely grown perennial forage legumes that are planted frequently for hay, pasture, and silage worldwide, due to its extremely nutritious forage and wide range of adaptability. High yield and economic efficiency of alfalfa (Medicago sativa L.) are important in determining the effective distribution of new cultivars to farmers. The present study was conducted to explain alfalfa yield variation induced by environmental conditions and genotype. Forage yield, aboveground phytomass, stems elongation, internodes number, growing rhythm, economic performance was assessed for a set of 10 Romanian alfalfa genotypes experienced at ARDS Caracal, Romania, in each of three years (2019-2022). Stem elongation values ranged between 131.4 cm for alfalfa line F2909-2 and 138,8 cm for alfalfa line F2910, while the average internode number ranged between 24.6 for F 2908 and 27 for F2906. Variation in stem elongation was associated with variation in the number of internodes and was positively correlated (r = 0.4448). Also, the fastest growing rhythm was observed to the genotype F2905 and the lowest to F2910. The most economic efficient and profitable was the genotypes F 2907, F2908 and F 2910. Alfalfa production offers a compelling case for both economic efficiency and sustainable agriculture.

Key words: *Medicago sativa, genotype, input costs, economic efficiency, yield*

INTRODUCTION

Alfalfa (*Medicago sativa* L. subsp. *sativa*, 2n =4x=32) known as “Queen of forages” is one of the most important forage crops worldwide having multiple benefits for both agriculture and environmental protection [9][22][24]. Alfalfa is one of the few crops that can withstand challenging growth circumstances. From the deserts 250 feet below sea level to approximately 10,000 feet above, in sandy or clay soils, it can grow in practically any elevation [15]. Despite of this, to adapt to and maybe benefit from the future climate, gradual modifications in management of perennial crops (planting dates, harvest dates, number of harvests, crop genetics, and pest control) will be necessary [7][23] [26] [30].
In the USA is the third crop in value behind corn and soybean being used also in the form of milk, cheese pizza, ice cream, honey, leather, or wool sweaters having high nutritional value (proteins 50–65%), available carbohydrate (5–20%), crude fibres (0.5–1.5%), fat (7–25%), ash (0.5–1.5%) and its average total energy is 439 kcal per 100 g [11][25].
Alfalfa is an excellent ground cover reducing soil erosion and phosphorus and pesticides into streams and lakes [27]. Also, alfalfa is capable of fixing atmospheric nitrogen which meets its requirements for high yields [8][29][34]. In addition to nitrogen, crops that follow alfalfa in a crop rotation generally yield up to 10-15% greater and require less pesticides [33].
Besides its role in soil fertility, alfalfa adds aesthetic value to the landscape and serves as a significant home for a variety of species, including many helpful insects [13][10][28].
Alfalfa is actually used by 28% of California's wildlife for either feeding, cover, or nutrition [22]. It is highly valued by organic and conventional farmers alike for its soil health-building characteristics. Also, compared to many other crops, alfalfa actually has a higher water use efficiency when measured as harvestable biomass/applied water [23].

Moreover, regards the irrigation management, alfalfa is incredibly adaptable because it is a perennial crop that naturally tolerates drought [20].

Alfalfa yield improvement has not been as successful as improvements in other qualities, and it has been slower than improvements in cereal production [3].

A number of issues that also apply to other perennial forages, such as low breeding investment, lengthy selection cycles, inability to choose true hybrids or pure lines, and high genotype environment interaction (GEI), limit genetic advancement for alfalfa producing ability [2].

Other reason for the limited yield in alfalfa is placed on yield per se than in the other grains, which contributes to the restricted increase in production [1][3][12].

Instead of measuring yield on plots grown at stand densities used in commercial production, as is done in the case of the major grain crops, alfalfa output is frequently determined indirectly based on evaluation of vigour on spaced plants or on short family rows [19]. However, for the last decades, alfalfa yields, forage quality and persistence have increased thanks to improved genetics, disease and insect control and more intensive nutrient and harvest management [17][18][19].

The global alfalfa market size was $21.63 billion in 2021 and is projected to grow to $35.20 billion in 2028 at a CAGR of 7.2% in forecast period, 2021-2028 [21]. Moreover, the risk of growing alfalfa is much lower than many other crops, making year-to-year profits steadier. Thus, improved varieties and better management tools continue to increase yields of alfalfa leading to profitability when compared to other forage crops over a number of years. Alfalfa and other forage crops can have a fruitful and sustainable future by breeding plans for the future and taking action to adapt to the climate change.

Considering the aspects above mentioned, the paper provides a comprehensive discussion on alfalfa Romanian germplasm diversity and explain the economic importance of growing new genotypes with better traits, climate change mitigation and improved performance.

MATERIALS AND METHODS

Selection for yielding capacity of ten Romanian alfalfa genotypes was carried out by a field experiment performed during 2019-2022 in the Breeding Field of the Agricultural Research Station Caracal of the University of Craiova, Romania (44°11'N and 24°37'E). The trial was conducted in a split–plot design with the main plots (10 m^2) arranged in a randomized complete block with three replicates.

All recommended cultural practices (pests' control with Decis 0,15l/ha and Mospilan 5 g/10 l water and fertilizing with Aminofed 20 g/10 l water, etc.) and other management were applied.

The local long term average rainfall amount was 541.7 mm, while long term average temperature was +11.6^{o}C. Severe summer drought was avoided by providing three irrigations of 55 mm each before harvests in all experimental years.

Total biomass and total dry matter yield on a plot basis was recorded over the three harvests for each experimental year.

Harvest took place when plants approached 10% blooming for every genotype. In addition, there were assessed: (a) stems elongation (cm), b) number of internodes and c) growth rhythm, each recorded on a subsample of ten plants per plot.

Economic efficiency was calculated using Total Costs (Ct), Net Profit (Vn) and Profitability Rate (R) [5]. For Total Costs was used the formula:

Ct = Cf + Cv, where:
Cf – fix costs (lei/ha) (Table 1)
Cv – the sum of variable costs) (lei/ha)

Net profit (Vn), using the formula:
Vn (lei) = (Pv × Qt) - Ct, where:
Pv – selling price (lei/kg)
Qt – Total Yield (kg)
Ct – Total Costs (lei/kg)

Profitability Rate (R), using the formula:
R (%) = (Vn/Ct) ×100

Table 1. Alfalfa Fix Costs (Cf) for experimental years (2019-2022)

No	Technology operation	1st year (lei/ha)	2nd year (lei/ha)	3th year (lei/ha)
1	Tillage	600		
2	Tilling 1	200		
3	Tilling 2	200		
4	Fertilizing	400	200	200
5	Sowing	200		
6	Seed	600		
7	Irrigation	1,600	1,600	800
8	Fertilizers	300	300	300
9	Mowing	450	450	450
10	Raking together	300	300	300
11	Balling	700	800	900
12	Transport	200	300	300
Total		5,750	3,950	3,250
TOTAL (lei/ha/3 years)		**12,950**		

Source: own calculations.

Worldwide increasing yield, improving nutritional value, growing economic performance and improving resistance to abiotic and biotic stressors are significant breeding objectives for alfalfa, as for other crops. Known as a perennial crop, alfalfa produces its maximum yields in the second year of growth. Alfalfa is grown for three to four years continuously in mild winter climates, whereas it is grown for six to nine years with a winter dormant period in continental areas with cold winters. The number of cuttings per growing season varies with climate and ranges from 2 to 12. Annually, the forage yield per cut varies with climatic conditions and genotype. Despite of this aspect, the markets for alfalfa have stayed much more stable than those for several other crops because it is resistant to weather changes and improved yielding capacity.

The experiment was based on the comparison of ten alfalfa genotypes performance as expressed by total biomass yield over three cropping years. Also, some morphological characters were considered.

The elongation of stems is influenced by a combination of external environmental and internal factors. Among external factors the most important is the light that influence positively the accumulation of dry matter and improving the yield of the crop [4]. Also, plant hormones play a major role in controlling plant height, and the majority of these genes are involved in the metabolism or signal transduction of hormones including GA3, IAA, CTK, and brassinolide (BR) [16]. Previous studies showed that among all hormones involved in regulating plant height, the most important is gibberellin (GA) and it can promote internode elongation in, rapeseed (*Brassica campestris*), sugarcane (*Saccharum officinarum*) and other crops [6][31][32].

Stem elongation values ranged between 131.4 cm for alfalfa line F2909-2 and 138.8 cm for alfalfa line F2910 (Table 2). Only the lines F 2906 and F2910 recorded slightly higher values of stem elongation that the control genotype Catinca, while all the others assessed alfalfa genotypes exhibited lower values. Stem length values that ranged between 80.58 cm and 86.77 cm for high alfalfa genotypes and between 54.46 cm and 55.65 cm were exhibited by [14] in China.

Table 2. Alfalfa stem elongation values (average 2019-2022)

No.	Genotype	Stems length (10 stems / variant) (cm)				Relative length %
		mower				
		I	II	III	Total cm	
1	Catinca - Control	38.6	47.7	52.0	138.3	100
2	F Ileana	35.7	47.7	49.4	132.8	96.0
3	F 2020	33.7	49.4	50.0	133.1	96.2
4	F 2905	37.8	45.8	50.1	133.7	96.6
5	F 2906	34.6	51.2	52.8	138.6	100.2
6	F 2907	31.7	49.4	54.3	135.4	97.9
7	F 2908	37.0	46.9	47.1	138.2	99.9
8	F 2909-1	34.7	47.8	49.5	132.0	95.4
9	F 2909-2	35.3	47.2	48.9	131.4	95.0
10	F 2910	37.2	50.4	51.2	138.8	100.3

Source: own data.

More and more genes related to internode lengthening and plant height have been cloned and functionally discovered as molecular biology research into these topics has progressed. However, as a typical example of forage, alfalfa has received minimal attention in terms of the process underlying stem elongation, with the majority of studies concentrating on the nutritional value of the stem.
To examine the patterns of internode elongation in alfalfa from a variety of perspectives, including phenotype, cytology, and molecular biology, and to clarify the mechanism of alfalfa plant height development, there is necessary to use tall- and short-stem alfalfa varieties with notable differences in internode length and constant internode numbers as experimental materials. Further study is still needed on the genetic control mechanism as well as the underlying causes of the variations in plant height in alfalfa.
The average internode number ranged between 24.6 for F 2908 and 27 for F2906 (Table 3). The genotypes F2905 and F2910 have the same internodes number (26) as the control genotype (Catinca). The only alfalfa genotype that recorded higher number of internodes was F 2906 with 3.8% more than the control.
[14] showed there is no significant difference in the number of internodes between tall- and short-stem alfalfa materials.

Table 3. Alfalfa number of internodes (average 2019-2022)

No	Genotype	Internodes number (10 stems / variant) mower				Relative number %
		I	II	III	Total cm	
1	Catinca - Control	9.0	8.9	8.1	26.0	100
2	F Ileana	8.1	9.4	7.6	25.1	96.5
3	F 2020	9.0	9.0	7.4	25.4	97.6
4	F 2905	8.8	9.5	7.7	26.0	100
5	F 2906	8.8	9.7	8.5	27.0	103.8
6	F 2907	8.3	9.6	7.8	25.7	98.8
7	F 2908	8.3	8.9	7.4	24.6	94.6
8	F 2909-1	8.3	9.2	8.0	25.5	98
9	F 2909-2	8.2	9.0	7.8	25.0	96.1
10	F 2910	8.7	9.5	7.8	26.0	100

Source: own data.

There was a significant and positive correlation between stem elongation and internode number (r = 0.4448). The growing rhythm seems to be particular for each alfalfa genotype depending on climatic conditions and genetic background [14]. Thus, the fastest growing rhythm was observed to the genotype F2905 and the lowest to F2910 (Table 4).

Table 4. Alfalfa growing rhythm (cm) (average 2019-2022)

No.	Genotype	Growth rhythm (cm)		
		*RI	RII	RIII
1	Catinca - Control	1.5	1.5	3.5
2	F Ileana	1.5	1.5	1.5
3	F 2020	2.5	1.5	1.0
4	F 2905	3.0	2.0	3.5
5	F 2906	1.0	2.0	3.5
6	F 2907	1.0	1.5	1.5
7	F 2908	1.5	3.0	2.0
8	F 2909-1	1.0	2.0	1.0
9	F 2909-2	1.0	3.0	1.0
10	F 2910	1.0	1.0	1.0

Source: own data *R= replication

Previous findings emphasized that alfalfa economic sustainability is threatened by lower rates of genetic yield gain in comparison with cereals, such as maize or wheat, which have gained importance as forage crops in the last decades [2].
The present study revealed that alfalfa yield can vary significantly based on factors like climate, genotype and management practices. However, under optimal conditions, alfalfa has shown remarkable yield potential, often surpassing other forage crops.
Analysis of input costs demonstrated that tillage, seed irrigation and balling were major cost components in alfalfa production (Table 5). This suggests that sustainable practices, such as no-till farming and efficient irrigation systems, can reduce these costs and enhance economic efficiency. The research found that alfalfa prices have remained relatively stable,

making it an attractive option for consistent revenue generation.
The results of this study suggest that alfalfa production can be economically efficient under various conditions.
The most economic efficient and profitable was the genotypes F 2907, F2908 and F 2910.

Table 5. Alfalfa economic efficiency (2019-2022)

No	Genotype	Yield	Price	Gain	Costs	Vn	R	
		Kg/ha/ 3 years	Lei/kg	lei/ha/ 3 years	lei/ha/ 3 years	lei/ha/ 3 years	%	Diff. %
1	Catinca Control	37,100	0.585	21,704	12,950	8,754	67.59	100
2	F Ileana	37,210	0.585	21,768	12,950	8,818	68.09	100.7
3	F 2020	37,930	0.585	22,189	12,950	9,239	71.34	105.5
4	F 2905	36,660	0.585	21,446	12,950	8,496	65.61	97.1
5	F 2906	36,530	0.585	21,370	12,950	8,420	65.02	96.2
6	F 2907	39,710	0.585	23,230	12,950	10,280	79.38	117.4
7	F 2908	39,630	0.585	23,184	12,950	10,234	79.02	116.9
8	F 2909-1	37,760	0.585	22,090	12,950	9,140	70.58	104.4
9	F 2909-2	36,010	0.585	21,066	12,950	8,116	62.67	92.7
10	F 2910	38,830	0.585	22,716	12,950	9,766	75.41	111.6

*Vn = net proft; R = Profitability Rate
Source: Own data.

Factors such as high yield potential, stable market prices, and the potential for reduced input costs make alfalfa a viable choice for farmers seeking to maximize their profitability. Managing input costs is critical to maximizing profitability. Moreover, the environmental benefits associated with alfalfa cultivation further enhance its appeal. Farmers can enhance their economic outcomes by adopting new alfalfa genotypes, improving resource use efficiency, and exploring sustainable production methods. Sustainable practices not only benefit the environment but also contribute to profitability.
Water-efficient irrigation, reduced tillage, and using new performant genotypes not only lower costs but can also open up premium markets for sustainably produced alfalfa.

CONCLUSIONS

For increasing alfalfa productivity and advancing the grass and animal industries, it is of great significance to cultivate new alfalfa (*Medicago sativa* L.) types with high yield and quality.
Forage yield and phenotypic traits varied between cultivars in each year of the experiment, as shown by the interactions between year x cultivar x forage yield. The most economic efficient and profitable was the genotypes F 2907, F2908 and F 2910.
Alfalfa production exhibits considerable economic efficiency potential, particularly when managed optimally and in regions with favourable conditions. Farmers, policymakers, and agricultural stakeholders should consider alfalfa as a sustainable and profitable crop choice. Future research should focus on refining management practices and assessing the long-term economic and environmental impacts of alfalfa cultivation.

REFERENCES

[1]Annicchiarico, P., 2021, Breeding gain from exploitation of regional adaptation: An alfalfa case study. Crop Science, Vol.61(4):2254-2271.
[2]Annicchiarico, P., Barrett, B., Brummer, E.C., Julier, B., Marshal, A.H., 2015, Achievements and challenges in improving temperate perennial forage legumes. Critical Reviews in Plant Science, Vol. 34:327–380.
[3]Brummer, E.C., Undersander, D.J., Sulc, R.M., Rhodes, L.H., Sheaffer, C.C., Lamb, J.F.S., 2006, Five decades of alfalfa cultivar improvement: Impact on forage yield, persistence, and nutritive value. Crop Science, Vol.46: 902–909.
[4]Cai, X.X., Zhang, S., Wang, H., Lv, R.L., Li, X.H., Zhou, Q., 2017, The present research situation and

application prospects of rice plant type genes. Molecular Plant Breeding, Vol.15:2809–2814.

[5]Caia, A., Magazin, P., Ștefan, G., 1998, Agrarian economy (Economie agrară). „Ion Ionescu dela Brad" Publishing House, Iași, pp.58.

[6]Chen, R.F., Fan, Y.G., Yan, H.F., Zhou, H.W., Zhou, Z.F., Weng, M.L., Huang, X., Lakshmanan, P., Li, Y., Qiu, L.H., Wu, J., 2020, Enhanced Activity of Genes Associated with Photosynthesis, Phytohormone Metabolism and Cell Wall Synthesis Is Involved in Gibberellin-Mediated Sugarcane Internode Growth. Frontiers in Genetics, Vol.11, 570094.

[7]Durău, C.C., Sărățeanu, V., Cotuna, O., Paraschivu, M., 2021, Impact of the grassland management planning application on some features of the grassland vegetation from Western Romania – Case Study. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 21(3):325-331.

[8]Elgharably, A., Benes, S., 2021, Alfalfa biomass yield and nitrogen fixation in response to applied mineral nitrogen under saline soil conditions. Journal of Soil Science and Plant Nutrition, Vol. 21:744-755.

[9]Fernandez, A.L., Sheaffer, C.C., Tautges, N.E, Putnam, D.H., Hunter, M.C., 2019, Alfalfa, Wildlife, and the Environment (2nd ed.). National Alfalfa and Forage Alliance, St. Paul, MN. pp.136.

[10]Frawley, B. J., Best, L. B., 1991, Effects of mowing on breeding bird abundance and species composition in alfalfa fields. Wildlife Society Bulletin (1973-2006), Vol.19(2):135-142.

[11]Hadidi, M., Palacios, J. C. O., McClements, D. J., Mahfouzi, M., Moreno, A., 2023, Alfalfa as a sustainable source of plant-based food proteins. Trends in Food Science & Technology, Vol. 135: 202-214.

[12]Holland, J. B., Bingham, E. T., 1994, Genetic improvement for yield and fertility of alfalfa cultivars representing different eras of breeding. Crop science, Vol. 34(4):953-957.

[13]Holland, J. D., Fahrig, L., 2001, Landscape woody border increases insect diversity in alfalfa fields. Hedgerows of the World, 167-176.

[14]Jing, F., Shi, S., A. Y., Guan, J., Lu, B., Wu, B., Wang, W., Ma, R., Nan, P., 2023, Analysis of Phenotypic and Physiological Characteristics of Plant Height Difference in Alfalfa. Agronomy. Vol. 13(7):1744.

[15]Julier, B., Gastal, F., Louarn, G., Badenhausser, I., Annicchiarico, P., Crocq, G., Le Chatelier, D., Guillemot, E., Emile, J. C., 2017, Alfalfa (lucerne) in European cropping systems. In D. Murphy-Bokern, F. Stoddard & C. Watson (Eds.), Legumes in Cropping Systems, p. 168–191.

[16]Kebrom, T.H., McKinley, B., Mullet, J.E., 2017, Dynamics of gene expression during development and expansion of vegetative stem internodes of bioenergy sorghum. Biotechnol. Biofuels, Vol.10, 159.

[17]Kumar, T., Bao, A. K., Bao, Z., Wang, F., Gao, L., Wang, S. M., 2018, The progress of genetic improvement in alfalfa (*Medicago sativa* L.). Czech Journal of Genetics and Plant Breeding, Vol. 54(2):41-51.

[18] Lamb, J. F., Sheaffer, C. C., Rhodes, L. H., Sulc, R. M., Undersander, D. J., Brummer, E. C., 2006, Five decades of alfalfa cultivar improvement: Impact on forage yield, persistence, and nutritive value. Crop science, Vol. 46(2): 902-909.

[19]Li, X., Brummer, E. C., 2012, Applied genetics and genomics in alfalfa breeding. Agronomy, Vol.2(1):40-61.

[20]Lindenmayer, R.B., Hansen, N.C., Brummer, J., Pritchett, J.G., 2011, Deficit irrigation of alfalfa for water-savings in the great plains and intermountain west: A review and analysis of the literature. Agronomy Journal, Vol.103: 45–50.

[21]Market Research Report, 2022, Alfalfa Market Size, Share and Covid-19 Analysis, by Animal Type (Cattle, Horse and Others), By Feed Type (Hay, Cubes and Pellets) and Regional Forecast, 2021-2028. https://www.fortunebusinessinsights.com/alfalfa-pellets-market-103597, Accessed on September 12, 2023.

[22]Putnam, D., Russelle, M., Orloff, S., Kuhn, J., 2001, Alfalfa, wildlife, and the environment: The importance and benefits of alfalfa in the 21st Century. California Alfalfa and Forage Association, Novato, CA. http://agric.ucdavis.edu/files/242006.pdf Accessed on September 12, 2023.

[23]Putnam, D., 2015, Why alfalfa is the best crop to have in a drought. University of California- Davis. Alfalfa and Forage News. https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=17721, Accessed on September 10, 2023.

[24]Russelle, M., 2021, After an 8,000-year journey, the "Queen of forages" stands poised to enjoy renewed popularity. American Scientist, Vol. 89:252–261.

[25]Santamaría-Fernández, M., Lübeck, M., 2020, Production of leaf protein concentrates in green biorefineries as alternative feed for monogastric animals. Animal Feed Science and Technology, Vol. 268, 114605.

[26]Sărățeanu, V., Cotuna, O., Paraschivu, M., Cojocariu, L.L., Horablaga, M.N., Rechițean, D., Mircov, V.D., Sălceanu, C., Urlică, A.A., Copăcean, L., 2023. Features of natural succession of ex-arable forest-steppe grass-land (from western Romania) under the influence of climate. Plants, Vol. 12(6):1204.

[27]Sheaffer, C. C., Martin, N. P., Lamb, J. F., Cuomo, G. R., Jewett, J. G., Quering, S. R., 2000, Leaf and stem properties of alfalfa entries. Agronomy Journal, Vol.92(4):733-739.

[28]Shebl, M. A., Kamel, S. M., Hashesh, T. A. A., Osman, M. A., 2008, The most common insect species in alfalfa fields in Egypt. Academic Journal of Entomology, Vol.1(2):27-31.

[29]Sun, H., Peng, Q., Guo, J., Zhang, H., Bai, J., Mao, H., 2022, Effects of short-term soil exposure of different doses of ZnO nanoparticles on the soil environment and the growth and nitrogen fixation of alfalfa. Environmental Pollution, Vol. 309, 119817.

[30]Velea, L., Bojariu, R., Burada, C., Udristioiu, M.T., Paraschivu, M., Burce, R.D., 2021, Characteristics of extreme temperatures relevant for agriculture in the near future (2021-2040) in Romania. Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. X:70-75.

[31]Wang, Y.J., Zhao, J., Lu, W.J., Deng, D. X., 2017. Gibberellin in plant height control: Old player, new story. Plant Cell Reports, Vol. 36:391–398.

[32]Wang, F.X., Yu, Z.P., Zhang, M.L., Wang, M.L., Lu, X.D., Liu, X., Li, Y.B., Zhang, X.S., Tan, B.C., Li, C.L., Ding, Z., 2022, ZmTE1 promotes plant height by regulating intercalary meristem formation and internode cell elongation in maize. Plant Biotechnology Journal, Vol.20:526–537.

[33]Yost, M.A., Russelle, M.P., Coulter, J.A., 2014, Field-specific fertilizer nitrogen requirements for first-year corn following alfalfa. Agronomy Journal, Vol.106: 645-658.

[34]Zhao, Y., Liu, X., Tong, C., Wu, Y., 2020. Effect of root interaction on nodulation and nitrogen fixation ability of alfalfa in the simulated alfalfa/triticale intercropping in pots. Scientific reports, Vol. 10(1), 4269.

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OBSTACLES OF ORGANIC AGRICULTURE IN IRAN

Masoud SAMIAN[1], Khalil MIRZAEI[2]

[1]Jihad University, Research Group for Entrepreneurship Development and Sustainable Rural Employment Studies, Hamedan, Iran. E-mails: samian.masoud@yahoo.com.
[2]Jihad University, Research Group for Entrepreneurship Development and Sustainable Rural Employment Studies, Hamedan, Iran. E-mails: khalilmirzayi@yahoo.com.

Corresponding author: samian.masoud@yahoo.com

Abstract

Nowadays, thousands tons of chemicals material are used to increase agricultural production that provides a risky situation for the communities. Recently, biological or organic agriculture is considered to get rid of such problems. But this style of agriculture is facing with many difficulties and challenges. The purpose of this research is to investigate the obstacles to the development of organic agriculture in Kohgiluyeh and Buyer-Ahmad provinces of Iran. This study was performed in three phases by using Delphi method. In this regard, the statistical population of the study were 32 experts of Jihad Agricultural Organization of Kohgiluyeh and Buyer-Ahmad Province, Iran. The results show that, regarding economic barriers, lack of governmental support; regarding social - cultural barriers, lack of consumption culture of organic products and regarding the political and administrative barriers, lack of clear policies and legislation in the field of organic farming are the main obstacles. Weakness in the education system for the production and consumption of organic products is also among the highest priorities in educational barriers. Education and culturalization in the field organic agriculture and appointing a special organization for this purpose seems to be essential.

Key words*: *organic agriculture Delphi Study barriers, Iran

INTRODUCTION

One of the basic requirements of people is the need for food and people. Governments around the world are trying to meet that need and to achieve food security by using agricultural production in different ways. But one of the problems of providing safe food the world's growing population is the excessive use of fertilizers and chemical pesticides causing health and environmental problems for communities. To get rid of problems including environmental pollution, food poisoning, destruction of soil structure, all due to the uncontrolled use of chemicals, organic or biological farming is now considered [6].
Organic agriculture is a new production system which avoids the use of artificial fertilizers, pesticides, growth regulators and livestock feed additives [18]. [6] and [16] believe that organic agriculture has the potential to solve some of the problems that modern agriculture can provide; also, this type of farming affects deeply on environmental issues of rural communities [3].
But [11], as quoted by Roberts (2004), stated that organic farming is a system that started in Europe long before the emergence of the effects of the great revolution of technology in agricultural. The idea of its pioneers is to develop a farm as a system that uses its resources. The external resources are used only when it is needed. An important organic agriculture theory states that: modern technology must be used in a selective manner and the use of risky or harmful elements should be avoided. Using such elements may lead to the separation of agriculture from its natural environment [10].
In different countries, in the last several years the tendency toward consuming organic products has increased due to some of the reasons that mentioned above.
Organic agriculture has been fundamentally established in Iran after developing national standards and is called “Guide to producing, processing, labeling and marketing organic

foods". This valuable national standard was approved in National Standard of Food and Food Products Committee on 3 October of 2008. After its approval, broad activities had been started in Iran Organic Association and private enterprises to execute all stages in accordance with this standard, from production to supply. The first organic inspection company received its approval from Iran Standards and Industrial Research on Summer of 2010. All of these activities lead to the creation of Iran National Organic Program. Various stages of the implementation of such activities have been facilitated since then [9].

According to what was mentioned above, the production of organic agricultural products must be taken seriously, and in order to produce, in terms of both the quantity and the quality, there must be a careful and systematic planning.

Kohgiluyeh and Buyer-Ahmad Province has 157,251 hectares of agricultural land and it has around 48,764 units of agricultural land exploitation (Iran Statistics Center, 2007) [7]. This province can be a very suitable region for organic agriculture due to climatic characteristics and also numerous talents in agriculture and gardening. But, organic agriculture is not implemented in production units and it is not highly welcomed among individuals. So, for this reason, in this study barriers and inhibitors of organic agriculture in this province are identified and reviewed.

Several researchers have been carried out many studies in Iran and other parts of the world regarding the importance organic agriculture; and, for ease of understanding, some of them are mentioned below. [13] have evaluated the status of organic agriculture as the context of sustainable development of agriculture. Findings show that lack of awareness of farmers is the most important barrier in organic agriculture and, informing the farmers is a viable solution in adopting organic agriculture. They also stated that factors such as lack of government support and market guarantees for organic products with reasonable prices are the other obstacles of organic agriculture [13].

[9] examined the barriers of converting of agriculture to organic agriculture in Canada. The results of the study indicated that farmers lack any conventional information about many areas of organic agriculture. Related institutions to organic agriculture can play an important role in providing useful information for organic farmers. Lack of knowledge and skills to manage an organic farm and lack of market opportunities for organic products might be the most important barriers of using it [16].

[14] also surveyed the role of extension in the development of Organic Agricultural in Iran. They believe that agriculture production in a sustainable and organic way leads to reducing healthcare costs, increasing the quality and quantity of agricultural production, increasing the exports and protecting the environment; and, this would be possible only if a holistic extension system is used. They also offer that in order to establish a sustainable movement for initiating and tracking of a biological agricultural system in Iran villages, the first step is to open an academic institution for research and education of production and consumption culture of agricultural products and food processing within a framework of an organic system [14].

On the other hand, [1] have studied the possible areas of the applications of organic agriculture from the perspective of agricultural experts of Kermanshah Province. The results of their study demonstrate that there is a significant relationship between educational and economic factors and the potential of organic agriculture [12].

[12] in their study about the factors affecting the knowledge of agricultural experts in the field of organic agriculture in Khozestan province, found that access to agriculture - environment information and job experience had significant and positive impact on the knowledge of agricultural experts in the field of organic agriculture. A better access to agricultural - environment information can be taken into account an achievement of dynamic and effective extension system [11].

[4] consider the performance reduction of products in the transition process to organic

agriculture. It is the most important concern of the farmers who are deciding to choose organic agriculture. They also examined the risks of such conversion mechanisms. They virtually estimated the rate of wheat production in Khorasan Province by using organic cultivation. The results of their study showed that the elimination of chemical inputs from the production process will decrease 18/95 percent the wheat performance. This size of reduction is even higher in small farms. Based on their findings, they proposed the following items: support such as extensional and financial supports, and also providing non-chemical inputs [17].

In a research on factors influencing adoption of organic agricultural products by consumers, [2] expressed four major factors in terms of their importance: education and information dissemination, servicing - supporting, supervising and economic factors. Education and information dissemination can be interpreted as extensional trainings. Organizing the granted subsides to the agriculture sector can be considered as the servicing - supporting activities [15].

[8], in their research, have identified principles, foundations and challenges of organic agriculture. They mentioned two major problems in organic production: firstly, *social issues*, such as uncertainty over the quality of organic products, inappropriateness of the appearance of organic products compared to other products; and second, economic *problems*, such as higher price of organic products than non-organic products due to higher cost of production. They also compare the usual agricultural products and organic products, and they attribute the common agricultural problems to some factors such as environmental issues, pesticide residues, chemical fertilizers, etc [8].

[18], in their paper, claim that organic agriculture in Europe has grown dramatically in terms of intervening, significant and various policies in recent years. They also investigated organic agriculture policy development in the Europe Union. They discussed the basic concepts of organic agriculture policies in Europe and the role of law in supporting and controlling of organic agricultural. They added that the role of rules can be very useful in achieving the goals [6].

On the other hand, [5], in their study, had compared organic agriculture to traditional one in terms of biodiversity impacts through a comparative investigation and the studies of two systems. These studies aims if there are some strong evidences about the advantages of biodiversity claimed by organic agriculture fans. They concluded that organic agriculture is inherently beneficial for wildlife and farmland and they pointed out that the farmers' knowledge of the environmental impacts of organic agriculture in agriculture and livestock is limited. And this is one of the major inhibitors of accepting organic agricultural [1].

[3] have investigated the factors influencing adopting organic products and they concluded that the major barrier in adopting such products is the consumers' uncertainty about higher quality of organic products [5].

[16] have examined awareness methods and developing organic products procedures in Malaysia and the results of this study suggest that sources of information used by farmers are extension agents, other farmers, researchers and the media, respectively [4].

In another article, Souza et al in their study in the West Virginia in America, have examined the factors influencing the adoption of sustainable farming practices. The results indicated that there is a negative significant relationship between the adoption of sustainable farming practices by farmers of West Virginia and with the farmers' age and cooperation. There is a positive significant relationship between the adoption of sustainable farming practices by farmers of West Virginia and the farmers' level of education.

MATERIALS AND METHODS

This study discusses on the obstacles of the organic agriculture in Boyer-Ahmad province by using Delphi method. In this regard, the statistical population of the study are 32 experts of Jihad Agriculture Organization of Kohgiluyeh and Buyer-Ahmad Province which were selected based on targeted sampling. In the first phase, some open questions were handed to the respondents, and their opinions about identifying barriers and inhibitors of organic farming in this province was discussed. Then in the second step, factorial analysis was used for analyzing the findings. These barriers are categorized into four groups: economic, social-cultural, political-managing and educational barriers. Then, after prioritizing and identifying these barriers, questionnaires were designed based on the mentioned barriers. The validity of the questionnaire was approved by the Faculty members of Yasuj University Department of Rural Development; and, to estimate reliability, 20 questionnaires were distributed out of statistical population, and then the collected data were analyzed by using SPSS software. The Cronbach's alpha coefficient of the questionnaire was more than 0.65 that shows that the questionnaire has high reliability. After gathering information, these barriers had been prioritized using the coefficient of variation.

RESULTS AND DISCUSSIONS

Descriptive analysis of the demographic characteristics of the respondents showed that the average age of the respondents is about 42.8 and the standard deviation was about 12.2 years. Regarding respondents' level of education, the degree of 4 people (12.5 percent) was General diploma 15 people (46.5 percent) was Bachelor of Science, and 6 people (18.7 percent) was Master of Science. Most of the respondents were male (87.5 percent or 28 people) and 12.5 percent of them (4 people) were female (Table 1).

Table 1. Frequency distribution of respondents according to demographic characteristics (n=32)

Variable	Levels of variable	frequency	percentage	Cumulative percentage	Mean	SD
Age	Less than 30	4	12.5	12.5	42.85 years	12.23
	30 to 40	15	46.5	59		
	41 to 50	10	31.2	90.2		
	More than 50	3	9.8	100		
	Total	32	100	_		
Level of education	General diploma	5	15.6	15.6		
	BS	21	65.7	81.3		
	MS	6	18.7	100		
	Total	32	100	_		
gender	Male	28	87.5	87.5		
	Female	4	12.5	100		
	Total	32	100	_		

Source: research findings.

As it can be seen in Table 2, regarding the economic barriers, the following items are the main priorities: low governmental supports (the coefficient of variation 0.15), the lower performance of organic products than non-organic ones (with a coefficient variation of 0.17), and financial weaknesses of the farmers and their needs to more products (with a coefficient variation of 0.18).

Table 3 also shows that regarding the cultural-social barriers, the following items are the main priorities: lack of consumption culture of organic products (with a coefficient variation of 0.10), the farmers' consideration of the quantity rather than the quality (with a coefficient variation of 0.12), uncertainty over higher quality of organic products and lack of necessity to produce and consume organic products (with a coefficient variation of 0.13).

Table 2. Prioritizing economic barriers to the implementation of organic agriculture

Economic barriers	Mean	SD	CV	Priority in group
Low governmental supports (loans and bank credits)	4.44	0.71	0.15	1
The lower performance of organic products than non-organic ones	4.53	0.80	0.17	2
Financial weaknesses of the farmers and their needs to more products	4.38	0.75	0.17	3
Organic products are less market-friendly	4.31	0.82	0.18	4
Increase in unemployment and migration due to organic cropping	3.94	0.84	0.19	5
Not-providing proper tools and infrastructure for organic agriculture	4.19	0.89	0.21	6
High costs of producing organic crops	4.06	0.91	0.22	7

Source: research findings.

Table 3. Prioritizing social - cultural barriers of the implementation of organic agriculture

Social - cultural barriers	Mean	SD	CV	Priority in group
Lack of consumption culture of organic products	4.62	0.49	0.10	1
The farmers' consideration of the quantity rather than the quality	4.41	0.56	0.12	2
Uncertainty over higher quality of organic products	4.28	0.58	0.13	3
Lack of necessity to produce organic products	4.34	0.60	0.13	4
Lack of necessity to consume organic products	4.31	0.69	0.16	5
More inappropriate appearance of organic products	4.38	0.70	0.16	6
Poor participation of the farmers	4.41	0.71	0.16	7
New technologies are difficult to be understood by farmers	4.19	0.79	0.21	8

Source: research findings.

The results shown in Table 4 also suggest that regarding political and managing barriers, the following items are the main priorities: lack of determined policy and legislation in the field of organic agriculture (with a coefficient variation of 0.10), lack of specific sponsorship in Agriculture Departments for organic agriculture (with a coefficient variation of 0.11) and lack of proper planning for the development of organic agriculture (with a coefficient variation of 12.0).

Table 4. Prioritizing political and managing barriers to the implementation of organic agriculture

Political and managing barriers	Mean	SD	CV	Priority in group
Lack of determined policy and legislation in the field of organic agriculture	4.69	0.47	0.10	1
Lack of specific sponsorship in Agriculture Departments for organic agriculture	4.56	0.50	0.11	2
Lack of proper planning	4.56	0.56	0.12	3
Lack of familiarity of some of the managers and politicians with organic agriculture	4.49	0.61	0.13	4
Lack of adequate coordination between policy organizations and extensional centers	4.44	0.59	0.13	5
The existence of some troublesome rules	4.56	0.87	0.21	6

Source: research findings.

Table 5 also shows that regarding the educational barriers, the following items are the main priorities: weaknesses of the schools and educational books to distribute the culture of the production and consumption of organic products (with a coefficient variation of 0.10), the farmers' limited ecological knowledge (with a coefficient variation of 0.11), weaknesses of mass media for extending the culture of using organic products (with the coefficient variation 0.12) and weakness of extension system in informing farmers about organic agriculture (with a coefficient variation of 0.12).

Table 5. Prioritize the educational barriers of implementing organic agriculture

Educational barriers	Mean	SD	CV	Priority in group
Weaknesses of the schools and educational books to distribute the culture of the production and consumption of organic products	4.66	0.48	0.10	1
The farmers' limited ecological knowledge	4.62	0.55	0.11	2
Weaknesses of mass media for extending the culture of using organic products	4.56	0.56	0.12	3
Weakness of extensional system in informing farmers about organic agriculture	4.44	0.61	0.12	4
Limited awareness about organic products	4.59	0.61	0.13	5
The farmers lack of knowledge about the hazards of pesticides and chemicals	4.44	0.71	0.16	6
The low level of education in the community	4.31	0.78	0.17	7
The low level of education in rural communities	4.34	0.74	0.18	8

Source: research findings.

CONCLUSIONS

In economic barriers, the following priorities had been identified: low governmental supports (loans and bank credits), the lower performance of organic products than non-organic ones, and financial weaknesses of the farmers and their needs to more products. The main social – cultural barriers are: lack of consumption culture of organic products, the farmers' consideration of the quantity rather than the quality, uncertainty over higher quality of organic products, lack of necessity to produce and consume organic products. The major political and managing factors are lack of determined policy and legislation in the field of organic agriculture, lack of specific sponsorship in Agriculture Departments for organic agriculture and lack of proper planning. And, finally, the major educational factors are weaknesses of the schools and educational books to distribute the culture of the production and consumption of organic products, the farmers' limited ecological knowledge, weaknesses of mass media for extending the culture of using organic products, and weakness of extensional system in informing farmers about organic agriculture.

As this study and other studies indicate, there are many obstacles facing the implementation of organic agriculture. Regarding the importance organic agriculture and in order to removing the obstacles, the following actions are recommended:

-Serious and increasing investment of the government to support organic agriculture;

-Considering the market of organic products and adopting policies such as guaranteed purchase of these products at a higher price;

-Culturalization and need creation for the production and consumption of these products;

-Legislations and specific policies and principled and professional planning for producing organic products;

-Creating an organization or a specific center in the community or agriculture departments which are responsible for this mode of production;

-Making attempts and planning of the media and educational system for organic culture;

-Developing coordination between policy-making organizations and extensional centers in order to extend this cropping method.

REFERENCES

[1]Ajodani, Z., Mehdizadeh, H., Detection of possible development and promotion of organic farming in the province, according to agricultural experts, Journal of Agricultural Research, Extension and Education, No. 4, Winter 2009, pp. 65-73. (In Persian).

[2]Akbarisari, M., Asadi, A., Akbari, M., Fakharzadeh, A., Sokhtanloo, M., 2008, Consumers' Attitudes and factors affecting the adoption of organic agricultural products, Journal of Research on the Economics of Agricultural Development, No. 39, Spring 2008, pp. 133-144. (In Persian).

[3]Angulo, M., Gil, J. M., Tamburo, L., 2003, Food safety and consumers' willingness to pay for labeled beef in Spain. Food Quality and Preference, 9(3): 119–133.

[4]Ghorbani, M., Kochaki, A., Mahmodi, H., 2009, Virtual estimated yield in organic production, Journal of Environmental Sciences, No. 6, Spring 2009, pp. 23-30. (In Persian).

[5]Hole, D. G., Perkins, A. J., Wilson, J. D., Alexander, I. H., Grice, P. V., Evans, A. D., 2005, Does organic farming benefit biodiversity? Biological Conservation. Available online at www. Sciencedirect. com. p: 113-130.

[6]Holt, G. C., Reed, M., 2006, Sociological perspective of organic agriculture, Journal of rural studies, 7(26): 1-20.

[7]Iran Statistics Center, 2007, https://www.amar.org.ir/english, Accessed on December 2007.

[8]Jafari, A., Mahloji, M., Davazdahemamei, S., Solhi, M., 2007, Management of pests, diseases and weeds in organic farming, "Journal of Sustainable Agriculture Science, No. 4, Winter 2007, pp. 42-50. (In Persian).

[9]Khaledi, M., Leyaghati, M., Mohamadamini, M., Vesn, S., 2010, Assessing barriers to conversion to organic farming in Canada, Journal of Environmental Sciences, No. 2, Winter 2010, pp. 109-126. (In Persian).

[10]Lampkin, N., 1997, "Organic Farming" turn translates Kochaki, A., Nakhforosh, A., Zarifketabi, A., 1997, Ferdowsi University of Mashhad Press, 1st. Ed., 331 pages.

[11]Mahmodi, H., Veisi, H., Mahdavidamghani, A., 2009, 2009, Farming approach for achieving sustainable rural development, agriculture, the introduction of multi-function paradigm, Proceedings of the First National Conference on Sustainable Rural Development, Summer. pp. 126-132. (In Persian).

[12]Maleksaedi, H., Ajili, A., Rezaeimoghadam, K., 2009, Factors Influencing Knowledge experts of Khuzestan Agricultural Organic Agriculture Organization of Agriculture, Journal of Research on the Economics of Agricultural Development, ¬ No. 40, Spring 2009, pp. 81-91. (In Persian).

[13]Moradi, ZH., Heydari, H., Azizi, M., Yaghoubi, A., 2011, Organic farming as a development platform Paydarkshavrzy the analysis in terms of farm (case study of city Diwandareh Qorveh), Proceedings of the Second National Conference on Sustainable Rural Development, Hamedan Bu Ali Sina University, Summer 2011. (In Persian).

[14]Norozi, A., Shahbazi, A., 2010, Promote the development of organic farming (biological) in rural areas of the country, Journal of Rural Development, No. 2, Fall Winter 2010, pp. 1-22. (In Persian).

[15]Organic Community Forums, 2008, http:// www.iranorganic.com, Accessed on December 2008.

[16]Roddy, G., Cowan, C. A., Hutchinson, G., 1996, Consumer attitudes and behavior to organic foods in Ireland. Journal of International Consumer Marketing, 9 (2): 41-63.

[17]Souza, D. G., Cyphers, D. M., Phipps, T., 1993, Factors affecting the adoption of sustainable agriculture practices. Agricultural and Resource Economics Review, 22(2): 165-170.

[18]Stolze, M., Lampkin, N., 2009, Policy for organic farming: Rationale and concepts. Food Policy. Journal, 14(39), pp: 237–244.

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ANALYSING AND FORECASTING COMPETITIVENESS: THE CASE OF THE TURKISH COTTON INDUSTRY

Deniz SARICA, Merve Muruvvet DAG

Isparta University of Applied Sciences, Faculty of Agriculture, Department of Agricultural Economics, Isparta-Türkiye, Phone: +902462146239, E-mails: denizsarica@isparta.edu.tr, mervedag@isparta.edu.tr

Corresponding author: denizsarica@isparta.edu.tr

Abstract

Cotton is a significant raw material source for textiles, food, and other sectors, as well as a major influence in worldwide and national trade and industry. The primary goals of this research are to examine the cotton production and trade in which Türkiye plays a significant role in global production; to analyse international competitiveness; and to forecast the next ten years using data from 1961 to 2020. The Revealed Symmetric Comparative Advantage (RSCA) method will be employed to investigate its international competitiveness, and the Autoregressive Integrated Moving Average (ARIMA) Box-Jenkins model will be used to forecast the comparative advantage of the Turkish cotton industry. According to the findings, Türkiye ranks seventh in cotton production, but there was a 21% decrease in 2020 (1.8 million tonnes) compared to 2005 (2.3 million tonnes). When world cotton exports were examined, the USA, Brazil, and India came to the fore, while Türkiye ranked 14th with 87 thousand tonnes in 2020. When the observed cotton RSCA indices for Türkiye were examined, the results revealed no competitive advantage and no specialisation in cotton exports over time. While the RSCA index was 0.68 in 1980, it was down until -0.42 in 2010. In 2020, the RSCA index was -0.03. Furthermore, the forecasting analysis shows that the RSCA indices for cotton export will gradually decline due to periodic fluctuations, eventually falling to -0.18 by 2030. Consequently, the inadequacy of cotton production to meet consumption, as well as cotton imports, may be expressed as reasons for Türkiye's comparative disadvantage.

Key words: *competitiveness, cotton industry, revealed symmetric comparative advantage, Box-Jenkins*

INTRODUCTION

Cotton is a significant raw material source for textiles, food, and other sectors, as well as a major influence in worldwide and national trade and industry. Cotton production is, therefore, strategically important for countries. Making effective use of this power will also contribute significantly to the growth of agriculture-based industries in these countries [10].

The fact that there are just a few countries suitable for cotton farming on the globe increases the plant's importance and worth. China, India, the United States of America (USA), Brazil, Pakistan, Uzbekistan, and Türkiye hold significant cotton agricultural positions in the 2019/2020 production period [51]. In Türkiye, one of the cotton-producing countries, the total cotton area planted in 2020 is 3,592,200 da, with a total production amount of 1,773,646 tonnes [50]. This production level accounts for approximately 2.1% of global cotton production. Despite Türkiye's major position in cotton production, cotton production area and amount have decreased throughout the years [50]. The causes of this drop are as follows: prices are not at an acceptable level; insufficient support; decreased inefficiencies; and increased costs [11, 32, 50]. All of these factors cause manufacturers to create goods that are alternatives to cotton, posing a threat to the sustainability of cotton production. Cotton, which is strategic for the countries, also helps with the development of Türkiye's agriculture-based industry. As a result, with the proper agricultural strategies, these common issues in cotton production should be eliminated as soon as possible.

The impact of agricultural subsidies, one of the most important agricultural policies in cotton farming, on production is fairly significant. According to certain international research [24, 52], cotton subsidies in the USA and Europe diminish cotton supply and raise global cotton prices. [47], on the other hand, indicated that a reduction in the USA cotton subsidies raises international cotton prices only to a certain amount, but this conclusion is not statistically significant.

In this study, the primary goal of the research is to examine the cotton production and trade, in which Türkiye is significant in world production, to analyse international competitiveness, and to forecast the next ten years. In order to analyse international competitiveness and identify the best model and forecast the comparative advantage of the Turkish cotton industry over the next ten years, time series data from 1961 to 2020 are employed. The Autoregressive Integrated Moving Average (ARIMA) Box-Jenkins model will be used to forecast the comparative advantage of the Turkish cotton industry, and the Revealed Symmetric Comparative Advantage (RSCA) method will be employed to investigate its international competitiveness.

As far as we know, no such procedure has been reported to be used in forecasting the Turkish cotton industry's comparative advantage. This research differs significantly from previous studies on the cotton trade. With this study, Türkiye's international competitiveness was revealed and it was aimed to assist the government in decision-making by offering appropriate policy recommendations. The realisation of these goals is of great importance in determining the sustainability of cotton production. Furthermore, the study could serve as an essential source in the design of future large-scale research on cotton.

MATERIALS AND METHODS

Data

The data on cotton export value ($) was collected to calculate RSCA for a period of 60 years from 1961 to 2020 by [16]. The RSCA data from 1961 to 2020 was used to create the best ARIMA model structure. Furthermore, academic studies from national and international scientific journals and books were used.

Competitiveness Calculation Method (RSCA)

The concept of comparative advantage was first introduced by David Ricardo [40] in his book "On the Principles of Political Economy and Taxation" published in 1817. According to this theory, some individuals or countries are more productive than others, and a country that exports the goods and services for which it has the highest comparative advantage in terms of productivity gains from this trade by importing those goods or services at the lowest level of comparative advantage. Afterwards, [5] established a method for determining a country's relative advantage or disadvantage in a specific product class using trade flows. This method, the Revealed Comparative Advantages (RCA) index, serves as the foundation for the computation of comparative advantages. The RCA index is generally used to measure the international competitiveness of countries in certain products or sectors. This index is widely used in agricultural sector research [7, 17, 26, 29, 48]. A country's comparative advantage determines a country's productivity level and explains the country's pattern of specialisation in the international market [43]. Therefore, it is paramount to investigate.

Balassa's [5] RCA index is shown in the equation below:

$$RCA_j^i = \frac{x_j^i / \sum x^i}{\sum x_j^w / \sum x^w} \quad \text{..............................(1)}$$

where:

RCA_j^i: The Revealed Comparative Advantage index of country i in product j,

x_j^i: The export value of product j of country i,

Σx^i: Total agricultural export value of country i,

Σx_j^w: Total world export value of product j,

Σx^w: Total world agricultural export value.

When RCA_j^i>1, it is said that the country has a comparative advantage. However, if RCA_j^i<1,

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the country is considered to have a comparative disadvantage for the particular product. The problem with this index is that the values are asymmetrical. For this reason, [13] proposed the Revealed Symmetric Comparative Advantage (RSCA) index to mitigate the effects of this problem. Because of this issue, the competitiveness of the cotton sector in Türkiye was calculated by using the RSCA index. The formula is as follows:

$$RSCA_j^i = \frac{RCA_j^i - 1}{RCA_j^i + 1} \quad \text{.........................(2)}$$

The result varies between -1 and +1. Accordingly, if the RSCA value is between 0 and 1, the country is a net exporter, and if it is between 0 and -1, it is a net importer.

[25] states that RSCA should be used instead of RCA. The reason for this is that the RCA index changes from 0 to 1 if a country is not specialised in a particular sector, and from 1 to infinity, if a country is specialised. This leads to an erroneous interpretation of the results. For this reason, RSCA values were used instead of RCA in the study.

ARIMA Estimation Method

Time series analysis methods are classified into two types: multivariate and univariate time series estimation methods. [9] estimation method is one of the techniques employed in univariate time series that uses statistical methods to make forward-looking estimations. This estimation method was used in the study to forecast the competitiveness of the cotton industry in Türkiye. To apply the method, the time series must have discrete, stationary, and evenly spaced observation values [2]. Autoregressive (AR), moving average (MA), and autoregressive moving average (ARMA), which combines AR and MA models, are the three most common linear stationary Box-Jenkins models [4]. The ability of the Box-Jenkins method to use previous observation values as an explanatory variable is a significant advantage. Box-Jenkins estimation techniques are an experimental process, not a method expressed with a predetermined model. They can select the appropriate model from a variety of model options and monitor the examination suitability of the chosen model at each stage.

An ARMA model is commonly denoted as ARMA (p, q), where p and q represent the orders of autoregression and moving average, respectively. In the ARMA model, the time series is a linear function of actual past values and random shocks [22]. Equation (3) defines a stationary time series, ARMA (p, q):

$$Y_t = \alpha + \vartheta_1 Y_{t-1} + \vartheta_2 Y_{t-2} + \cdots + \vartheta_P Y_{t-p} + \epsilon_1 + \theta_1 \epsilon_{t-1} + \cdots + \theta_q \epsilon_{t-q} \quad \text{..(3)}$$

where:

α is a constant term for the mean of Y. At time t, Y_t is the dependent variable, and Y_{t-1}, $Y_{t-2} \ldots Y_{t-p}$ denotes the independent variables at lags t-1, t-2,…, t-p. ϑ s denotes the coefficients to be estimated. ϵs are the error terms, uncorrelated random variables with constant variance and zero means. θs are also estimated coefficients.

The AR, MA, and ARMA processes are used on stationary series. Therefore, it is necessary to make a non-stationary process stationary. A non-stationary time series can be made stationary by calculating the difference to the appropriate degree. The original series is referred to as a homogeneous non-stationary series in this case. The time series that are not stationary yet are made stationary by taking the difference and complying with the autoregressive integrated moving average [ARIMA (p, d, q)] processes. Here, the letter d stands for integration (difference). Visual inspection of the data graph, the structure of the autocorrelation, and partial correlation coefficients are useful for confirming stationarity. Another method for determining stationarity is to use unit root tests. If the model is found to be non-stationary, differencing the series will bring it into stationarity. The Generalized Least Square Dickey-Fuller (DF-GLS) [15] unit root test was used in the study to achieve this goal. Furthermore, autocorrelation function (ACF) and partial autocorrelation function (PACF) graphs were created, and it was attempted to visually determine (correlogram) what type of development the series contained.

After determining whether the series is stationary, the identifying process moves on to selecting the initial values for the orders of parameters, p and q. During the identification phase, one or more models that seem to provide statistically appropriate representations of the relevant data are tentatively chosen. The parameters of the model are then precisely estimated using least squares.

Several models are run separately and collectively for various AR and MA combinations. Low Akaike (AIC) or Schwarz (SIC) information criterion, the lack of autocorrelations for residuals, and the importance of the parameters are used to evaluate which model is the best. The information criteria proposed by [1] and [45] are two criteria employed to choose among time series models. The SIC and AIC must have low values. The delayed order, in which values are small, is recognised as the appropriate delay order. As a result, the model with the smallest information criteria value is chosen.

RESULTS AND DISCUSSIONS

Production and trade analysis of the Turkish cotton industry

World cotton production was 29.5 million tonnes in 2020. The top five countries that come to the fore in cotton production are, respectively, China (35.5%), India (21.3%), the USA (11.7%), Brazil (8.5%), and Pakistan (4.2%). These countries account for 81.2% of the total cotton production in the world. China has the highest production share (Table 1).

According to [27], China has a significant share of cotton production and the world price of cotton is the price of cotton in China and nearby ports. Benin experienced the greatest increase in production during the study period. It is, however, still far behind other countries. The reason for this is improper fertiliser application in Benin’s cotton production [19]. Türkiye ranks seventh in global cotton production, accounting for 2.1% of world production. It was discovered that Türkiye’s cotton production had gradually decreased over time, with a 21% decrease in cotton production in 2020 compared to the production period of 2005 (Table 1). Among the reasons for this, the high cost of cotton production in Türkiye, the existence of alternative product diversity in regions such as the Aegean and Cukurova, and the agricultural policies implemented by countries such as the USA are mentioned [3]. Another reason is the decrease in domestic prices due to the effect of cotton stock policies of countries such as China, which play a significant role in cotton agriculture, on the price of the product [36].

Table 1. Volume of world cotton production (1,000 tonnes)

Countries	2005	2010	2015	2016	2017	2018	2019	2020
China	17,142	17,910	16,830	16,029	17,130	18,493	23,505	29,500
India	9,828	17,760	15,943	17,308	17,425	14,657	18,558	17,731
The USA	12,876	9,474	8,469	10,083	12,000	11,133	12,819	9,737
Brazil	3,668	2,950	4,007	3,464	3,843	4,956	6,893	7,070
Pakistan	6,337	5,614	4,872	5,237	5,855	4,828	4,480	3,454
Uzbekistan	3,728	3,443	3,361	2,959	2,854	2,286	2,692	3,064
Türkiye	2,245	2,150	2,050	2,100	2,450	2,570	2,200	1,774
Argentina	448	754	795	673	616	814	873	1,046
Burkina Faso	713	530	769	785	844	482	724	783
Benin	191	137	269	451	598	678	715	728
Others	12,454	8,504	8,667	8,388	10,227	11,153	10,401	8,226
World	69,632	69,224	66,033	67,478	73,842	72,049	83,859	83,113

Source: [16].

According to [38], foreign dependency on production factors raises production costs; the advantage of producing alternative products profitably and with less labour, as well as the inability to supply domestically required and qualified raw materials, are the cotton industry's weaknesses in Türkiye.

The world cotton export amount increased by 4.7% in 2020 compared to 2005 and reached 9.2 million tonnes, and the export value increased by 39.6% and reached 14 billion dollars (Table 2). Cotton exports are dominated by the USA (42.5%), Brazil (23%), India (10.3%), Greece (3.2%), and Benin (3.2%). These countries account for 82.3% of the total global export value. The USA has the highest amount and value of cotton exports. The USA is a major producer and exporter of cotton in the global cotton market [28]. The highest increase in the amount and value of exports belongs to Brazil. Cotton production is important for Brazil in terms of both social and economic terms, as in most countries [8]. Furthermore, Brazil is one of the world's leading cotton producers and is a major competitor of the USA in cotton markets in Asia and Europe [21]. Türkiye ranked 14th in cotton exports in the production period of 2020, with lower global export amounts (0.9%) and values (1.1%) than other countries. Among the reasons why Türkiye lags in cotton exports are as follows: the fluctuations in world prices; the increase in production costs; and the increase in importation due to the need for raw materials in the textile industry [35].

Table 2. World cotton export volume and value

	Countries	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Export Volume (1,000 tonnes)	The USA	3,400	2,962	2,397	2,469	3,253	3,575	3,563	3,822
	Brazil	391	512	834	805	834	916	1,614	2,125
	India	598	1,566	1,251	866	945	1137	616	965
	Greece	232	226	219	218	232	215	360	289
	Benin	161	67	233	122	218	260	270	280
	Australia	599	474	448	717	873	478	541	170
	Burkina Faso	195	164	248	307	226	198	218	167
	Argentina	28	43	51	58	33	105	92	117
	Tajikistan	138	72	66	87	76	93	94	100
	Uzbekistan	1,020	466	345	155	279	116	159	100
	Türkiye	38	29	48	76	59	95	131	87
	Others	2,006	1,171	1,330	1,116	1,048	1,138	1,300	1,001
	World	8,808	7,754	7,470	6,995	8,076	8,325	8,959	9,225
Export Value (1,000 $)	The USA	3,923,870	5,747,637	3,889,807	3,959,220	5,827,921	6,545,933	6,147,102	5,969,433
	Brazil	449,732	821,547	1,290,394	1,215,457	1,357,711	1,587,344	2,640,378	3,226,916
	India	639,704	2,972,199	1,860,980	1,345,899	1,673,471	2,198,729	1,075,032	1,448,516
	Greece	260,561	487,791	326,645	344,201	393,970	399,685	582,635	449,992
	Benin	168,667	98,332	262,356	175,462	345,437	445,433	450,976	448,829
	Australia	770,495	957,524	813,350	1,207,109	1,617,545	977,425	1,086,133	307,109
	Burkina Faso	210,651	222,846	285,427	397,617	332,531	320,077	352,017	263,296
	Argentina	24,866	74,708	47,598	70,405	48,673	165,402	121,126	113,673
	Tajikistan	144,000	123,622	85,679	120,931	121,026	165,303	139,601	135,994
	Uzbekistan	1,170,000	810,155	511,172	229,415	477,102	222,136	281,638	147,318
	Türkiye	52,826	64,206	76,441	124,443	115,659	178,585	229,206	159,811
	Others	2,234,704	1,884,104	1,940,598	1,677,400	1,809,111	1,996,050	2,034,034	1,361,809
	World	10,050,076	14,264,671	11,390,447	10,867,559	14,120,157	15,202,102	15,139,878	14,032,696

Source: [16].

In 2020, global cotton imports increased in quantity (2.5%) and value (34.2%) over 2005, reaching 8.5 million tonnes and 13.7 billion dollars (see Table 3). China (26.6%), Vietnam (15.8%), Bangladesh (14.6%), Türkiye (12%), and Pakistan (9.6%) are the leading cotton importers. China appears to have the highest import amount and value. Since China could not produce enough cotton, it started to import cotton from international markets to meet the demand [42]. However, later on, it decided to reduce its reliance on the global market and began stocking large quantities of cotton in 2010 for this purpose [27]. However, despite this move by China, imports have decreased over time, and it remains the leader in fibre cotton imports (Table 3). During the research period, the highest increase in cotton import amount (9.19 fold) and value (13.01 fold) was experienced in Vietnam. Most of the imported cotton in Vietnam, which ranks second in cotton imports, is from the USA, and this import is usually re-exported to China as yarn [30]. Türkiye ranked fourth in cotton imports in the production period of 2020. It accounted for 12.5% of the total import volume and 12% of the total import value. Türkiye has come to the fore in imports as a result of the decrease in the production area of cotton [12]. Other reasons contributing to the increase in imports include fluctuations in global prices, increases in production costs, and the increase in the need for raw materials in the textile sector [35]. It is also claimed that the tariff applied by China with the increase in imports harms countries such as Türkiye and Argentina [44].

Table 3. World cotton import volume and value

	Countries	2005	2010	2015	2016	2017	2018	2019	2020
Import Volume (1,000 tonnes)	China	2,922	3,123	1,663	1,038	1,283	1,720	1,968	2,158
	Vietnam	151	357	938	1,018	1,269	1,408	1,341	1,389
	Bangladesh	515	401	1,320	655	1,008	1,049	1,142	1,191
	Türkiye	776	889	803	821	914	752	946	1,065
	Pakistan	388	343	275	333	388	606	399	819
	Indonesia	455	613	673	678	788	763	654	486
	Egypt	21	45	85	64	111	113	239	190
	India	83	33	215	464	446	270	687	174
	Thailand	504	384	504	257	255	259	205	134
	Malaysia	55	47	87	92	91	170	205	122
	Others	2,425	1,536	1,179	1,080	1,062	1,043	921	773
	World	8,294	7,771	7,742	6,501	7,616	8,153	8,708	8,500
Import Value (1,000 $)	China	3,580,704	6,171,348	2,846,653	1,777,016	2,408,675	3,419,363	3,754,031	3,661,535
	Vietnam	167,210	673,516	1,607,212	1,643,254	2,331,827	2,727,485	2,400,181	2,176,156
	Bangladesh	665,581	794,399	2,229,517	1,163,288	1,997,370	2,308,893	2,131,906	2,014,804
	Türkiye	908,201	1,720,010	1,232,451	1,238,673	1,676,281	1,395,590	1,585,807	1,652,640
	Pakistan	519,977	596,094	543,748	580,537	761,455	1,048,967	708,505	1,315,549
	Indonesia	576,004	1,148,391	1,087,557	1,087,200	1,268,050	1,441,949	1,117,648	774,649
	Egypt	51,032	120,574	143,588	121,386	236,963	254,343	236,285	168,794
	India	155,766	84,107	386,494	878,983	956,123	621,694	1,320,897	344,649
	Thailand	612,944	735,252	531,971	433,431	484,050	520,954	367,415	218,573
	Malaysia	77,890	90,010	156,844	154,372	169,404	329,646	289,523	209,468
	Others	2,941,103	2,921,086	2,047,097	1,780,467	2,020,321	2,113,627	1,711,225	1,223,539
	World	10,256,412	15,054,787	12,813,132	10,858,607	14,310,519	16,182,511	15,623,423	13,760,356

Source: [16].

The analysis of the competitiveness of the Turkish cotton industry

According to the Revealed Symmetric Comparative Advantage index, Tajikistan (0.98), Benin (0.97), Burkina Faso (0.96), Uzbekistan (0.80), Greece (0.74), India (0.66), the USA (0.62), and Brazil (0.60) had a revealed symmetric comparative advantage in world cotton exports. It was determined that Australia (0.03), Türkiye (-0.07), and Argentina (-0.47) had a comparative disadvantage in 2020 (see Table 4). In Tajikistan, the country with the highest revealed symmetric comparative advantage, cotton is a dominant product of the agricultural sector and the largest source of export revenues [49]. For Benin, which ranks second in terms of comparative advantage, [31] stated that cotton is an important foreign exchange provider in Benin. Other countries with revealed symmetric comparative advantages, including the USA and Brazil, have long been in contentious disagreement over the USA's policies that support cotton producers and exporters through various subsidies and credit guarantees [41]. The USA implemented these policies to increase its competitiveness in cotton against other countries. However, while this situation has an impact on world cotton prices, it also prevents competition [38]. As a matter of fact, it was so, and the cotton trade in Brazil, which competes in the same foreign markets as the USA, has recently stagnated, and the reasons for this have been shown to be decreasing prices, high transportation costs, and a lack of capital to increase productivity [39, 41].

According to the findings of the study, Türkiye lacks competitiveness in the cotton trade. Türkiye has shown a fluctuating course in terms of comparative advantage over the years, eventually becoming a disadvantaged country in 2020. Table 4 shows that Türkiye's comparative disadvantage in exports has become increasingly chronic since the 1980s. The reasons for this are the decisions of January 24, 1980, which had a significant impact on agricultural policies and the military coup of September 12th. The approach to market liberalisation in these decisions altered the course of agricultural policies. Input and product subsidies have been severely reduced or eliminated, the privatisation of public institutions that regulate markets has gained prominence, and markets have been opened to foreign capital [20, 37]. All these have transformed Türkiye from an exporter to an importer of agricultural products. For instance, the RSCA index was 0.68 in 1980 and fell to -0.42 in 2010. The RSCA index was -0.03 in 2020. Consequently, cotton production in Türkiye is insufficient to meet demand, so an average of 900,000–950,000 tonnes of cotton is imported each year [6].

Table 4. RSCA indices for the cotton industry in the world

RSCA	1961	1970	1980	1990	2000	2010	2015	2016	2017	2018	2019	2020
Tajikistan	-1.00	-1.00	-1.00	-1.00	0.95	0,95	0.97	0.98	0.97	0.98	0.97	0.98
Benin	0.16	0.60	0.73	0.94	0.96	0,85	0.97	0.97	0.97	0.97	0.97	0.97
Burkina Faso	-0.68	0.65	0.87	0.93	0.95	0,96	0.96	0.97	0.96	0.95	0.96	0.96
Uzbekistan	-1.00	-1.00	-1.00	-1.00	0.96	0,96	0.96	0.93	0.94	0.88	0.88	0.80
Greece	0.27	0.44	-0.18	0.29	0.76	0,76	0.73	0.74	0.73	0.70	0.79	0.74
India	-0.22	-0.24	0.33	0.70	-0.68	0,85	0.76	0.72	0.69	0.74	0.56	0.66
The USA	0.37	0.01	0.33	0.41	0.37	0,57	0.52	0.55	0.61	0.63	0.62	0.62
Brazil	0.11	0.24	-0.93	-0.28	-0.73	-0,02	0.33	0.35	0.26	0.29	0.52	0.60
Australia	-1.00	-0.90	-0.61	0.17	0.57	0,47	0.45	0.63	0.62	0.45	0.51	0.03
Türkiye	0.42	0.76	0.68	0.33	-0.22	-0.42	-0.31	-0.03	-0.16	0.01	0.08	-0.07
Argentina	-0.70	-0.49	-0.21	-0.05	-0.53	-0,71	-0.72	-0.61	-0.74	-0.33	-0.51	-0.47

Source: Authors' calculations.

Forecasting the comparative advantage of the Turkish cotton industry

As previously stated, trend analysis using the ARIMA Box-Jenkins technique was used in this research to anticipate Turkish cotton competitiveness from 2020 to 2030. In the study, a unit root test was first conducted to get reliable findings from the model evaluation. Therefore, the Generalized Least Square Dickey-Fuller (DF-GLS) [15] and Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) [23] unit root tests were employed, and the results of the tests are presented in Table 5. [15] expanded on the ADF test by proposing the DF-GLS unit root test, which is an efficient approach for detecting if a single time series has a unit root. The DF-GLS test surpasses the augmented Dickey-Fuller (ADF) test [14] in terms of small sample size and power. Furthermore, the Modified Akaike Information Criterion (MAIC) of [34] determines the optimal lag order, while the Schwert Criteria indicate the maximum lag length [46]. Regarding the KPSS test, it is assumed that the series is stationary. For the majority of unit root tests, the null hypothesis is that the series is non-stationary. The KPSS test, on the other hand, takes a different technique, and the null hypothesis is the inverse. Hence, the test is generally performed as a confirmatory analysis. To obtain correct results, lag length selection is critical, and [33] suggested an automatic lag order selection technique for this test. Consequently, the maximum lag length is found in the research using this technique since it provides the highest performance in small samples [18]. The data series were examined under the linear trend and constant cases, as in the DF-GLS test. In the DF-GLS test, the series was non-stationary in the constant and linear trend cases, although it was non-stationary with a significance of 5% in the constant case and a significance of 10% in the linear trend case in the KPSS test. Overall, evidence suggests that all series are non-stationary. The first-order differencing approach was employed to make it stationary, and the results are reported as I(1) in Table 5.

Table 5. DF-GLS and KPSS time series unit root tests

		Lag Length	Constant	Lag Length	Trend
DF-GLS	**I(0)**	2	-1.016	2	-1.861
	I(1)	1	-10.054	1	-10.085
KPSS	**I(0)**	6	0.789	5	0.134
	I(1)	4	0.088	4	0.088

Notes:
(1)The test was performed in EViews 10.
(2)In the DF-GLS test, the asymptotic critical values for constant case are -2.606 (1%), -1.947 (5%) and -1.613 (%10), and for the trend case are -3.743 (%1), -3.168 (%5) and -2.869 (%10).
(3)In the KPSS test, the asymptotic critical values for constant case are 0.739 (1%), 0.463 (5%) and 0.347 (%10), and for the trend case are 0.216 (%1), 0.146 (%5) and 0.119 (%10).
Source: Authors' calculations.

Thus, no further differentiation of the time series is required, and d = 1 for the ARIMA (p, d, q) model. This test allows us to move forward in the development of the ARIMA model by selecting appropriate values for p in AR and q in MA in the model. As a result, the next step is to analyse the ACF and PACF graphs and statistics for stationary and non-stationary time series (Figure 1).

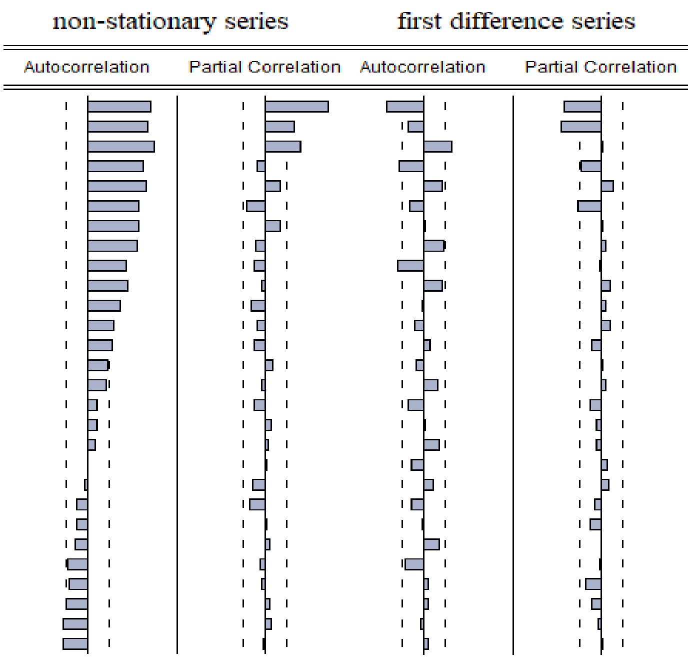

Fig. 1. ACF and PACF graphs of non-stationary and first differenced series
Note: The correlogram was performed in EViews 10.

The ARIMA model for the RSCA of cotton series was detected using the ACF and PACF graphs. There is no autocorrelation or partial autocorrelation in the series because the lag values were determined to be within the limits, and the coefficients were not related to each other.

Following the examination of the correlograms, many different ARIMA models were explored, and the ARIMA (2, 1, 3) model yielded the best statistical results.

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Table 6 displays the model's results, and all variables were found to be statistically significant.

Table 6. Results for the ARIMA (2, 1, 3) model of the RSCA index series

TYPE	Coefficient	Std. Error	P-value
C	0.200031	0.174711	0.2571
AR(2)	0.562565	0144448	0.0003
MA(3)	0.352634	0.105801	0.0015
SIGMASQ	0.082101	0.019837	0.0001
R-squared	0.561244		
F-statistics	23.87787		
AIC	0.489977		
SIC	0.629600		
HQ	0.544591		
Durbin-Watson stat.	1.437373		

Note: The model was performed in EViews 10.
Source: Authors' calculations.

Furthermore, the DF-GLS and KPSS unit root tests were used to assess the model's accuracy by creating the residual variable. Consequently, the residual series is stationary (Table 7).

Table 7. DF-GLS and KPSS time series unit root tests for residuals

	Lag Length	Constant	Lag Length	Trend
DF-GLS	0	-5.399	1	-7.255
KPSS	1	0.832	11	0.130

Notes:
(1)The test was performed in EViews 10.
(2)In the DF-GLS test, the asymptotic critical values for constant case are -2.606 (1%), -1.947 (5%) and -1.613 (%10), and for the trend case are -3.743 (%1), -3.168 (%5) and -2.869 (%10).
(3)In the KPSS test, the asymptotic critical values for constant case are 0.739 (1%), 0.463 (5%) and 0.347 (%10), and for the trend case are 0.216 (%1), 0.146 (%5) and 0.119 (%10).
Source: Authors' calculations.

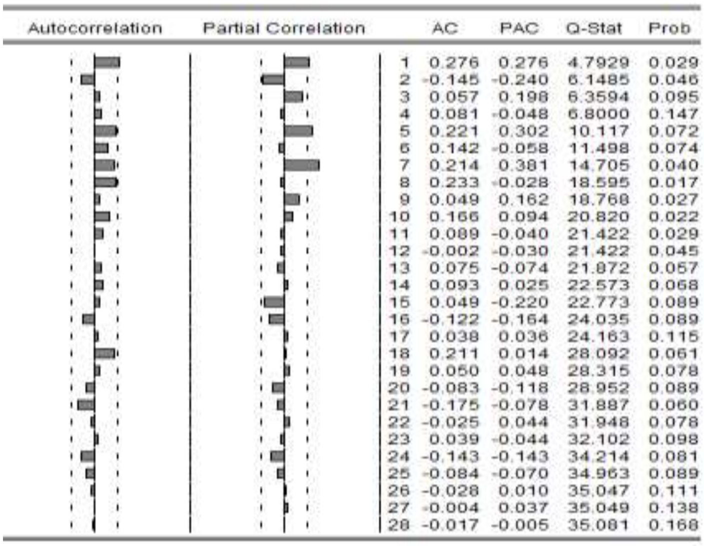

Fig. 2. ACF and PACF graphs of the residual values of the ARIMA (2, 1, 3) model
Note: The correlogram was performed in EViews 10.
Source: Authors' calculations.

It was discovered that there was no fluctuation, the levels of significance were not surpassed, and the model had appropriate levels for forecasting, when the ACF and PACF graphs of the ARIMA (2, 1, 3) model's residual values were examined (Figure 2). Based on these results, it is evident that ARIMA (2, 1, 3) is the best fitting model for the RSCA series.

The RSCA indices were calculated using cotton export data from 1961 to 2020. The ARIMA model was employed to forecast for the period 2020–2030 after analyzing the competitiveness level of the Turkish cotton industry using the RSCA indices. Figure 3 shows the RSCA indices' actual and forecast graphs for the considered period.

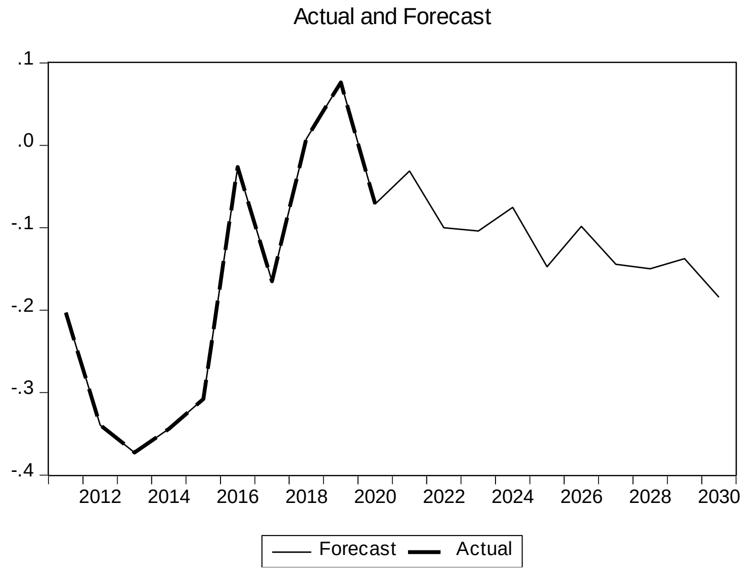

Fig. 3. Actual (1961-2020) and forecasted (2020-2030) data graphs for cotton RSCA index of Türkiye
Note: The graph was performed in EViews 10.
Source: Authors' calculations.

Furthermore, the RSCA indices for the cotton forecast from 2020 to 2030 will have gradually decreased by experiencing periodic fluctuations and will have dropped to -0.18 by 2030. It shows that the competitiveness of the cotton industry will deteriorate over the years. It can be a guide for policymakers as they prepare to determine policies based on future cotton export and increase competition to take necessary action and make changes.

CONCLUSIONS

Cotton is one of the most important agricultural products traded globally, contributing to the country's economy. Cotton is a strategic product due to the limited number of countries in the world that are suitable for cotton farming. When it comes to foreign trade, it is critical to the economy of every country, especially in today's globalising world. For this purpose, calculating and forecasting the competitiveness of such significant commercial crops is crucial for the future of the cotton industry. Firstly, in this study, production and trade analysis of the cotton industry was examined. Secondly, Türkiye's international competitiveness in the cotton industry is demonstrated by the Revealed Symmetric Comparative Advantage (RSCA) index. Finally, the cotton RSCA indices in Türkiye for the following ten years were estimated using the time series estimation technique of the ARIMA Box-Jenkins model.
It was revealed that the most important cotton producers in the world are China, India, the USA, Brazil, Pakistan, Uzbekistan, Türkiye, Argentina, Burkina Faso, and Benin. Türkiye ranks seventh in cotton production, but it was seen that there was a 21% decrease in production in 2020 (1.8 million tonnes)

compared to the production period of 2005 (2.3 million tonnes). When world cotton exports were examined, the USA, Brazil, and India came to the fore, while Türkiye ranked 14th with 87 thousand tonnes in 2020. Among the reasons why Türkiye lags in cotton exports are the fluctuations in world prices, the increase in production costs, and the increase in importation due to the need for raw materials in the textile sector.

According to the RSCA index used in the study, Tajikistan, Benin, Burkina Faso, Uzbekistan, Greece, India, the USA, and Brazil have a revealed symmetric comparative advantage in world cotton exports, while Australia, Türkiye, and Argentina have a comparative disadvantage. When the observed cotton RSCA indices for Türkiye were specifically investigated, the results revealed no competitive advantage and no specialization in cotton exports over time. For example, while the RSCA index was 0.68 in 1980, it was down until -0.42 in 2010. In 2020, the RSCA index was -0.03. The inadequacy of cotton production to meet consumption, as well as cotton imports, are expressed as reasons for Türkiye's comparative disadvantage.

Regarding the forecasting of cotton RSCA indices in Türkiye for the following ten years, the best model structure was developed using data from 1961 to 2020. Furthermore, the forecasting analysis shows that the RSCA indices for cotton export will gradually decline due to periodic fluctuations, eventually falling to -0.18 by 2030.

Foreign trade is critical to the economies of all countries, especially in the modern globalising world. Trade policy, as one of the most important political tools used by developing countries for industrialisation, plays a particularly active role in economic growth. Economic growth is the leading determinant of welfare worldwide, and it is driven by exports and imports. For this purpose, the policies affecting the most important agricultural products of a country are of great importance. Therefore, to increase the competitiveness of Türkiye's cotton exports and ensure stability, policies that disrupt producers and entrepreneurs investing in the sector should be avoided. Furthermore, problems such as the high cost of cotton production in Türkiye, agricultural policies implemented by countries such as the USA, the effect of cotton stock policies of countries such as China on the price of the product, and the country's inability to obtain qualified raw materials should be resolved with appropriate policies covering research and practises for stronger cotton production. Hence, medium- and long-term projects that will increase cotton production and export may be developed. Also, adequate assistance may be provided by the government. Türkiye's cotton exports may be able to increase significantly with the help of new production strategies and bilateral trade relations.

This type of application may allow policymakers to plan ahead of time for the storage, export, or import of cotton. Also, taking these precautions may prevent resource waste. As far as we know, no projection study on the competitiveness of cotton in Türkiye has been conducted. As a result, the study intends to contribute to the literature by addressing this gap.

REFERENCES

[1]Akaike, H., 1974, A new look at the statistical model identification. IEEE Transactions on Automatic Control Vol. 19(6):716–723.

[2]Akdag, M., Yigit, V., 2016, Forecasting inflation with box-jenkins and artificial neural network models. Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi Vol. 30(2):269–283.

[3]Anonymous, 2022, Pamuk raporu. Ticaret Bakanlığı (Cotton report, Ministry of Commerce), http://www.upk.org.tr/User_Files/editor/file/2019%20Pamuk%20Raporu.pdf, Accessed on 27 September, 2022.

[4]Ataseven, B., 2013, Forecasting by using artificial neural networks. Öneri Dergisi Vol. 10(39):101–115.

[5]Balassa, B., 1965, Trade liberalization and "revealed" comparative advantage. The Manchester School of Economic and Social Studies Vol. 33(2):92–123.

[6]Basal, H., Karademir, E., Goren, H.K., Sezener, V., Dogan, M.N., Gencsoylu, I., Erdogan, O., 2019, Cotton production in Turkey and Europe. In Jabran K, Chauhan BS (eds) Cotton production, Wiley & Sons Ltd, 297–321. https://doi.org/10.1002/9781119385523.ch14

[7]Bashir, D, 2019, Investigating Pakistan's revealed comparative advantage and competitiveness in cotton sector. Review of Economics and Development Studies Vol. 5(1):125–134.

[8]Borém, A., Freire, E.C., Penna, J.C.V., Barroso, P.AV., 2003, Considerations about cotton gene escape in Brazil: a review. Crop Breeding and Applied Biotechnology Vol. 3(4):315–332.

[9]Box, G.E.P., Jenkins, G.M., 1970, Time Series Analysis: Forecasting and Control. San Francisco, CA: Holden Day.

[10]Cevheri, C.I., Sahin, M., 2020, Dünyada ve Türkiye'de pamuk üretiminin tekstil sektörü açısından önemi (The importance of cotton production in the world and in Turkey for the textile industry). Harran Üniversitesi Mühendislik Dergisi Vol. 5(2):71–81.

[11]Copur, O., 2018, GAP projesinin Türkiye pamuk üretimine etkisi: son on yıldaki değişimler (Impact of the GAP project on Turkish cotton production: changes in the last decade). ADYUTAYAM Dergisi Vol. 6(1):11–18.

[12]Dagdelen, N., Gurbuz, T., Tunali, S.P., 2019, Aydın ovası koşullarında farklı pamuk çeşitlerinde damla sulama yöntemiyle oluşturulan su stresinin su-verim ilişkileri üzerine etkileri (The effects of water stress created by drip irrigation method on water-yield relationships in different cotton varieties in Aydin plan conditions), Derim Vol. 36(1):64–72.

[13]Dalum, B., Laursen, K., Villumsen, G., 1998, Structural change in OECD export specialisation patterns: de-specialisation and "stickiness". International Review of Applied Economics Vol. 12(3):423–443.

[14]Dickey, D.A, Fuller, W.A., 1979, Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association Vol. 74:427–431.

[15]Elliott, G., Rothenberg, T.J., Stock, J.H., 1996, Efficient tests for an autoregressive unit root. Econometrica Vol. 64:813–836.

[16]FAO, 2022, Agricultural production data. Food And Agriculture Organization. https://www.fao.org/faostat/en/#data/TCL, Accessed on 16 July, 2022.

[17]Girik Allo, A., Sukartini, N.M., Widodo, T., 2017, Dynamic changes in comparative advantage of Indonesian agricultural products. MPRA Paper No. 80028. https://mpra.ub.uni-muenchen.de/80028/. Accessed on 23 September, 2022.

[18]Hobijn, B., Franses, P.H., Ooms, M., 2004, Generalizations of the KPSS-test for stationarity. Statistica Neerlandica Vol. 58(4):483–502.

[19]Honfoga, B.G., 2018, Diagnosing soil degradation and fertilizer use relationship for sustainable cotton production in Benin. Cogent Environmental Science Vol. 4(1):1422366.

[20]Kazgan, G., 1999, 1980'lerde Türk tarımında yapısal değişme, 75 yılda köylerden şehirlere (Structural change in Turkish agriculture in the 1980s, from villages to cities in 75 years), Türkiye. İş Bankası Kültür Yayınları, İstanbul.

[21]Kiawu. J., Valdes, C., Macdonald, S., 2011, Brazil's cotton industry: economic reform and development. CWS-11d-01 Economic Research Service/USDA. https://www.ers.usda.gov/webdocs/outlooks/35849/6125_cws11d01_1_.pdf?v=5920.1. Accessed on 29 September, 2022.

[22]Kiran, B., 2014, Time Series Analysis. Lecture Notes, Istanbul University Distance Education Application and Research Center.

[23]Kwiatkowski, D., Phillips, P.C.B., Schmidt, P., Shin, Y., 1992, Testing the null hypothesis of stationarity against the alternative of a unit root. Journal of Econometrics Vol. 54:159–178.

[24]Laouan, A.M., 2021, Developed countries agricultural subsidies and cotton production in Burkina Faso: an analysis using the vector autoregressive model (VAR). Modern Economy Vol. 12(1):46–68. https://doi.org/10.4236/me.2021.121003

[25]Laursen, K., 2015, Revealed comparative advantage and the alternatives as measures of international specialization. Eurasian Business Review Vol. 5(1):99–115. Conference, Addis Ababa, Ethiopia, June 14–17.

[26]Leua, A., Gamit, P., Parmar, G., Sharma, S., Shukla, R., 2019, An assessment of competitiveness of agricultural export products of India vs. world agricultural market. In SS Kalamkar, H Sharma (Eds) Emerging global economic situation: Impact on trade and agribusiness in India, Allied Publishers, 261–268.

[27]Macdonald, S., Gale, F., Hansen, J., 2015, Cotton policy in China. MPRA Paper No. 70863, 1–38.

[28]Maqbool, M.S., Mahmood, T.A., 2020, Comparative analysis of export competitiveness of top five cotton exporting countries. Pakistan Journal of Social Sciences Vol. 40(1):123–131. http://pjss.bzu.edu.pk/index.php/pjss/article/view/826. Accessed on 30 September, 2022.

[29]Mirzaei, F., Mostafavi, S.M., Yazdani, S., 2012, Export comparative advantage analysis of Iranian hen egg by RCA & RSCA and RC criteria. Modern Economy 3(5):553–556.

[30]Muhammad, A., Smith, S.A., Macdonald, S., 2019, Impacts of the trade war on the US cotton sector, No. 2325-2020-388, Extension Institute of Agriculture, The University of Tennessee. https://extension.tennessee.edu/publications/Documents/W835.pdf. Accessed on 09 September, 2022.

[31]Najib, D.C.S., Fei, C., Dilanchiev, A., Romaric, S., 2022, Modeling the impact of cotton production on economic development in Benin: a technological innovation perspective. Frontiers in Environmental Science Vol. 10:1–11. https://doi.org/10.3389/fenvs.2022.926350

[32]Narin, M., 2006, Türkiye'de pamuğa yönelik destekleme politikaları ve devlete getirdiği yük. (Support policies for cotton in Turkey and the

burden it brings to the state), Verimlilik Dergisi Vol. 1:61–88.
[33]Newey, W.K., West, K.D., 1994, Automatic lag selection in covariance matrix estimation. Review of Economic Studies Vol. 61(209):631–653.
[34]Ng, S., Perron, P., 2001, Lag length selection and the construction of unit root tests with good size and power. Econometrica Vol. 69(6):1519–1554.
[35]Okumus, M., 2012, Tarım politikaları ve zaman serileri analizi: Türkiye'de pamuk fiyatlarına bir uygulama. (Agricultural policies and time series analysis: An application to cotton prices in Turkey), Dissertation, Adnan Menderes Üniversitesi, Fen Bilimleri Enstitüsü.
[36]Onder, K., 2017, Pamuk arzını etkileyen faktörlerin panel veri ile analizi. (Analysis of the afctors affecting cotton supply with panel data). Eskişehir Osmangazi Üniversitesi İİBF Dergisi Vol. C(12):1–83.
[37]Oral, N., Sarıbal, O., Şengül, H., 2013, Cumhuriyet döneminde uygulanan tarım politikaları. (Agricultural policies implemented in the Republican period), Türkiye'de tarımın ekonomi-politiği 1923-2013. TMMOB Ziraat Mühendisleri Odası Bursa Şubesi-NotaBene Publishing.
[38]Ozudogru, T., 2021, Dünya ve Türkiye'de pamuk üretim ekonomisi.(Cotton production economy in the world and in Turkey). Tekstil ve Mühendis Vol. 28(122):149–161.
[39]Pereira, T.Z., 2021, Taxation and the stagnation of cotton exports in Brazil, 1800–60. The Economic History Review Vol. 74(2):522–545.
[40]Ricardo, D., 1817. On the principles of political economy and taxation, John Murray, London.
[41]Ridley, W., Devadoss, S., 2014, US–Brazil cotton dispute and the world cotton market. The World Economy Vol. 37(8):1081–1100.
[42]Robledo, V., 2020, International cotton trade and causes of price volatility in the United States. Beyond the Numbers: Prices & Spending Vol. 9(12):1–7.
[43]Rossato, F.G.F.S., Susaeta, A., Adams, D.C., Hidalgo, I.G., De Araujo, T.D., De Queiroz, A., 2018, Comparison of revealed comparative advantage indexes with application to trade tendencies of cellulose production from planted forests in Brazil, Canada, China, Sweden, Finland and the United States. Forest Policy and Economics Vol. 97:59–66.
[44]Sabala, E., Devadoss, S., 2021, Spatial equilibrium analysis of Chinese tariff on world cotton markets. The World Economy Vol. 44(7):2188–2202.
[45]Schwarz, G., 1978, Estimating the dimension of a model. The Annals of Statistics 461–464.
[46]Schwert, G.W., 1989, Tests for unit roots: a Monte Carlo investigation. Journal of Business and Economics Statistics Vol. 7:147–159.
[47]Shepherd, B., 2004, The impact of US subsidies on the world cotton market: a reassessment. Groupe d'Economie Mondiale, Institut d'Etudes Politiques de Paris. https://econwpa.ub.uni-muenchen.de/econ-wp/it/papers/0511/0511012.pdf. Accessed on 27 March, 2022.
[48]Tandra, H., Suroso, A.I., Syaukat, Y., Najib, M., 2022, The determinants of competitiveness in global palm oil trade. Economies Vol. 10(132):1–20. https://doi.org/10.3390/economies10060132
[49]Tashrifov, M.Y., 2005, The effects of market reform on cotton production efficiency: the case of Tajikistan. Australian National University. ANU Crawford School of Public Policy, Working/Technical Paper. http://hdl.handle.net/10440/1196. Accessed on 28 September, 2022.
[50]TSI, 2022, Data portal for statistics. Turkish Statistical Institute. https://www.tuik.gov.tr/. Accessed on 21 September, 2022.
[51]USDA, 2021, Cotton: world markets and trade. United States Department of Agriculture. https://apps.fas.usda.gov/psdonline/circulars/cotton.pdf. Accessed on 21 September, 2022.
[52]Wubeneh, N.A., 2006, General equilibrium analysis of the impact of eliminating US cotton subsidies on US and world cotton market. 9th Annual Global Economic Analysis Conference, Addis Ababa, Ethiopia, June 14-17.

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REALITIES AND PROSPECTS OF MANAGING THE DEVELOPMENT OF AGRICULTURAL BUSINESS IN UKRAINE

Tetiana SHMATKOVSKA[1*], Oksana AGRES[2], Yurii LUCHECHKO[3*], Liudmyla KOROBCHUK[3], Nataliia NAUMENKO[1**], Maksym VOICHUK[3***], Mykola DZIAMULYCH[3*]**

[1]Lesya Ukrainka Volyn National University, *Department of Accounting and Taxation, **Department of International Economic Relations and Project Management, 28 Vynnychenko str., 43025, Lutsk, Ukraine. Emails: shmatkovska2016@gmail.com, naumenko.ns@gmail.com
[2]Lviv National Agrarian University, Department of Finance, Banking and Insurance, 1 Volodymyra Velykogo str., 80381, Dubliany, Lviv region, Ukraine. Email: oksana_agres@ukr.net
[3]Lutsk National Technical University, *Department of Economics, **Department of ecology and agronomy, ***Department of Entrepreneurship, Trade and Logistic, 75 Lvivska str., 43018, Lutsk, Ukraine. Emails: nashaorbita2018@gmail.com, luda.iv13a@gmail.com, voichukmaxym@gmail.com, m.dziamulych@lntu.edu.ua

Corresponding author: shmatkovska2016@gmail.com

Abstract

The world`s food security largely depends on the stability of agri-business worldwide, but mainly in the main producing countries of agri-food products. The purpose of the study is to determine the current realities and opportunities for the development of agrarian business in Ukraine in crisis conditions for the development of effective strategies and promising growth of the agrarian sector. Research methods: monographic, abstract-logical methods, method of analogies and comparisons, systematic approach, statistical and graphic methods. In the course of the study, it was determined that in 2022, a significant number of agricultural enterprises suffered losses as a result of the system challenges. The loss of 15-20% of cattle, pigs, and poultry, and the loss of production facilities and animal husbandry complexes led to a reduction in production in both the crop and animal husbandry sectors. The article highlights the exogenous and endogenous risks of the functioning of the agricultural sector. Internal risks include loss of production and resource potential of the agricultural sector; the liquidation of a significant number of agrarian business enterprises; change of specialization due to significant economic losses; loss of part of the infrastructure facilities for storage and primary processing of agricultural products; difficulty in selling products to foreign markets. Exogenous risks are described, in particular, the reduction of investments in agricultural production, problems with the purchase and import of fertilizers and plant protection products into the country, and delays in the purchase of modern agricultural machinery. It was noted that the presence of the listed external risks will have a negative impact on the country`s economy and food security. The actions of the government for the sustainability of agrarian business are described, namely, the restoration of the export of agricultural products by sea, the development of alternative logistics networks for export, solving the problems of the seed company, and providing the possibility of special credit programs and tax holidays. The main problematic issues that the government needs to solve to ensure the stability of the agrarian business and the possibility of its further effective functioning are presented.

Key words: *agrarian business, risks, tax holidays, sustainable development, innovative entrepreneurship, preferential lending*

INTRODUCTION

The agricultural business of Ukraine is one of the key sectors of the country`s economy.

Ukraine is recognized as an important producing and exporting country of agri-food products in Europe.

The great potential of agriculture, significant cultivated areas, and favourable climatic conditions for the cultivation of various crops make it possible to conduct business effectively.

The economic crisis, which started since the end of 2021 and continued in 2022, has affected all spheres of activity, in particular, the agrarian direction. The government and Ministry of Agriculture make huge efforts to sustain agriculture taking into account its importance in supplying agri-food products to cover the needs of the domestic and international market.

The agricultural sector plays a significant role in achieving this goal: ensuring the functioning of business, supporting the country`s economy, providing the basic needs of the population, and providing jobs – all this can be done by the agricultural sector in conditions of systemic risks. However, the agricultural sector of Ukraine has its own risks, problems, and unresolved questions for the government.

Many scientists are engaged in the study of the state of the agricultural sector of Ukraine and the analysis of the dynamics of its development, in particular, scientists I. Lazaryshyna [2], A. Nikolaeva [5], T. Shmatkovska [7, 8], I. Voronenko [11] studied the main problems of the pre-war agricultural sector that prevented further effective activities of the sector, analyze the impact of the financial crisis on the functioning of the agrarian sector. Leading specialists of the National Institute of Strategic Studies [4] are studying the potential of the agro-industrial complex in conditions of systemic risks, researching the directions of state policy to protect the Ukrainian economy.

Despite the conducted research, the question of assessing the impact of the financial and economic crisis on the agrarian business of Ukraine and its further development remains insufficiently studied, which led to the choice of the research direction of this article.

In this context, the aim of the study is to determine the current realities and opportunities for the development of agrarian business in Ukraine in crisis conditions for the development of effective strategies and promising growth of the agrarian sector.

MATERIALS AND METHODS

Scientific works of domestic and foreign scientists dedicated to the study of the state of the agricultural sector of Ukraine and the analysis of the dynamics of its development served as the theoretical and methodological basis of the study.

To achieve the goal, modern research methods were used: system analysis – in the study of the theoretical and methodological foundations of the functioning and development of agrarian business; monographic and abstract-logical method for revealing the analytical potential of the agricultural sector; the method of analogies and comparisons – when comparing various processes and trends regarding the development of agrarian business in Ukraine. The systematic approach made it possible to identify exogenous and endogenous risks of agrarian business during 2022. The use of statistical and graphic methods allowed us to display the rate of export of grain and oil crops, as well as the number of agricultural producers who took advantage of the preferential credit program.

RESULTS AND DISCUSSIONS

The powerful agricultural and production potential of Ukraine ensures the stability of food security not only in its territory but also in a number of countries around the world. During 2022, the total number of economic entities of the agro-industrial complex, that suffered losses as a result of the systemic risks, is 2,653 units.

A significant reduction in the area of arable land and perennial plantations was observed by 1.9 million hectares and 9 thousand hectares, respectively [3]. Today, the problem of non-compliance by land users with protection requirements is quite acute, which can have serious consequences for the environment and natural resources. Below are some of the possible effects of this loss of control:

- decrease in soil quality;
- pollution of water resources;
- loss of biodiversity;
- loss of recreational and cultural values.

All these led to the reduction of cultivated areas, as a result of which the volume of crop production decreased by 35-40%. If the problems of the agrarian industry are not systematically solved, the area planted under grain crops may decrease by 45%.

According to the Ministry of Agrarian Policy, 15-20% of cattle, pigs, and poultry have been lost in the livestock industry over the past year. These most affected business formations in Chernihiv, Kharkiv, Sumy, Kyiv, Donetsk, Luhansk, Mykolaiv, Kherson, and Zaporizhzhia regions, where at the beginning of 2022 all categories of farms were concentrated: cattle population – 25.3%, cows – 25.8%, pigs – 31.5%, sheep and goats – 28.2%, poultry – 24.9%. The production of animal products in these regions was: meat – 20%, milk – 28.7%, and eggs – 44.8% [10].

Analyzing the given figures, we can conclude that there was a significant reduction in production in both industries, which in turn slows down the conduct of agrarian business.

The next step of our research will be the identification of endogenous and exogenous risks in the functioning of the agricultural sector (Fig. 1).

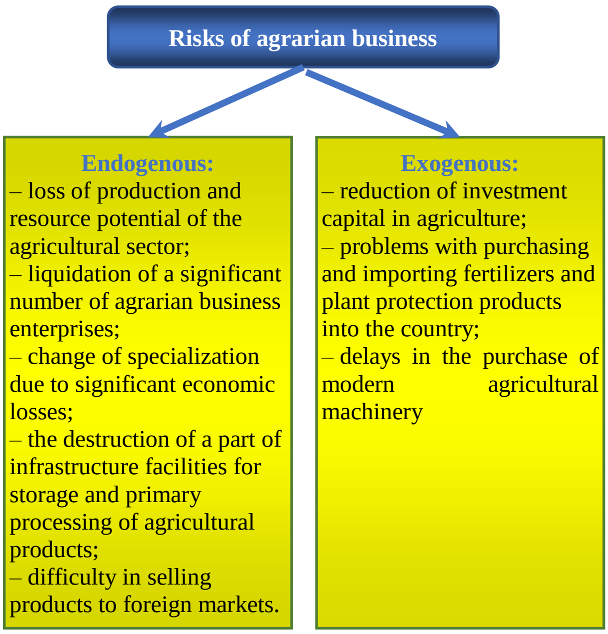

Fig. 1. Agricultural business risks during 2022
Source: grouped by authors based on sources [1; 4; 9].

One of the main risks of agrarian business is the loss of production and resource potential of the agricultural sector. As mentioned above, this is a significant reduction of agricultural land, which made it impossible to carry out agricultural activities (in 2022, compared to 2021, the total sown area decreased by 20%). The decrease in productivity and deterioration in the quality of agricultural land is caused by a decrease in the number of fertilizers and plant protection products. According to experts' estimates, the domestic consumption of nitrogen fertilizers in 2022 decreased by 40–55% – from 4.75 million tons to 2–2.9 million tons [10].

Failure to comply with technical standards leads to their removal from cultivation for a long time, and this is a third of the territory, which is classified as a zone of risky agriculture, which will require significant funds for their return to active use by farmers.

Systemic risks had a negative impact on the capital of the agribusiness sector, in particular, the costs of production capacity increased– more than 1.6 billion USD, in livestock complexes – more than 1.5 billion USD [3].

The liquidation of agrarian business enterprises or a change in their specialization should be singled out as a separate risk. A significant number of workers in this field and farmers were forced to stop their activities (more than 150,000 people). There were problems related to grain storage infrastructure. According to estimates, the deficit of storage capacities (10–15 million tons) due to the closing of granaries increased to 20 million tons [4].

Considering the various consequences of the liquidation of agribusiness enterprises, it is important to conduct a thorough analysis and develop effective strategies that ensure the balanced development of the sector and minimize the negative impact.

During the studied period, there was a reduction in investment in agricultural production. There are problems with the purchase and import of fertilizers and plant protection products into the country and delays in the purchase of modern agricultural machinery. The presence of the listed external risks will have a negative impact on the country's economy and food security.

As of January 1, 2023, the direct losses of agricultural producers are estimated at 7,832.4 million dollars. At the same time, great hopes

are placed on the agricultural sector. Therefore, it is appropriate to highlight the actions of the government for the sustainability of the agrarian business:
– «Grain corridor»;
– logistics in conditions of blockade of ports;
– solving the problems of the seed company;
– financial support;
– lending;
– tax holidays.

An important achievement of the government was the restoration of the export of agricultural products by sea, the so-called «grain corridor», this happened on August 1, 2023. In this way, Ukraine was able to export more than 3.5 million tons of agricultural products to the countries of Asia, Europe, and Africa. Figure 2 shows the rate of export of grain and oil crops from March 2022 to March 2023.

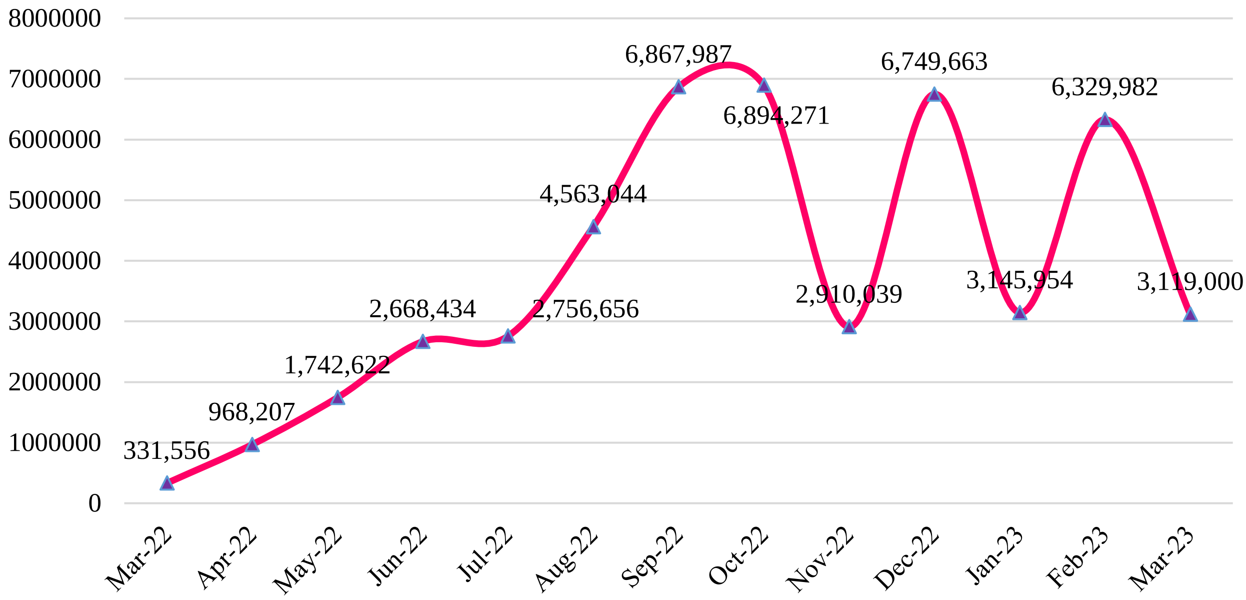

Fig. 2. Export rates of grain and oil crops during March 2022 – March 2023.
Source: [10].

From this figure, we can see that it was precisely from August that the growth of exports took place. In November 2022 and January 2023, due to the influence of systemic risks, we notice a sharp drop in the curve. Since the beginning of March 2023, 3,119 tons of agricultural products have been exported. We hope that this indicator will increase until the end of the year and will be within the previous level.
Therefore, the Government is carrying out all the necessary work so that the ports of "Great Odesa" to export 3-4 million tons of agrarian business products every month. Note that before 2022, the volume of such cargo amounted to almost 5 million tons per month. This suggests that under such difficult conditions, the economy of Ukraine receives billions of profit from the agrarian business.

The business community is making every effort to reach agreements with Romania and Bulgaria for exports through their seaports. Another logistics direction is railway communication, but, in this respect, significant funding is needed to expand the railway infrastructure network of both Ukraine and neighbouring countries.
The sowing campaign remains an urgent problem for the Government. In this field, a number of measures have been taken, among which we can highlight the following: the processing of the necessary licenses and certificates has been minimized, the import of agricultural plant products has been simplified, the principle of extraterritoriality has been introduced, a zero rate of excise tax has been introduced and VAT has been reduced to 7% on fuel, work with pesticides

and agrochemicals has been simplified, provided the possibility of operating tractors, self-propelled chassis without their registration. These innovations will certainly have a positive effect on the sowing, but the work to ensure the functioning of the agricultural sector must remain systematic and planned. In particular, the problem of the sharp rise in fuel and fertilizer prices remains relevant, which requires additional government, measures to solve it.

Agricultural business needs financial assistance from the state. Therefore, the Government adopted the resolution «On Amendments to Certain Acts of the Cabinet of Ministers of Ukraine on Providing Credit Support to Agricultural Producers» [5], which defines financial support for farmers. This resolution is more intended for small and medium-sized enterprises with a turnover of no more than 20 million EUR per year, and which cultivate up to 10,000 hectares of land. The point is to compensate the interest rate on borrowed loans. The maximum amount of the loan, which is subject to interest rate compensation, is up to UAH 50 million.

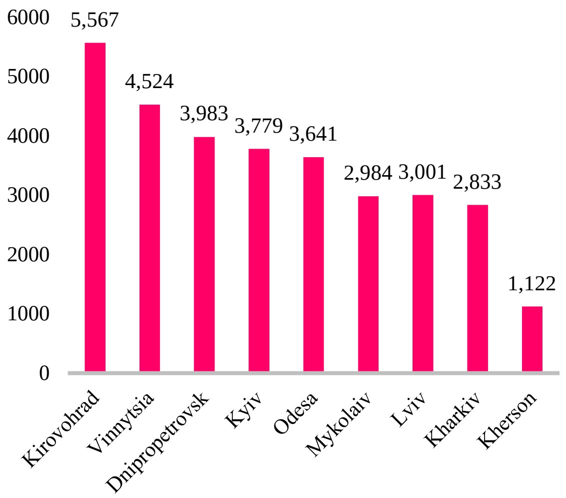

Fig. 3. The number of rural commodity producers who used the «5-7-9 Available Loans» program by region, 2022.
Source: calculated by the authors based on [10].

Lending should be considered as an integral part of the effective functioning and development of agrarian business. The program «Affordable Loans 5-7-9» became a significant support for agricultural producers. The availability of such loans at a normal rate with partial compensation from the state and also with state guarantees has attracted considerable interest from agricultural enterprises (Fig. 3).

From Figure 3, we can see that quite a large number of enterprises in the agrarian sector throughout Ukraine received credit funds, which they use for the purchase of seeds, fertilizers, fuel and lubricating materials for preparation for sowing and harvesting, for the payment of wages to employees, etc. Opportunities to obtain credit under such conditions allow the agrarian business to support the national economy, creating demand in related industries and providing jobs in the countryside. It should be noted that today this industry provides the lion's share of foreign exchange earnings and maintains the UAH exchange rate. However, the government's promise to extend this Program in 2023 has not yet been put into practice, so farmers are forced to return last year's loans.

In general, according to the program, one business entity received a preferential loan in the amount of UAH 90 million for a term of up to 12 months. If the government does not continue the program, farmers will need to return about UAH 38 billion in loans. And this is on the eve of the start of sowing campaign, for which it is additionally necessary to attract about 40 billion UAH.

A positive moment is the tax holiday from the Government. Law No. 2120-XX [6] declares non-assessment and non-payment of land tax and rent for land plots of state and communal forms of ownership for certain preferential categories of enterprises.

Today, agrarian business is an extremely important direction of food and financial independence therefore, for its full functioning; the following key issues must be resolved:

1. To provide conditions for farmers to carry out all the necessary fieldwork. It is worth involving representatives of the EU to support Ukrainian farmers and facilitate the implementation of spring sowing.

2. Contribute to the restoration of the animal population and the reconstruction of livestock complexes. The government needs to appeal to partner countries and international organizations so that the latter introduces specialized grant programs aimed at the purchase of young animals by domestic farmers, their vaccination, the construction of family-type livestock farms, and also provide funding for such programs.
3. Ensure uninterrupted the «grain corridor». It is also important to expand the grain initiative to the Mykolaiv port hub, as well as to include in the agreement the possibility of importing mineral fertilizers to Ukrainian ports.
4. Adapt the agrarian policy of Ukraine to the relevant provisions of the Common Agrarian Policy of the EU, and promote bringing domestic legislation in this area into compliance with the requirements related to Ukraine's accession to the EU. At the same time, legislative and normative legal acts, which will be difficult for agrarians to implement under today's conditions, should be adopted with a delayed implementation period.
5. To make a decision on the extension of the «Affordable 5-7-9 Loans» program and to increase lending limits from 90 million to 180 million UAH per enterprise.

If the Government solves these problematic issues, the agrarian business will be able to work effectively and will have the opportunity to fill the state treasury.

CONCLUSIONS

The agricultural sector plays an important role in providing food, production of raw materials for industry, export of agricultural products, and provision of vital needs of the population. It ensures the development of rural areas, occupies a significant share of the labor force and has a great influence on the country's economy.

Overcoming the main risks of the agrarian sphere, namely the loss of the production and resource potential of the agro-industrial complex, the high level of soil pollution and degradation, the forced liquidation of agrarian business enterprises, and the reduction of investments will enable agrarian business to function effectively and ensure food security. The development and modernization of the agricultural sector is an important task for ensuring the productivity, efficiency and sustainability of this industry. For this, the government needs to ensure the implementation of a complex of field works, to contribute to the restoration of the animal population and the reconstruction of livestock complexes, to adapt the agrarian policy of Ukraine to the relevant provisions of the Common Agrarian Policy of the EU, to promote the bringing of domestic legislation in this area into compliance with the requirements related to Ukraine's accession to the EU, to make a decision on the extension of the «5-7-9 Affordable Loans» program and to increase the lending limits from UAH 90 million to UAH 180 million per enterprise. We hope that the state leadership will solve all problematic issues of agrarian business as effectively as possible and provide the population with the necessary food products.

REFERENCES

[1]Dziamulych, M., Rogach, S., Shulha, O., Stupen, N., Tendyuk, A., Stryzheus, L., Bilochenko, A., 2023, Management of production resources of agricultural enterprises in Ukraine: a case study of Volyn region. Scientific Papers Series “Management, Economic Engineering in Agriculture and Rural Development”. 23(1): 179-188.
[2]Lazaryshyna, I., Antoniuk, N., Dobryanskyy, O., Didkivska, O., Rudyk, O., Chudovets, V., Bodakovskyy, V., Kotenko, T., 2023, Financial, accounting, and analytical ensuring of the formation of the anti-crisis potential of financial regulation and control systems in Ukraine under the conditions of digitalization. AD ALTA: Journal of interdisciplinary research. Vol. 13(2). Special Issue XXXV: 101-106.
[3]Marchuk, D., 2023, Sowing 2023 in question? League Blogs. https://blog.liga.net/user/dmarchuk/article/49717, Accessed on July 1, 2023.
[4]National Institute of Strategic Studies of Ukraine, 2023, The agricultural sector of the economy: the results of 2022 and the forecast for 2023. https://niss.gov.ua/en/node/4860, Accessed on July 1, 2023.

[5]Nikolaeva, A., Voronenko, I., Shulha, O., Bondarenko, I., Palchyk, M., 2022, Digital and information technologies in the management of financial activities in Ukraine in the conditions of the digitalization of the economy. AD ALTA: Journal of interdisciplinary research, 12(2). Special Issue 29: 97-101.

[6]On making changes to some acts of the Cabinet of Ministers of Ukraine regarding the provision of credit support to agricultural producers, 2022, Order of the Cabinet of Ministers of Ukraine from March 27, 2022. No.378. Legislation of Ukraine. https://zakon.rada.gov.ua/laws/show/378-2022-%D0%BF#Text, Accessed on July 1, 2023.

[7]Shmatkovska, T., Britchenko, I., Voitovych, I., Lošonczi, P., Lorvi, I., Kulyk, I., Begun, S., 2022, Features of banks` liquidity management in the context of the introduction of the LCR ratio in Ukraine. AD ALTA: Journal of interdisciplinary research, Vol. 12(1), Special Issue XXVII: 153-156.

[8]Shmatkovska, T., Kulinich, T., Dziamulych, M., Rogach, S., Bilochenko, A., Serdiukova, O., 2022, Analysis of investment efficiency in the agricultural sector of Ukraine on the basis of sustainable development. Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development". Vol. 22(3): 649-657.

[9]Sobkevych, O. V., Shevchenko, A. V., Rusan, V. M., Byelashov, YE. V., Zhurakovska, L. A., 2021, The real sector of the economy of Ukraine in conditions of systemic challenges. National Institute of Strategic Studies of Ukraine. https://niss.gov.ua/doslidzhennya/ekonomika/realniy-sektor-ekonomiki-ukraini-v-umovakh-sistemnikh-viklikiv, Accessed on July 1, 2023.

[10]State Statistics Service of Ukraine, http://www.ukrstat.gov.ua, Accessed on April 10, 2023.

[11]Voronenko, I, Klymenko, N., Nahorna, O., 2022, Challenges to Ukraine's Innovative Development in a Digital Environment. Management and Production Engineering Review, 13(4): 48-58.

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THE ADAPTATION TO TECHNOLOGY OF TEACHERS AND STUDENTS IN THE PERIOD 2020-2022: A NON-PARAMETRIC ANALYSIS

Simona Ionela SIPICĂ (ALDEA)[1,2], Elena TOMA [1,2], Alexandru SIPICĂ[3]

[1]University of Agricultural Sciences and Veterinary Medicine Bucharest, 59 Marasti, District 1, 11464, Bucharest, Romania, Phone: +40213182564, Fax: +40213182888, E-mails: simona.sipica@yahoo.com, elenatoma2001@yahoo.com
[2]Academy of Romanian Scientists, 54, Splaiul Independentei, 050094, Bucharest, Romania; E-mails: simona.sipica@yahoo.com, elenatoma2001@yahoo.com
[3]National Institute of Research and Development in Informatics ICI Bucharest, 8-10, Maresal Averescu Avenue, District 1, 011455, Bucharest, Romania, Phone: +40 21 316 52 62, E-mail: alexandru.sipica@ici.ro

Corresponding author: alexandru.sipica@ici.ro

Abstract

The adjustment of educators and pupils to the technological modifications enforced on the educational process during the epidemic is a crucial factor for forthcoming educational reforms. So, the primary objective of this study was to assess the perception of teachers and students in the pre-university setting regarding their adaption to technology during the period of 2020-2022. The data was collected in 2022 by administering questionnaires to a sample of 100 teachers and 100 students. It is important to note that 53% of the teachers and 59% of the students surveyed come from rural areas. The results revealed significant disparities between the participants (teachers and students) in terms of their utilization of IT resources and their level of engagement in online coursework (7 out of 11 items). Disparities were also identified between the instructors and the students originating from urban and rural regions. The findings illustrate the impact of respondents' IT skill and engagement in the learning process on their technological response patterns from 2020 to 2022.

Key words: *IT technology, non-parametric test, professors, pupils, COVID-19 pandemic, adaptability*

INTRODUCTION

The COVID-19 pandemic has had far-reaching consequences on our society, impacting the educational system. During the pandemic, advancements in technology have facilitated the development of flexible learning environments that are readily available. Professors utilized computer-based educational technology to communicate with pupils, exchange text and video resources, participate in online training and meetings, and manage job-related tasks [3]. Nevertheless, educators faced obstacles in immediately adjusting their instructional strategies [5]. Teachers lacking extensive training in educational technology had to quickly adapt their instructional plans to incorporate a variety of technological tools. Their goal was to facilitate student learning through the use of technology, particularly digital platforms. This rapid integration of technology was necessary to address the challenges posed by the pandemic within the school community [1]. O the other hand, students and pupils encountered issues in adapting to the online learning environment and in achieving their learning goals, especially those who lack self-accountability [4]. Nevertheless, research conducted during the epidemic has shown that students who display a readiness to use online learning technologies are more likely to continue using them [10]. Actually, individuals are more likely to adopt instructional technology when it is seen as straightforward to comprehend and use. Different studies have investigated the substantial influence of perceived usefulness and perceived simplicity of use on consumers' desire to adopt technology [6].

Specifically, in educational environments, instructors' perception of the usefulness and simplicity of use of educational technology is positively correlated with their intention to incorporate it into their teaching practice [7].

Before the pandemic, we could encounter teachers that used in the classroom different types of technologies (like interactive presentations, software, virtual travels, etc) or universities/schools which offered 100% online classes, while models such as flipped learning or hybrid (blended learning) were rarer and generally in lower classes or during extracurricular activities. Online education, as we have become accustomed to it during the pandemic, has been a mixture of models based on the use of the Internet. Lectures, assignments, tests were activated on virtual platforms and classes were held synchronously [8]. Actually, during the pandemic, an abundance of online resources became accessible, varying in terms of ease of use. Consequently, both learners and teachers had to undergo substantial adaptation to effectively utilize technological tools for educational course delivery. [2]. However, more than 80% of teachers returned to traditional methods of teaching and they are using digital methods only for presentations [9]. In this context, the purpose of this study was to assess the perception of teachers and students in the pre-university setting regarding their adaption to technology during the period of 2020-2022. Also, it aimed to identify the differences between instructors and students originating from urban and rural regions.

MATERIALS AND METHODS

This report presents preliminary findings from a survey carried out in 2022 across seven educational institutions, comprising two high schools and one urban school, as well as three schools and one high school from rural locations. As part of our research, we aimed to investigate whether there is a disparity in the overall perception of online education between 2020 and 2022. To achieve this, we designed and administered questionnaires using the 5-Linkert scale to a sample of 100 teachers and 100 students. The data was encoded and analyzed using IBM SPSS Version 20 software. The present study employed descriptive statistics and the Mann Whitney U test to analyze variations in values across different responder categories.

The participants were instructed to evaluate their level of adjustment to technology during the epidemic by assigning ratings ranging from 1 to 5 (where 1 represents "Strongly Disagree," 2 represents "Disagree," 3 represents "Indifferent," 4 represents "Agree," and 5 represents "Strongly Agree") for various items. Specifically, pupils were asked to assess 16 statements, while instructors were asked to rate 15 statements. To carry out this comparative analysis, we selected 11 common statements. These statements are as follows: *1. "It was easy for me to work/study online" 2. "I worked harder than in face-to-face schooling" 3. "I changed my teaching/learning technique" 4. "I am at an intermediate-advanced level of laptop/PC use" 5. "I worked for the first time with a tablet/laptop/PC" 6. "I was more stressed and tired than in face-to-face schooling" 7. "I received online teaching/learning support from the institution" 8. "I needed more time to prepare the lessons than in face-to-face schooling" 9. "It was easy to learn to work with online programs" 10. "The schedule was malleable" 11. "I had several teaching/learning tools at my disposal".*

The reliability test conducted on the study questionnaire (the above 11 items) yielded a Cronbach alpha value of 0.59, which was considered acceptable for further analysises.

We employed the Mann Whitney U test to make comparisons between groups. This is a non-parametric method used to assess the distribution of data. It serves as a non-parametric substitute for the t-test when comparing independent samples. This statistical method is employed to assess the disparities between two distinct groups. It compares the medians of the two groups under examination, namely teachers and students, and determines whether their ranks exhibit significant differences. This test utilizes 5-point Linkert ordinal variables. Null hypothesis: there is no statistically significant disparity between the two groups, with a significance level set at 0.05. The test considers both the central and dispersion tendencies and calculates the ordination score for each of the groupings. Although the outcome may lack statistical significance, it is still possible to compare the two groups based on their score values. The working hypothesis H1 in our research posits that there are no substantial disparities in the perception of technological adaptation between teachers and students. In the Mann-Whitney U test model in SPSS, the dependent variable is represented by the statement variables, while the independent variable (grouping variable) is represented by the respondent category.

Fawad (2021) states that by utilizing Cohen's (1988) criterion, we can determine the approximate value of r starting with the value of Z. In this context, r represents the effect size and is calculated as z divided by the square root of N, where z is the z statistic and N is the number of cases. The resulting value of r indicates the significance of the effect. A range of values from 0.1 to 0.3 or -0.1 to -0.3 indicates a modest effect. A range of values from 0.3 to 0.5 or -0.3 to -0.5 indicates a medium effect. A value of 0.5 or larger, or -0.5 or less, indicates a strong influence. The interpretation of the effect size is done in conjunction with the significant threshold.

RESULTS AND DISCUSSIONS

The Mann-Whitney U Test was employed to investigate discrepancies in viewpoints between professors and students. The test revealed statistically significant differences for 8 of the examined assertions ($p < .05$), leading to the rejection of the null hypothesis (Table 1).

Table 1. Summary of Mann-Whitney U Test based on category of respondents

Statement	Respondent	N	Median	Mean rank	Sum of Ranks	Mann-Whitney U	Z	Asymp. Sig. (2-tailed)	Effect of Z test	Efect type
It was easy for me to work/study online	Professor	100	2	85.64	8,563.50	3,513.500	-3.441	**.001**	-0.2	Modest
	Pupil	97	3	112.78	10,939.50					
It was easy to learn to work with online programs	Professor	99	4	94.10	9,315.50	4,365.500	-1.144	.253	-0.1	Modest
	Pupil	97	2	102.99	9,990.50					
The schedule was malleable	Professor	97	2	92.71	8,993.00	4,240.000	-1.462	.144	-0.1	Modest
	Pupil	99	3	104.17	10,313.00					
I worked harder than in face-to-face schooling	Professor	100	3	131.10	13,109.50	1,940.500	-7.715	**.000**	-0.5	Large
	Pupil	100	4	69.91	6,990.50					
I had more teaching/learning tools at my disposal	Professor	97	0	102.85	9,976.00	4,477.000	-.957	.339	-0.1	Modest
	Pupil	100	2	95.27	9,527.00					
I changed my teaching/learning technique	Professor	91	3	84.82	7,718.50	3,532.500	-2.243	**.025**	-0.2	Modest
	Pupil	95	3	101.82	9,672.50					
I am at an intermediate-advanced level of laptop/PC use	Professor	96	3	84.38	8,100.00	3,444.000	-3.016	**.003**	-0.2	Modest
	Pupil	95	3	107.75	10,236.00					
I worked for the first time with a tablet/laptop/PC	Professor	46	4	80.48	3,702.00	1,979.000	-1.405	.160	-0.1	Modest
	Pupil	100	3	70.29	7,029.00					
I was more stressed and tired than in face-to-face schooling	Professor	97	4	111.55	10,820.00	3,439.000	-3.502	**.000**	-0.2	Modest
	Pupil	98	4	84.59	8,290.00					
I received online teaching/learning support from the school	Professor	97	3	111.81	10,845.50	3,607.500	-3.194	**.001**	-0.2	Modest
	Pupil	100	3	86.58	8,657.50					
I needed more time to prepare the lessons than in face-to-face schooling	Professor	97	3	123.96	12,024.00	2,235.000	-6.653	**.000**	-0.5	Large
	Pupil	98	4	72.31	7,086.00					

Source: Own calculation.

No statistically significant variances have been noticed in the level of satisfaction about working with online applications, working time, or the availability of working materials.

Concerning these variables, the effect is minimal, suggesting that the analysis lacks practical importance. However, the obtained ranking clearly shows that the students demonstrated a greater level of consensus than the teachers when it comes to the convenience of using online apps and the program's increased flexibility.

Still, the test holds importance in both statistical ($p<0.05$) and practical ($r>0.5$) terms when assessing the claims of the online effort in terms of physical and temporal aspects, as well as the level of adaptation to IT equipment.

However, the test holds importance in both statistical ($p<0.05$) and practical ($r>0.5$) terms when assessing the claims of the online effort in terms of physical and temporal aspects, as well as the level of adaptation to IT equipment. Teachers are currently earning increased recognition for their diligent work throughout the pandemic, while kids are demonstrating a diminished level of proficiency in utilizing information technology equipment.

Concerning the other elements, it is crucial to acknowledge that they have statistical significance, implying that the probability of the observed impact happening randomly is minimal. Moreover, these variables exhibit a moderate impact, indicating their practical significance. After examining the test results (the average rank attained), it is clear that there are contrasting perspectives between teachers and students. Hence, the students greatly appreciate the convenience of working online and the opportunity to evaluate their competence in utilizing the laptop/PC.

Table 2. Summary of Mann-Whitney U Test for Professors based on residential environment

Statement	Location	N	Median	Mean rank	Sum of Ranks	Mann-Whitney U	Z	Asymp. Sig. (2-tailed)	Effect of Z test	Efect type
It was easy for me to work online	Urban	47	3	59.48	2,795.50	823.500	-3.193	**.001**	-0.3	Medium
	Rural	53	2	42.54	2,254.50					
It was easy to learn to work with online programs	Urban	46	3.5	50.82	2,337.50	1,181.500	-.273	.785	0.0	Modest
	Rural	53	4	49.29	2,612.50					
The schedule was malleable	Urban	46	3	46.67	2,147.00	1,066.000	-.822	.411	-0.1	Modest
	Rural	51	3	51.10	2,606.00					
I worked harder than in face-to-face schooling	Urban	47	4	54.98	2,584.00	1,035.000	-1.558	.119	-0.2	Modest
	Rural	53	4	46.53	2,466.00					
I had more teaching/learning tools at my disposal	Urban	44	3	50.95	2,242.00	1,080.000	-.674	.501	-0.1	Modest
	Rural	53	3	47.38	2,511.00					
I changed my teaching/learning technique	Urban	44	2.5	48.91	2,152.00	906.000	-1.106	.269	-0.1	Modest
	Rural	47	2	43.28	2,034.00					
I am at an intermediate-advanced level of laptop/PC use	Urban	45	3	51.26	2,306.50	1,023.500	-.980	.327	-0.1	Modest
	Rural	51	3	46.07	2,349.50					
I worked for the first time with a tablet/laptop/PC	Urban	28	2	21.18	593.00	187.000	-1.503	.133	-0.2	Modest
	Rural	18	3.5	27.11	488.00					
I was more stressed and tired than in face-to-face schooling	Urban	46	3	54.20	2,493.00	934.000	-1.919	.055	-0.2	Modest
	Rural	51	3	44.31	2,260.00					
I received online teaching/learning support from the school	Urban	46	4	55.68	2,561.50	865.500	-2.403	**.016**	-0.2	Modest
	Rural	51	2	42.97	2,191.50					
I needed more time to prepare the lessons than in face-to-face schooling	Urban	46	4	55.13	2,536.00	891.000	-2.379	**.017**	-0.2	Modest
	Rural	51	4	43.47	2,217.00					

Source: Own calculation.

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They also recognize to a greater extent the necessity to alter their behavior in relation to the teaching process. In contrast, instructors experience a notably greater degree of contentment when they receive assistance from the school in fulfilling their teaching duties. Furthermore, they indicate encountering higher levels of stress and exhaustion in comparison to teaching in person. The study sought to ascertain if there were discrepancies in the aforementioned characteristics depending on the living setting of the subjects. The results are presented in Tables 2 and 3.

The professor's findings reveal significant disparities in the level of convenience in online work (Mean Ranks 59.48 vs 42.54, p = 0.001), support from the school (55.68 vs 42.97, p = 0.016), and the extra time needed (55.13 vs 43.47, p = 0.017) depending on the individual's place of residence (urban vs rural). There were no significant discrepancies in the other statements. However, it can be deduced that professors in distant areas had a more flexible schedule in contrast to traditional in-person teaching, but they are also less acquainted with information technology.

Table 3. Summary of Mann-Whitney U Test for Pupils based on residential environment

Afirmație	Respondent	N	Median	Mean rank	Sum of Ranks	Mann-Whitney U	Z	Asymp. Sig. (2-tailed)	Effect of Z test	Efect type
It was easy for me to study online	Urban	38	4	56.62	2,151.50	831.500	-2.208	**.027**	-0.2	Medium
	Rural	59		44.09	2,601.50					
It was easy to learn to work with online programs	Urban	38	4	54.82	2,083.00	900.000	-1.724	.085	-0.2	Modest
	Rural	59		45.25	2,670.00					
The schedule was malleable	Urban	40	4	63.41	2,536.50	643.500	-3.926	**.000**	-0.4	Medium
	Rural	59		40.91	2,413.50					
I worked harder than in face-to-face schooling	Urban	41	1	38.49	1,578.00	717.000	-3.632	**.000**	-0.4	Medium
	Rural	59		58.85	3,472.00					
I had more teaching/learning tools at my disposal	Urban	41	4	51.27	2,102.00	1,178.000	-.228	.819	0.0	Modest
	Rural	59		49.97	2,948.00					
I changed my teaching/learning technique	Urban	36	3	45.97	1,655.00	989.000	-.583	.560	-0.1	Modest
	Rural	59		**49.24**	2,905.00					
I am at an intermediate-advanced level of laptop/PC use	Urban	36	4	44.83	1,614.00	948.000	-.909	.363	-0.1	Modest
	Rural	59		**49.93**	2,946.00					
I worked for the first time with a tablet/laptop/PC	Urban	41	3	58.33	2,391.50	888.500	-2.356	**.018**	-0.2	Modest
	Rural	59		45.06	2,658.50					
I was more stressed and tired than in face-to-face schooling	Urban	39	3	42.91	1,673.50	893.500	-1.924	.054	-0.2	Modest
	Rural	59		**53.86**	3,177.50					
I received online teaching/learning support from the school	Professor	41	3	52.24	2,142.00	1138.000	-.515	.606	-0.1	Modest
	Pupil	59		49.29	2,908.00					
I needed more time to prepare the lessons than in face-to-face schooling	Urban	39	3	46.49	1,813.00	1033.000	-.872	.383	-0.1	Modest
	Rural	59		**51.49**	3,038.00					

Source: Own calculation.

The results for the students show significant differences in the level of difficulty in studying online (Mean Ranks 56.62 vs 44.09, p = .027), the flexibility of the program (63.41 vs 40.91, p = .000), the intellectual effort required (38.49 vs 58.85, p = .000), and IT literacy (58.33 vs 45.06, p = .018) based on their place of residence (urban vs rural).
These results suggest that students from rural areas exhibited greater effort in their studies, whereas students from metropolitan areas found it easier to study online and adapt to class schedules, likely due to their greater familiarity with computers.
The other seven statements don't show significative differences. Although students from rural areas are more familiar with IT equipment, they felt, more than students from cities, a greater pressure in the educational process, including fatigue, stress or the need to change the way of learning.

CONCLUSIONS

The study's findings indicate that professors and students exhibited distinct responses during the period of 2020-2022 when online, hybrid, and physical classes were conducted. The teachers exhibited varying responses, primarily attributing the situation to weariness, stress, and the time required for class preparation. Conversely, students hold a more favorable viewpoint towards working online and utilizing computer apps, while possessing less expertise in the field of information technology compared to teachers. Conversely, teachers from metropolitan regions exerted greater effort, whilst students from rural areas encountered more challenges in adapting to technology.

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REFERENCES

[1]Afonso, P., Trindade, B., Santos, D., Pocinho, R., Silveira, P., Silva, P., 2020, Teachers' adaptation to technologies during the pandemic by COVID-19. In Eighth International Conference on Technological Ecosystems for Enhancing Multiculturality (pp. 817-820). https://doi.org/10.1145/3434780.3436590. Accessed on 22 June 2023.
[2]Farsawang, P., Songkram, N., 2023, Fostering technology integration and adaptability in higher education: Insights from the COVID-19 pandemic. Contemporary Educational Technology,15(4), https://doi.org/10.30935/cedtech/13513. Accessed on 28 October 2023.
[3]Hong, X., Zhang, M., Liu, Q., 2021, Preschool teachers' technology acceptance during the COVID-19: An adapted technology acceptance model. Frontiers in Psychology, 12, p.691492. https://doi.org/10.3389/fpsyg.2021.691492. Accessed on 30 June 2023.
[4]Mamun, M. A., Lawrie, G., Wright, T., 2020, Instructional design of scaffolded online learning modules for self-directed and inquiry-based learning environments. Computers & Education, 144, 103695. https://doi.org/10.1016/j.compedu.2019.103695. Accessed on 18 July 2023.
[5]Milosievski, M., Zemon, D., Stojkovska, J., Popovski, K., 2020, Learning online: Problems and solutions. UNICEF Young Reporters. Available online at: https://www.unicef.org/northmacedonia/stories/learning-onlineproblems-and-solutions. Accessed on 18 July 2023.
[6]Rafique, H., Almagrabi, A. O., Shamim, A., Anwar, F., Bashir, A. K., 2020, Investigating the acceptance of mobile library applications with an extended technology acceptance model (TAM). Comput. Educ. 145:103732. https://doi.org/10.1016/j.compedu.2019.103732. Accessed on 10 September 2023.
[7]Scherer, R., Siddiq, F.,Tondeur, J., 2019, The technology acceptance model (TAM): a meta-analytic structural equation modeling approach to explaining teachers' adoption of digital technology in education. Comput. Educ. 128, 13–35. doi: 10.1016/j.compedu.2018.09.009. Accessed on 5 August 2023.
[8]Sipica (Aldea), Toma E., 2022, The main challenges in education in the context of the digital transformation of learning. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural

Development, 22(3), 681-687. https://managementjournal.usamv.ro/pdf/vol.22_3/Art73.pdf. Accessed on 20 October 2023.
[9]Sipica (Aldea), Toma E., 2023, Digital tools utilized in online, hybrid and traditional teaching models in pre-university studies. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 23(1), 733-737, https://managementjournal.usamv.ro/pdf/vol.23_1/Art76.pdf. Accessed on 20 October 2023.
[10]Thongsri, N., Chootong, C., Tripak, O., Piyawanitsatian, P. and Saengae, R., 2021, Predicting the determinants of online learning adoption during the COVID-19 outbreak: a two-staged hybrid SEM-neural network approach, Interactive Technology and Smart Education, Vol. 18(3), 362-379. https://doi.org/10.1108/ITSE-08-2020-0165. Accessed on 5 August 2023.

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DETERMINING FACTORS AFFECTING THE ABILITY OF TEACHERS AND PUPILS TO ADAPT TO TECHNOLOGY BETWEEN 2020 AND 2022

Simona Ionela SIPICĂ (ALDEA)[1,2], Elena TOMA [1,2], Alexandru SIPICĂ[3]

[1]University of Agricultural Sciences and Veterinary Medicine Bucharest, 59 Marasti, District 1, 11464, Bucharest, Romania, Phone: +40213182564, Fax: +40213182888, E-mails: simona.sipica@yahoo.com, elenatoma2001@yahoo.com
[2]Academy of Romanian Scientists, 54, Splaiul Independentei, 050094, Bucharest, Romania; E-mails: simona.sipica@yahoo.com, elenatoma2001@yahoo.com
[3]National Institute of Research and Development in Informatics ICI Bucharest, 8-10, Maresal Averescu Avenue, District 1, 011455, Bucharest, Romania, Phone: +40 21 316 52 62, E-mail: alexandru.sipica@ici.ro

Corresponding author: alexandru.sipica@ici.ro

Abstract

This study examined the variables that influenced instructors' and students' conduct over the 2020–2022 school year. A questionnaire that was given to 100 pre-university students and 100 teachers in 2022 was used to gather the results (over half of them were from rural areas). Principal components analysis was used to find the identified factors. Two main elements were discovered in grouping models for teachers and students following the inquiry. The results demonstrated that, for teachers, the most important tasks during the pandemic were effectively using computers and the effort needed to complete this step; for students, on the other hand, the online component of teaching and interacting with parents and other students were the most important tasks.

Key words: *principal component analysis, teachers, pupils, COVID-19, adaptability, IT technology*

INTRODUCTION

The quickening pace of digitization and the increasing infusion of technology into everyday life is causing a dramatic and immediate transformation of society and the world economy. Initiatives to modernize educational institutions and make significant modifications to them in order to adapt to the rapid changes brought about by technology are the top goals for many different nations, wealthy and poor. Since 2020, every research on the topic of education's digitization and the new roles it should play has focused on the COVID-19 pandemic. Discussions about how to modernize and enhance teachers' skills have arisen as a result of changes in a number of areas, including new communication channels, adjustments to the classroom and school, diversity of educational resources, flexibility of curricula, management styles, learner profiles, and parent profiles.

Following the COVID-19 epidemic, education was shifted to an online platform in 2022, followed by a hybrid structure in 2021, and a return to in-person instruction for all pupils in 2022. Several studies have been carried out to determine the factors affecting the conduct of teachers, students, and learners at this time.

Numerous respondents confirmed that there has been a distinct shift in the relationship between teacher- and student-centered technology use. First off, trust, work engagement, effort expectancy, social influence, technology anxiety, performance expectancy, and work engagement are factors that significantly affect teachers' behavioural intention to use distance learning technologies, according to some evaluations of these technologies' acceptability [3]. Furthermore, individual inventiveness in educational technology and perceived utility have an indirect impact on the acceptance of computer technology [12]. Other scholars have noted that the following elements influence actual technology use: "perceived usefulness, perceived ease of use, perceived enjoyment, intention to use, actual use, compatibility, attitude, and self-efficacy" [9]. Moreover, as instructors became more acclimated to using technology, the relationship between it and instructional practices weakened over time [5].

The epidemic has created a new atmosphere in which the dynamics of the relationships between teachers and pupils also change. Teachers faced a number of difficulties, including a lack of technology, students' lack of respect, and parental engagement [7]. By the end of the pandemic, a large number of them had come to the conclusion that in-person instruction is superior and that online learning negatively affected the entire educational system [8].

However, students have a variety of viewpoints. When taking lessons online, several students felt they were not getting their teacher's full attention [4]. Additionally, the living conditions of the students—parents, access to a personal computer, etc.—had an effect on their opinions toward online learning, their perceptions of their level of IT competency, their level of study motivation, and their experiences with overload [11]. The majority of learners' assessments of the online features were favorable, but they also highlight the need for educational institutions to design a visually stimulating and captivating environment in order to effectively deliver online courses [1]. Furthermore, a few studies looked at the relationship between students' intention to utilize technology, compatibility with it, and reported enjoyment. They discovered that these variables may have a favorable impact on students' actual use of technology in the classroom [10]. The primary advantages that the students themselves recognized had to do with overcoming the difficulties associated with studying virtually and the sense of fulfilment that came from participating in peer-to-peer activities. An effort of this kind makes it possible for students to work in a flexible and healthy atmosphere, which facilitates better online learning. Additionally, it teaches students new online working techniques that they were not aware of, how to resolve intervening difficulties on their own, and who to contact for support when needed [6]. The study aimed to determine the key elements that influence teachers and students in their adoption of digital technologies in the educational context.

MATERIALS AND METHODS

To analyze the data, we conducted a factorial analysis known as Principal Components Analysis. We used the responses from the 5-Linkert questionnaires, which consisted of 15 variables for teachers and 16 variables for students (Table 1).

Table 1. Variables for PCA

Statement	Professor	Pupil
“It was easy for me to work online”	x	x
“It was easy to learn to work with online programs”	x	x
“The schedule was malleable”	x	x
“I worked harder than in face-to-face schooling”	x	x
“I had more teaching/learning tools at my disposal”	x	x
“I changed my teaching (learning) technique”	x	x
“I am at an intermediate-advanced level of laptop/PC use”	x	x
“I worked for the first time with a tablet/laptop/PC”	x	x
“I was more stressed and tired than in face-to-face schooling”	x	x
“I received online teaching/learning support from the school”	x	x
“I needed more time to prepare the lessons than in face-to-face schooling”	x	x
“I changed the content of the taught assignments”	x	
“It was easy to keep students motivated online”	x	
“In online I had conflicts with parents”	x	
“In online, students do not follow the lessons”	x	
“It was easy to focus online”		x
“I could not collaborate with my colleagues online”		x
“I constantly needed the help of my parents”		x
“I couldn't follow the teacher online”		x
“I felt more pressure from my parents when I was online”		x

Source: Own calculation.

Principal Component Analysis (PCA) is a statistical method employed for data reduction. It involves transforming a big set of variables into a smaller set of components that represent the original variables. This enables us to explore additional variables of interest that are associated with a reduced number of unobservable parameters. The technique essentially analyzes the systematic interrelationship among a set of observable variables, and those variables that exhibit a stronger correlation are grouped together. The approach is characterized by exploration, as we seek to understand the relationship between variables inside the principal components. Exploratory analysis, when applied to a data set, aims to identify links between variables by examining various combinations. The ultimate goal is to condense the variables into a more concise collection of composite factors.

The process of applying the ACP (Analytic Continuation Principle) approach in SPSS consists of multiple sequential steps:

-conducting the Kaiser-Meyer-Olkin (KMO) measure test to assess the suitability of the selected data set for factor analysis (KMO value must exceed 0.5).

-conducting Bartlett's test of sphericity to evaluate the null hypothesis, which states that the variables in the population are uncorrelated. A significance level below 0.05 indicates a strong relationship between the variables, making them suitable for factor analysis.

The Varimax model is chosen as the factor extraction method because it minimizes the correlation between factors and reduces the number of variables with high loadings on a single factor. The threshold for the minimal factor loading was established at 0.70.

RESULTS AND DISCUSSIONS

Examining the factors that influence teacher behavior in connection to technology

Principal Component Analysis (PCA) was utilized to analyze the 15 variables measured on a 5-point Likert scale. The dataset consisted of responses from 100 teachers. The results were statistically significant (Bartlett's test with $p<0.5$), and the Kaiser-Meyer-Olkin test (with a value of 0.559) showed that it was appropriate to do the factor analysis. The study yielded a factor solution consisting of four factors, which accounted for 74.4% of the variation in the data. Nevertheless, certain components that did not exhibit significant loading on any dimension were detected, necessitating the repetition of the analysis four times.

The ultimate model produced validated a configuration consisting of two primary elements (Table 2) exhibiting the following attributes: The Kaiser–Meyer–Olkin value of 0.626 is deemed sufficient for doing the component analysis. The Bartlett test validates the model's statistical significance. The two dimensions account for 73.3% of the variation among the study's items. The correlation matrix, derived from the extracted components, indicates that less than 50% of the residuals are below 0.05 [2]. This finding supports the validity of the model, as 45% of the residuals have an absolute value greater than 0.05 and are not redundant.

Factor 1, accounting for 42% of the data's variance, encompasses items related to computer interaction and technology adaptation. Factor 2, explaining approximately 31% of the variance, pertains to the effort exerted in online work, time management, and school support. The matrix of rotated factors reveals that the items pertaining to the teaching process have a higher loading on the first principal component (with values exceeding 0.83), whereas the amount of time and effort needed to prepare online classes has a significant loading on the second component (with a value of 0.94). The latter three items exert minimal and predominantly adverse influence on the initial group, indicating that they do not regard the exerted effort as crucial factors for delineating the process of adapting to technology within the pandemic. In the second group, the emphasis was placed on the level of effort exerted rather than the actual understanding of IT components.

Investigation on the factors influencing student behavior in regard to technology

Principal Component Analysis (PCA) was utilized to analyze the 16 variables measured on a 5-point Likert scale in the database, which consisted of responses from 100 student participants.

Table 2. ACP model for teachers

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.									**.626**
Bartlett's Test of Sphericity				Approx. Chi-Square					543.280
				Df					28
				Sig.					**.000**
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.360	42.003	42.003	3.360	42.003	42.003	3.353	41.909	41.909
2	2.500	31.252	73.256	2.500	31.252	**73.256**	2.508	31.347	73.256
3	.761	9.515	82.771						
4	.555	6.938	89.710						
5	.347	4.333	94.043						
6	.268	3.350	97.393						
7	.129	1.613	99.006						
8	.080	.994	100.000						
Extraction Method: Principal Component Analysis.									

Rotated Component Matrix[a]

	Component	
	1	2
"It was easy for me to work online"	.771	(-.128)
"It was easy to learn to work with online programs"	.783	(-.324)
"I changed my teaching technique"	.834	(.137)
"I changed the content of the taught assignments"	.838	(.143)
"I am at an intermediate-advanced level of laptop/PC use"	.797	(.178)
"I was more stressed and tired than in face-to-face schooling"	(-.133)	.926
"I received online teaching/learning support from the school"	(.304)	.755
"I needed more time to prepare the lessons than in face-to-face schooling"	(-.053)	.942

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a.Rotation converged in 3 iterations.

Source: Own calculation

The results were statistically significant (Bartlett's test with p<0.5), and the Kaiser-Meyer-Olkin test (with a value of 0.616) showed that it was appropriate to do the factor analysis. The study resulted in a factor solution that identified five variables, which collectively accounted for 63.5% of the variation in the data. Nevertheless, certain components that did not exhibit substantial loading on any dimension were noted, necessitating the repetition of the research on four occasions.

The ultimate model produced (Table 3) validated a configuration consisting of two primary elements (Table 2) possessing the subsequent attributes: The Kaiser-Meyer-Olkin value of 0.660 is deemed sufficient for doing the factor analysis. The Bartlett test validates the statistical significance of the model. The two dimensions account for 74.8% of the variability among the items in the study.

The correlation matrix, derived from the extracted factors, indicates that 50% of the residuals are below 0.05 when compared to the initial correlation matrix (Field, 2009). This finding provides evidence for the validity of the model. Factor 1, accounting for 46.8% of the variance in the data, encompasses items related to adapting to technology. Factor 2, explaining approximately 28% of the variance, pertains to the interactions with coworkers and parents.

Table 3. ACP model for pupils

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**.660**
Bartlett's Test of Sphericity	Approx. Chi-Square	151.542
	Df	10
	Sig.	**.000**

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.339	46.784	46.784	2.339	46.784	46.784	2.286	45.712	45.712
2	1.404	28.083	74.867	1.404	28.083	74.867	1.458	29.155	74.867
3	.525	10.494	85.361						
4	.481	9.624	94.985						
5	.251	5.015	100.000						

Extraction Method: Principal Component Analysis.

Rotated Component Matrix[a]

	Component	
	1	2
"It was easy for me to work online"	.903	(-.119)
"It was easy to learn to work with online programs"	.873	(.056)
"The schedule was malleable (i liked that ...) "	.811	(-.087)
"I could not collaborate with my colleagues online"	(.094)	.865
"I felt more pressure from my parents when I was online"	(-.205)	.827

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Source: Own calculation.

CONCLUSIONS

Drawing on the data derived from the factor analysis, it can be deduced that, in the midst of the pandemic, educators regarded the amount of effort they put in to complete their real computer-related tasks as the most important aspect of their work. For children, the most important thing was the online learning environment, followed by interacting with other students and parents.

Nonetheless, we must acknowledge that the digital world has created a new learning environment, particularly in light of artificial intelligence (AI) technology' substantial impact on all informational processes. This learning environment, which is discussed in today's educational literature, has a new dimension because of the digital world. In addition to the learning environment, this universe has opened up new dialogue on significant subjects including the nature, provenance, and nature of knowledge itself. It represents endless, multilingual, and multicultural truths that are defined for different purposes. Online learning is a test procedure that has revealed new debate topics, even if it has been crucial to the COVID-19 process and will remain a helpful practice for learning settings in the future.

Apart from spearheading innovations in fields such as curriculum development and delivery, this experience will surely offer substantial perspectives on the architectural design of schools and classrooms in the future. There is still potential for online or distant learning—but only if the necessary circumstances are in place for students to engage in it, if educators receive didactic training specific to the demands of this mode of instruction, and if student-teacher collaboration is fostered throughout the learning process

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REFERENCES

[1]Agyeiwaah, E., Baiden, F.B., Gamor, E., Hsu, F.C., 2022, Determining the attributes that influence students' online learning satisfaction during COVID-19 pandemic. Journal of Hospitality, Leisure, Sport & Tourism Education, 30, p.100364. https://doi.org/10.1016/j.jhlste.2021.100364. Accessed on 28 August 2023.

[2]Field, A., 2009, Discovering Statistics Using SPSS (3rd ed.). London: SAGE Publications, https://shorturl.at/BIRZ5. Accessed on 23 September 2023.

[3]Jevsikova, T., Stupurienė, G., Stumbrienė, D., Juškevičienė, A. and Dagienė, V., 2021, Acceptance of distance learning technologies by teachers: Determining factors and emergency state influence. Informatica, 32(3), pp.517-542. https://doi.org/ 10.15388 /21-INFOR459. Accessed on 25 September 2023.

[4]Lade, K., Gaglani, H., Khare, S., Muley, S., Jha, R., 2022. Perception of student's towards online learning during COVID-19 pandemic. Int. J. Health Sci, 6, pp.473-480. https://doi.org/ 10.1097/MD.000000 0000024821. Accessed on 10 October 2023.

[5]Lai, C., Wang, Q., Huang, X., 2023, The evolution of the association between teacher technology integration and its influencing factors over time, Journal of Research on Technology in Education, 55:4,727-747, https://doi.org/10.1080/15391523.2022.2030266. Accessed on 10 October 2023.

[6]Maier, R., 2021, The Participatory Behaviour and the Students' Adaptability in the Online Environment during the Pandemic. BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 12(2), pp.112-121. https://doi.org/10.18662/brain/12.2/195. Accessed on 8 October 2023

[7]Preda, M, Toma, E., 2021a. The quality of education in rural areas from the perspective of primary and secondary school teachers, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 21(2), 493-498, http://managementjournal.usamv.ro/pdf/vol.21/2/Art57.pdf. Accessed on 28 August 2023.

[8]Preda, M, Toma, E., 2021b, The impact of 2020 pandemic restrictions on middle school education, in Romanian rural areas, EDULEARN21 Proceedings, 13th International Conference on Education and New Learning Technologies, 5-6 July, 2021, Online Conference, Pages: 6133-6139, doi: 10.21125/edulearn.2021.1237. https://library.iated.org/view/PREDA2021IMP. Accessed on 28 August 2023.

[9]Rad, D., Magulod Jr, G.C., Balas, E., Roman, A., Egerau, A., Maier, R., Ignat, S., Dughi, T., Balas, V., Demeter, E., Rad, G., 2022, A radial basis function neural network approach to predict preschool teachers' technology acceptance behavior. Frontiers in Psychology, 13, p.880753. https://www.frontiersin.org/articles/10.3389/fpsyg.2022.880753/full. Accessed on 10 October 2023.

[10]Rad, D., Egerău, A., Roman, A., Dughi, T., Kelemen, G., Balaș, E., Redeș, A., Schipor, M.D., Clipa, O., Mâță, L., Maier, R., 2023, On the technology acceptance behavior of Romanian preschool teachers. Behavioral Sciences, 13(2), p.133. https://doi.org/10.3390/bs13020133. Accessed on 10 October 2023.

[11]Radovan, M., Makovec, D., 2022, This is not (the new) normal. Students' attitudes towards studying during the COVID-19 pandemic and the determinants of academic overload. Electronic Journal of e-Learning, 20(3), pp.pp257-269. https://doi.org/10.34190/ejel.20.3.2366. Accessed on 8 October 2023.

[12]Tao, D., 2009, Intention to use and actual use of electronic information resources: Further exploring Technology Acceptance Model (TAM). Annu. Symp. Proc. AMIA Symp. 2009, 629–633. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2815463/. Accessed on 28 August 2023.

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PROSPECTS FOR EUROPEAN UNION'S MEAT PRODUCTION IN THE CONTEXT OF CURRENT CONSUMPTION CHALLENGES

Elena SOARE, Paula STOICEA, Carina-Andreea DOBRE, Adina Magdalena IORGA, Aurelia-Vasilica BĂLAN, Irina-Adriana CHIURCIU

University of Agronomic Sciences and Veterinary Medicine Bucharest of Bucharest, 59 Marasti Boulevard, District 1, 011464, Bucharest, Romania, Phone: +40213182564, Fax: +40213182888, Mobile: +40744 6474 10, Emails: soare.elena@managusamv.ro, stoicea.paula@managusamv.ro, dobre.carina@managusamv.ro, iorga.adina@managusamv.ro, balan.aurelia@managusamv.ro, chiurciu.irina@managusamv.ro

Corresponding author: chiurciu.irina@managusamv.ro

Abstract

Meat is an important element in human nutrition, and its consumption is expected to increase in the coming years in parallel with population growth. However, the livestock sector faces problems related to climate change, animal protection and welfare, and various epizootics, which have decimated livestock. In this context, the article analyses pig, cattle and sheep herds, as well as the production of pig, beef and sheep meat resulting from slaughterhouses in the EU, focusing on the main animal breeders and meat producers, for the period 2018-2022. The results of the study show that the number of pigs, cattle and sheep in the EU decreased during the period under review, as well as the total production of slaughtered meat. The most important pig breeders were Spain, Germany and France, for cattle - France, Germany and Ireland, and for sheep - Spain, Romania and Greece. Among the meat-producing countries stood out: for pork - Spain, Germany and France; for beef - France, Germany and Italy and for sheep meat - Spain, France and Ireland. At the same time, the article presents the perspectives of meat consumption, in the context of the pressures to which the livestock sector is subject and the changes that are manifested in the food preferences of European consumers.

Key words: *beef meat, livestock, meat consumption, meat production, pig meat, sheep meat*

INTRODUCTION

Consumed by humans since ancient times, meat is an important food due to the intake of vitamins (B12, B3, B6), minerals (iron, phosphorus, zinc, selenium), creatine and carnosine - a powerful antioxidant [2].

Global population growth is reflected in higher demands for food, mainly meat and dairy products [20].

Meat is currently a product consumed across the globe, which has made the meat industry well-developed, being valued at $960 billion in 2022. A continuous increase in its value is foreseen until 2027, based on the increase in meat consumption [18].

A study available on the Statista platform on global meat consumption, between 2020-2022, shows that the average for the mentioned period was 28.1 kg per capita [19]. The North American continent was in first place, with 78.6 kg per capita, and the last place was occupied by the African continent, with 9.6 kg per capita. The amount of 52.1 kg of meat per capita placed Europe in third place, with a value almost double in comparison with the world average (Figure 1).

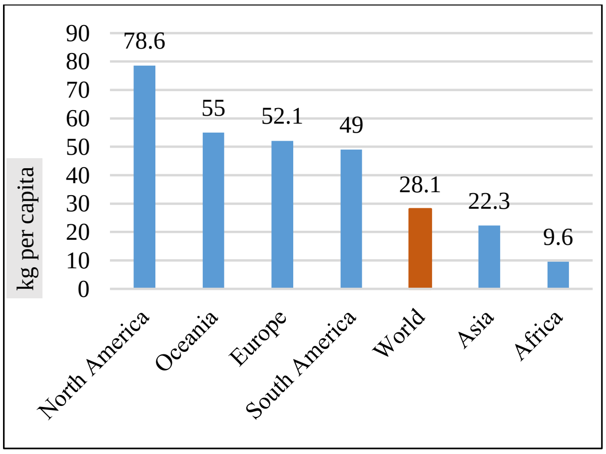

Fig. 1 Average of worldwide meat consumption per capita from 2020 to 2022.
Source: own representation after [19].

The type ofmeat preferred by Europeans has been and is expected to remain pork [13], with Europe leading the consumption of meat for this category [1].
At the same time, in 2022 the EU was the 4th consumer of beef worldwide [1, 18], and among the member countries, Germany had the highest consumption of meat in kg per capita, especially pork [18].
Starting from the information regarding the increase in meat consumption, the article aims to highlight the evolution of factors influencing meat consumption, such as EU pig, cattle and sheep herds, and meat production obtained in slaughterhouses from these categories of animals.

MATERIALS AND METHODS

The bibliographic method was used to obtain the data presented in this article, and the study period was 2015-2022.
The indicators analyzed included the livestock of the following species: pigs, cattle and sheep from the EU, and the production of meat obtained from animals slaughtered in slaughterhouses. It should be noted that the article analyzes data on animal species that were studied within Project number 1060/15.06.2022, "Proposals for strategic measures in Romanian agriculture in the context of geopolitical instability", Acronym AgRoMaS, within IPC 2022; co-financer PRO-AGRO Federation.
The statistical data in the article were processed and graphically represented based on information obtained from specialized websites such as Eurostat, OECD and Statista.
At the same time, a number of specialized materials on the chosen topic were studied, available on the websites of reference institutions in the EU, the European Commission and DG Agri.

RESULTS AND DISCUSSION

According to Eurostat, in the EU, in the period 2015-2022, the number of animals of the analyzed species decreased, as follows: in the category of pigs by 6.87%, cattle by 5.67% and sheep by 6.26%.
Spain, Germany and France were the most important pig farmers in the EU in 2015-2022. Their combined herds accounted for half of all pigs raised in the EU (50.31%). The highest percentage was held by Spain, 25.35% (Figure 2).
It should be noted that Figure 2 shows the pig herds in the EU states that raised more than 1,000,000 swine in 2022, 15 in number, which accounted for 95.99% of the pig herds in the EU. The other 12 EU Member States accounted for 4.01%.

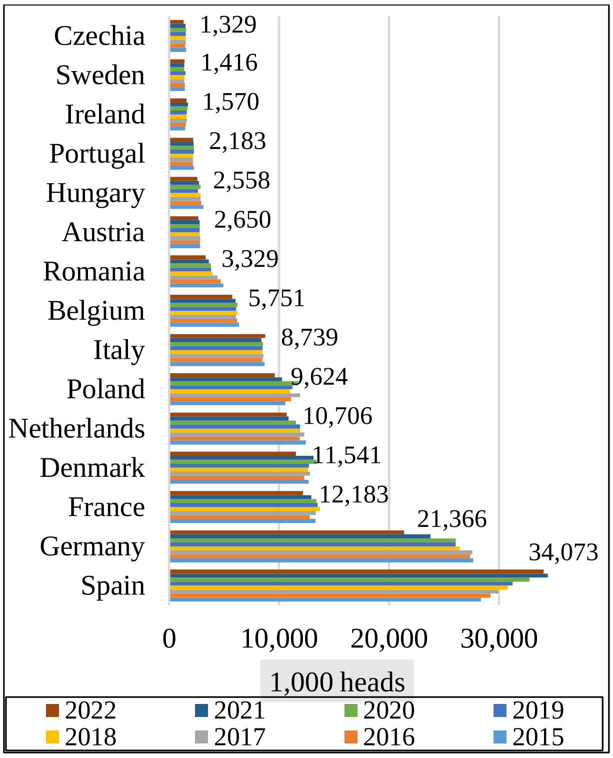

Fig. 2. Pig herds in the main pig farming states in the EU, 1,000 heads.
* 2022 values
Source: own representation after [9].

The trend in the period under review was a decrease in the number of pigs for most EU States. One explanation for this phenomenon is the diseases that have affected swine lately, such as "African swine fever". The largest decreases were registered by Slovakia -39.84%, Romania – 32.44% and Malta – 32.27%. There were also 3 exceptions, which recorded the following increases: Spain –

20.11%, Ireland – 6.50%, Italy – 0.27% and Bulgaria – 0.27%.

The top 3 countries that raised the largest number of cattle between 2015 and 2022 were France, Germany and Ireland. The herds of the first 2 ranked accounted for more than a third of the total cattle in the EU (37.41%), and for the largest breeder, France - 22.41% (Figure 3).

Figure 3 shows the top 14 countries in the EU, with more than 1,000,000 cattle in 2022, which accounted for 92.30% of the cattle in the EU. The remaining 13 states owned cattle that accounted for 7.70% of the total.

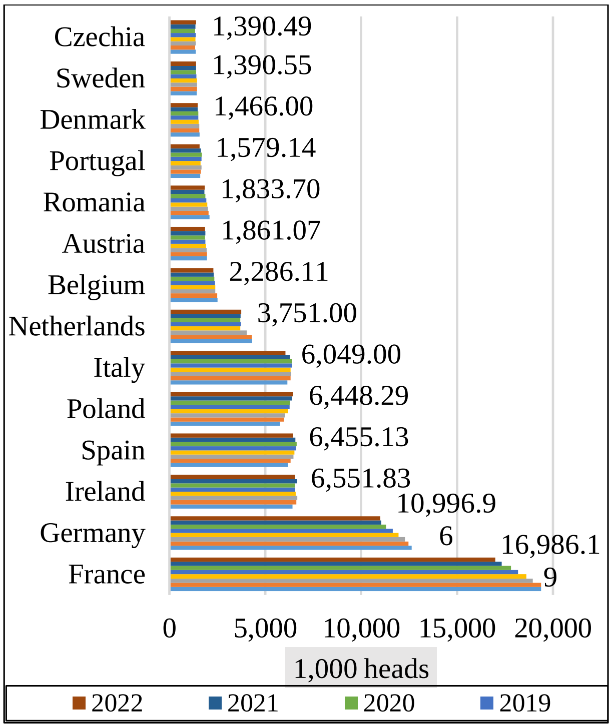

Fig. 3. Cattle herds in the main cattle breeding states in the EU, 1,000 heads.
* 2022 values
Source: own representation after [9].

As in the case of pigs, the general trend was that of decreasing the number of cattle, the highest values being recorded for the Netherlands – 13.07%, France – 12.38% and Romania – 12.36%. Cattle numbers increased in Cyprus by 38.36%, Poland – 11.90%, Hungary – 8.89%, Spain - 4.40%, Bulgaria – 3.35%, Ireland – 2.02% and Czechia – 1.77%.

In the EU a large proportion of sheep are grown in economically vulnerable areas, for example in mountainous regions [3, 5] and EU grants farmers income support payments [5].

The dynamics of sheep flocks in the EU Member States that grew over 1,000,000 specimens in 2022 is shown in Figure 4.

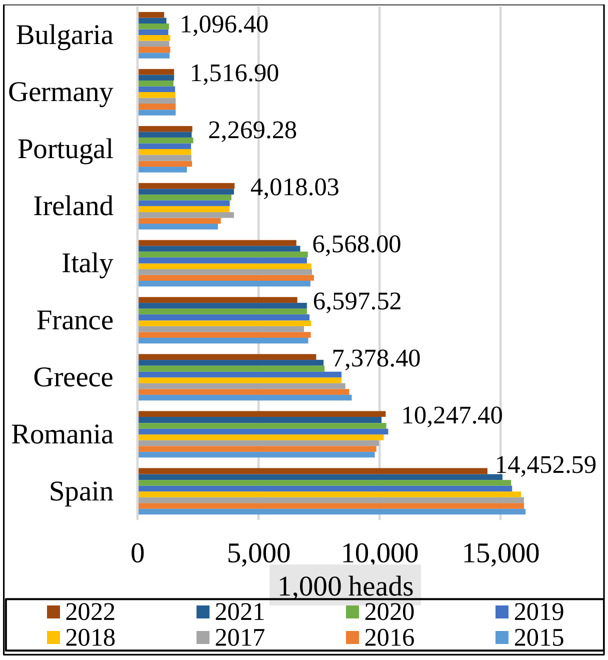

Fig. 4. Sheep flocks in the main sheep breeding states in the EU, 1,000 heads.
* 2022 values
Source: own representation after [9].

The flocks in the top 3 countries with the most sheep (Spain, Romania, Greece) represented 54.36% of the EU total, although in Spain and Greece the number of animals decreased by 9.82% and 16.65%, respectively.

Despite the fact that the total number of sheep in the EU recorded a decrease, in 10 countries the sheep flocks increased, the largest increases being recorded for Malta (30.60%), Ireland (20.85%) and Poland (20.43%).

For Sweden, the largest decrease in the number of sheep was recorded, of 42.69%, followed by the Netherlands – 29.94%.

In the EU meat production is closely related to the dynamics of livestock, the objectives and support of the Common Agricultural Policy and the prices of crops used in animal production [16]. Consumer preferences will be also very important [14].

Regarding the production of meat obtained from animals slaughtered in slaughterhouses, in the analyzed period, the available data also revealed decreases for pork by 0.67% and 0.92% for bovine meat [9].

The EU is the world's second producer of pig meat after China and the largest exporter of pig meat and pig meat products [6].

The total pork production obtained in slaughterhouses in the EU fluctuated, recording increases from 2015 to 2021, when 23,393.67 thousand tons were obtained, and in 2022 it decreased to 22,065.92 thousand tons.

This downward trend in production was also manifested in 13 of the EU countries. Thus, Malta, Germany and Romania recorded the largest decreases, with 20.18%, 19.34% and 19.15% respectively.

In contrast, meat production in slaughterhouses in the other 15 countries increased, most notably in Bulgaria by 35.15% and in Spain by 31.43%.

Figure 5 shows the pig meat productions made by the first 8 EU countries that obtained in the period 2015-2022 more than 1,000,000 tons of meat in slaughterhouses. It should be noted that the production of these states accounted for 86.40% of the total in 2022.

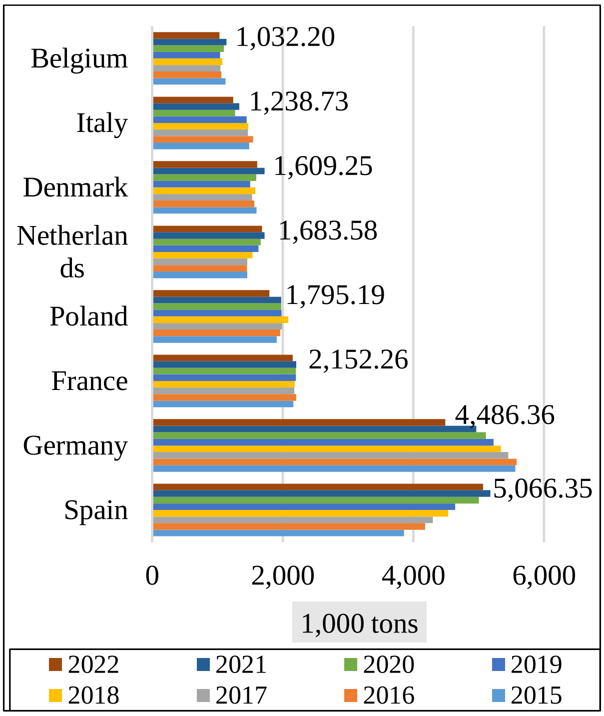

Fig. 5. Pork production obtained in the main producing countries in the EU, 1,000 tons.
* 2022 values
Source: own representation after [9].

As can be seen, the main producers were Spain and Germany. In 3rd place was France, whose production decreased by 0.49% in 2022.

The EU is also a major beef producer. It supports farmers through income support payments and uses a number of market measures to stabilize the beef market [4].

The total production of beef obtained in slaughterhouses in the EU increased from 2015 to 2018, and decreased from 2019.

More than half of the EU states have shown the trend of declining beef production and only 10 states have obtained higher yields. The largest production increases were recorded by Bulgaria (32.70%), Portugal (17.08%) and Spain (16.84%), and the largest decreases – by Romania, 19.92%, Latvia, 16.30% and Greece – 15.34%.

Figure 6 shows the beef productions made by EU states that obtained in the period 2015-2022 more than 1,000,000 tons of meat in slaughterhouses. These states had a production of 6,217.3 thousand tons, which meant 93.63% of the total EU beef production in 2022.

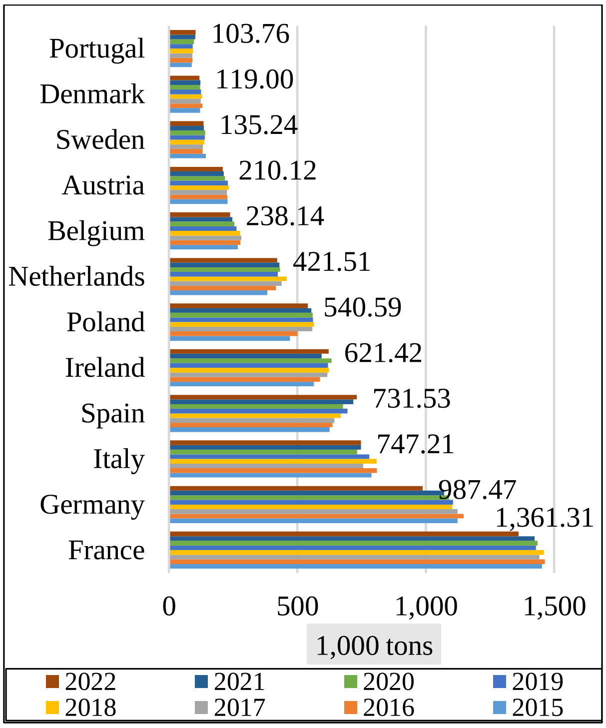

Fig. 6. Beef production obtained in the main producing countries in the EU, 1,000 tons.
* 2022 values
Source: own representation after [9].

From the analysis of the data presented in Figure 6, it results that France, Germany and Italy ranked in the first 3 places in the ranking of beef producers, despite the fact that the quantities of meat obtained in slaughterhouses in these countries decreased by 6.30%, 12.15% and 5.21%, respectively.

The information available on the Eurostat website regarding the production of sheep meat obtained in slaughterhouses, indicated that the main sheep breeders are not also the most important meat producers. This is the case of Romania, which was ranked second in terms of the number of sheep raised, and in the ranking of meat producers it occupied only the 10th place, with a production of 5.14 thousand tons in 2022, decreasing compared to 2015 by 44.19%, the largest decrease recorded for the analyzed period. It is known that Romanians eat sheep meat seasonally, and mainly around the Easter holidays [3, 11], and the government tries through various programs to sensitize consumers and change preferences regarding meat types [11].

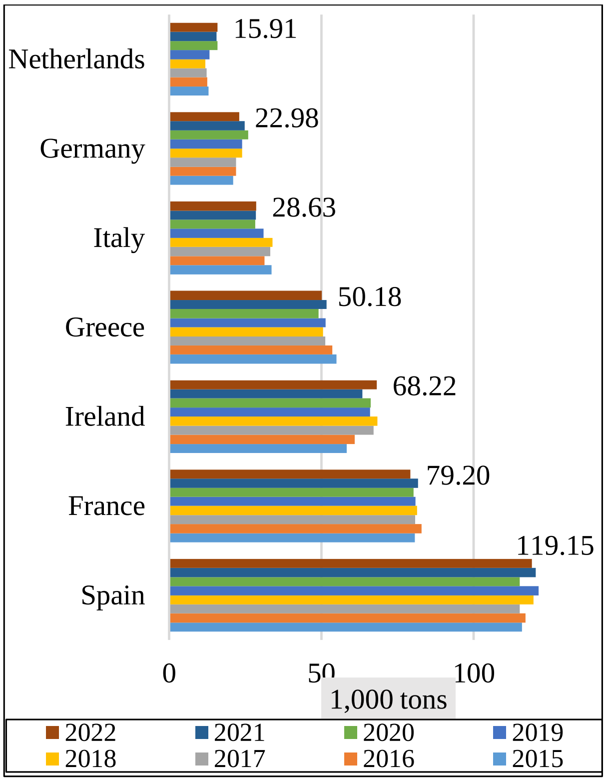

Fig. 7. Production of sheep meat obtained in the main producing countries in the EU, 1,000 tons.
* 2022 values
Source: own representation after [9].

Figure 7 shows the production of sheep meat obtained in states where more than 10 thousand tons of meat were produced in slaughterhouses in 2022. The first place was occupied by Spain, with 119.15 thousand tons in 2022, followed by France (79.20 thousand tons) and Ireland (68.22 thousand tons).

The production obtained by the 7 main producing states in Figure 7 in 2022 was 384.27 thousand tons of meat, while the other states obtained together 37.90 thousand tons.

Between 2015 and 2022, half of the EU countries recorded increases in sheep meat production, the highest values being recorded for Poland – 116.07%, Estonia, 77.78% and Hungary – 73.81%. At the same time, production declines were noted, outside Romania a large percentage being held by Denmark – 32.22% and Czechia – 27.78%.

It should be noted that another type of meat widely consumed in the EU is poultry meat. Meat production, which amounted to 43.92 million tons in 2021, was made up of 52.3% pork, 31% poultry, 15.5% beef and veal, and 1.2% sheep and goat. In terms of poultry meat, Poland and France were the top producers in the EU [15]. The EU was the fourth largest producer of poultry meat worldwide in 2022 [18].

In the coming period, a change in the content of the shopping cart in the EU is foreseen: beef consumption will continue its downward trend, pork will continue to be replaced by poultry, while sheep meat consumption will increase due to the diversification of the meat diet and the changes in the EU demography (migration and religious traditions) [8].

Another trend that will manifest itself is the change in food preferences, namely the switch to another type of diet, a trend already felt by the largest meat consumer in the EU, Germany [14]. In Germany, Poland and France, in the age category 18 - 29 years over 5% of people are vegetarians [18].

Various factors such as: animal welfare concerns, climate change, health problems, or epizootic causes consumers to switch to a diet based mainly or only on plants, thus adopting the vegetarian, vegan or flexitarian diet.

As an alternative, the EU recommends the consumption of "in vitro" meat, vegetable meat or insect consumption [7, 17].

In this situation, some companies in the meat industry have started to produce substitutes for plant-based meat. Consumption of these products is expected to increase in the European Union and reach a total of 178.8 million kilograms by 2028 [18].

At the same time, "Greenpeace" believes that pigs and cattle contribute to increasing climate problems and has asked the European Commission to recognize the environmental impact of meat and dairy consumption [10]. Simultaneously, "The Guardian" study showed that about 60% of greenhouse carbon emissions come from meat production [12]. "Greenpeace" has proposed to include in the "Farm to fork" strategy targets such as reducing meat consumption by 71% by 2030 and by 81% by 2050 [10].

Contrary to the information presented above, the Statista platform [19] estimates for 2032 an increase in meat consumption, both for the world average – 28.8 kg per capita and at the level of the continents, as follows: 2.9 kg per capita for South America, 2 kg per capita for Asia, 0.6 kg per capita for Europe, 0.5 kg per capita for North America and 0.3 kg per capita for Africa. A decrease will be recorded in Oceania, where consumption will reach 53.3 kg per capita.

CONCLUSIONS

From the analysis of livestock dynamics and production of pig, beef and sheep meat in the EU for the period 2015-2022, the following conclusions were drawn:

• the livestock in the 3 categories analyzed decreased, the most affected being the pig sector, which recorded the highest percentage - 6.87%;

• Spain, Germany and France were the most important pig breeders, owning 50.31% of the EU specimens;

• Spain, the EU state with the largest number of pigs (25.35%) recorded a 20.11% increase in their number;

• The first 2 cattle breeders were France and Germany, and their herds represented 37.41% of the total EU;

• France registered a decrease of 12.38% in the number of cattle during the studied period;

• The first 3 sheep breeders, Spain, Romania and Greece, owned 54.36% of the total EU herds;

• the production of pig and bovine meat resulting from slaughterhouses in the EU recorded a slight decrease, the highest percentage being obtained by bovine meat - 0.92%;

• The EU is the world's second largest pig meat producer and largest exporter of pig meat and pork products;

• The major EU pork producers were: Spain, Germany and France, and for beef France, Germany and Italy;

• Regarding sheep meat production, Spain, France and Ireland occupied the first 3 places;

• in the perspective of increasing sheep meat consumption, an increase in production is also foreseen.

In the coming period, the livestock sector will be subject to new challenges due to new trends in food consumption, EU directives on climate change and competition with new types of meat or meat substitutes, and at the same time the demands due to population growth.

That is why compliance with the conditions regarding animal welfare, adaptation to the technologies promoted by Agriculture 4.0 in parallel with the preservation of traditional occupations and the implementation of the "Zero-Waste Concept", will represent essential elements in carrying out activities specific to the livestock sector.

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REFERENCES

[1]AgroInfo 2019, Carnea preferată de europeni: 40 kg pe cap de locuitor pe an!/Meat preferred by Europeans: 40 kg per capita per year!, https://www.agroinfo.ro/economic/carnea-preferata-de-europeni-40-kg-pe-cap-de-locuitor-pe-an, Accessed on 11.09.2023.
[2]Agrointeligenta, 2015, Consumul de carne și motivele pentru care nu trebuie să renunți la acest obicei alimentar/ Meat consumption and the reasons why you should not give up this eating habit, available at: https://food-retail.agrointel.ro/consumul-de-carne-si-motivele-pentru-care-nu-trebuie-sa-renunti-la-acest-obicei-alimentar/, Accessed on 11.09.2023.
[3]Chiurciu, I.A., Zaharia, I., Fintineru, G., Din,u T.A., Soare, E., 2023, Sheep and goat breeding in Romania - Between tradition and consumption. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 23(2), 135-144.
[4]Directorate-General for Agriculture and Rural Development 2023, Beef, https://agriculture.ec.europa.eu/farming/animal-products/beef_en, Accessed on 03.10.2023.
[5]Directorate-General for Agriculture and Rural Development 2023, Lamb, mutton and goat meat, https://agriculture.ec.europa.eu/farming/animal-products/lamb-mutton-and-goatmeat_en, Accessed on 03.10.2023.
[6]Directorate-General for Agriculture and Rural Development 2023, Pork, https://agriculture.ec.europa.eu/farming/animal-products/pork_en, Accessed on 03.10.2023.
[7]Directorate-General for Health and Food Safety, Food, Farming, Fisheries – Food Safety 2023, Approval of fourth insect as a Novel Food, https://food.ec.europa.eu/safety/novel-food/authorisations/approval-insect-novel-food_en, Accessed on 05.10.2023.
[8]European Commission, DG Agriculture and Rural Development 2021, EU agricultural outlook for markets, income and environment, 2021-2031. DOI 10.2762/753688, https://agriculture.ec.europa.eu/system/files/2023-01/agricultural-outlook-2021-report_en_0.pdf, Accessed on 04.10.2023.
[9]Eurostat, 2023, Database, https://ec.europa.eu/eurostat/data/database, Accessed on 09.09.2023.
[10]Greenpeace European Unit, 2020, EU climate diet: 71% less meat by 2030, https://www.greenpeace.org/eu-unit/issues/nature-food/2664/eu-climate-diet-71-less-meat-by-2030/#:~:text=Brussels%20%E2%80%93%20Meat%20consumption%20in%20the,to%20new%20analysis%20by%20Greenpeace., Accessed on 11.09.2023.
[11]Maerescu, C.M., Ţuţui, D., Chereji, A.I. 2018, Evolutions and perspectives concerning the production and consumption of sheep meat in Romania. From a declining industry to a rising star. Annals of the University of Oradea, Fascicle: Ecotoxicology, Animal Husbandry and Food Science and Technology, Vol. XVII/A 2018, 87-94, https://protmed.uoradea.ro/facultate/publicatii/ecotox_zooteh_ind_alim/2018A/Animal/Maerescu_2018.pdf. Accessed on 11.09.2023.
[12]Milman, O. 2021, Meat accounts for nearly 60% of all greenhouse gases from food production, study finds, in press: The Guardian 2021, https://www.theguardian.com/environment/2021/sep/13/meat-greenhouses-gases-food-production-study, Accessed on 23.09.2023.
[13]OECD / Food and Agriculture Organization of the United Nations 2023, "Meat", in OECD-FAO Agricultural Outlook 2023-2032, DOI: https://doi.org/10.1787/f01f6101-en, https://www.oecd-ilibrary.org/sites/f01f6101-en/index.html?itemId=/content/component/f01f6101-en, Accessed on 09.09.2023.
[14]Pitulice, V., 2023, Europenii reduc consumul de carne de porc. Nemții, la dietă/ Europeans are reducing their consumption of pork. Germans, on a diet, in press: Puterea/ The Power, https://www.puterea.ro/europenii-reduc-consumul-de-carne-de-porc-nemtii-la-dieta/, Accessed on 09.09.2023.
[15]Popescu, A., Dinu, T.A., Stoian, E., Serban, V., 2022, Livestock decline and animal output growth in the European Union in the period 2012-2021. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22(3), 503-514.
[16]Sandu, M., Mantea, Ș., 2017, Study on the meat sector in the European Union. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 17(1), 375-380.
[17]Stan, A., 2023, Se interzice carnea? După interzicerea automobilelor cu benzină din 2035, Europa trebuie să reducă consumul de carne animală cu 71% până în 2030. Un oraș olandez face primul pas – interzice reclamele la carne animal din 2024/ Is meat prohibited? After the 2035 ban on essence cars, Europe must reduce animal meat consumption by 71% by 2030. A Dutch city takes the first step – it bans commercials for animal meat from 2024, in press: MEDIAFAX 2023, https://www.mediafax.ro/politic/dupa-interzicerea-automobilelor-benzina-2035-europa-reduca-consumul-carne-animala-71-pana-2030-oras-olandez-face-primul-pas-interzice-reclamele-carne-animala-2024-21617410, Accessed on 23.09.2023.
[18]Statista, 2023, Meat industry in Europe - statistics & facts, https://www.statista.com/topics/4197/meat-industry-in-europe/#topicOverview, Accessed on 07.09.2023.

[19]Statista, 2023, Per capita consumption of meat worldwide from 2020 to 2022, with a forecast for 2032, by region, https://www.statista.com/statistics/1037429/per-capita-consumption-of-meat-worldwide-by-region/, Accessed on 07.09.2023.

[20]Tirpe, A.R., Veres, A., Crecan (Letea), N.I., Maerescu, C. M., Chereji, A. I. 2023, The evolution of cattle herds in Romania in the period 2017-2021. Case study North West Region period 2017-2021. Annals of the University of Oradea, Fascicle: Ecotoxicology, Animal Science and Food Science and Technology, Vol. XXII/A 2023, 212-217, https://protmed.uoradea.ro/nou/images/Publicatii/Ecotox/2023A/33._Tirpe.pdf. Accessed on 07.09.2023.

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OVERVIEW OF AGRICULTURAL HOLDINGS IN ROMANIA AND THE EUROPEAN UNION

Gabriela-Dalila STOICA

Research Institute of Agriculture and Rural Development, Romania, stoica.gabriela@iceadr.ro; University of Economic Studies, Romana Square 6010374, Bucharest, Romania, E-mail: dalila.stoica@eam.ase.ro, stoica.gabriela@iceadr.ro

Corresponding author: stoica.gabriela@iceadr.ro

Abstract

This study aims to complement previous studies and create an overview of the subject of agricultural holdings both at the Romanian and European level. According to the statistical data and using a quantitative and qualitative research method, it was found that more than 30 years after the restoration of land ownership, a percentage of approximately 96% of the holdings in Romania are smaller than 10 hectares, while over 70% of them are represented by farms up to 2 hectares. Therefore there huge differences and discrepancies between Romania and other EU countries in terms of agricultural holdings. The results obtained confirm that small-sized farms are found in countries such as Romania, Malta, Cyprus, Greece and Portugal, while medium-sized holdings are found especially in countries such as Poland, Spain and Italy, the rest of the holdings, those between 50 and over 100 hectares, they are mostly found in Luxembourg, Finland, the Netherlands and even Germany and France.

Key words*: *agricultural holdings, Romania, European Union

INTRODUCTION

The unit of measure established in each of the structural checks of each EU member state is the agricultural holding and is based on the definition of agricultural exploitation regulated by European Commission Regulation no.1166/2008, where it is mentioned that "the exploitation means a single unit, both from a technical and economic point of view, with a single management, which carries out its agricultural activities on the economic territory of the EU, either as primary activities or as secondary activities" [8].

Although the member states are based on this definition, the level of compliance and comparability of farms differs from one state to another. There are only a few states (Romania, Germany, Slovenia, and Ireland) that have concretely introduced the definition of agricultural holding. For other states, the national definitions show a marked lack of terminology, using common terms such as farm, enterprise, unit, private holding, etc. So, for some states, slight deviations in the national definitions of the concept of agricultural exploitation, compared to the EC eregulation were observed. For example, in Belgium, in some cases, it was observed that the data recorded by a single "unit" (agricultural holding) actually included several holdings. This occurred because the sampling frame included some farmers who made a single declaration for several agricultural holdings.

In Croatia, the definition of agricultural holding mentions, among other things, that the scope of the survey includes other non-profit institutions, such as schools, hospitals, etc., which carry out agricultural activities as a secondary or additional activity [6]. However, as long as these units meet the other criteria that define an agricultural holding, they are not in contradiction with the EC Regulation. In the Netherlands, the national census also includes holdings that breed livestock, other than rabbits, but this activity is contrary to Regulation 1166/2008 [8].

In Romania, agricultural holdings can be classified according to the following criteria [9]; [10]:

• The type of activities carried out within the farm;

• Legal personality;
•Property form;
• The economic dimension and the physical dimension;

Mainly, the surface of the land owned by the agricultural holding, including the total number of animals it owns, determines the size of the holding [3]. Agriculture with a higher level of performance is generally possible within large and modern agricultural holdings. Also, this type of agriculture is also possible within some holdings that meet certain agrotechnical requirements, which are specific to these types of holdings.

The statement that the area used by commercial holdings is to a large extent equal to the surface area used by subsistence holdings generated the idea of maintaining and persisting the high level of importance of agriculture in Romania within the rural economy [1].

After the period of '89, through the legislation of that time regarding the land framework but also regarding the promotion and development of new holding structures based on the concept of private ownership of land, it reached the level of 2010 that agricultural holdings did not have personality legal entity to own more than half (53%) of the total holdings present at that time in Romania.

At the same time, more than half of the agricultural area (56%) was used by them, while holdings with legal status (47%) used an agricultural area in percentage of 44% [4].

At the moment, at the level of Romania, there is a multilateral and very complex legal framework, which influences in a clear and direct way the carrying out of activities within the holdings but also the establishment of new agricultural holdings [2]. Thus, the dimension of Romanian agriculture today, which is in continuous development, is shaped and supported mainly by the development and consolidation of holdings that have legal personality. At the same time, their development and consolidation has maintained a strong link with the other category of agricultural holdings, those without legal personality, which continue to contribute to the maintenance and support of the social protection of all rural households, but also to the support of land funds that are owned in different forms legal [11].

In this context, the purpose of this study was to present a general framework and an overview of the evolution of agricultural holdings in Romania and European Union in 2020.

MATERIALS AND METHODS

The data used in this study can be found in the database of the National Institute of Statistics in Romania and in the Eurostat database. A quantitative and qualitative data research method was used for the realization of the work, with the aim of presenting a complex framework and an overview of the evolution of agricultural holdings.

The data used refer to the distribution of agricultural holdings, but also to the distribution of agricultural areas used according to the size of the holding

This scientific paper presents information on:
- the share of agricultural holdings, analyzed according to the size classes of the agricultural areas used;
- the distribution of holdings in Romania, including the agricultural areas used;
- the number of agricultural holdings in Romania, including the areas used depending on their size;
- the distribution of agricultural holdings at the level of the EU member states and the surface used by them depending on the size of the holding;
-distribution of farms with physical size < 5 ha in EU countries;
-distribution of farms with a physical size between 10 and 49.9 ha and between 50 - >100 ha in EU countries.

RESULTS AND DISCUSSIONS

Around 2.87 million agricultural holdings were registered in 2020. Of these, 99% (2.86 million holdings) were represented by agricultural farms that do not have legal status, as a result, only about 1% (25.3

thousand holdings) were those with legal status (Table 1).

Table 1. Number of agricultural holdings by legal status in 2020

The legal status of agricultural holdings	No. of holdings	%
Agricultural holdings without legal personality	2,861,673	99
Agricultural holdings with legal personality	25,394	1
Total	2,887,067	100

Source: National Institute of Statistics [5].

Observing the information related to agricultural holdings from the period 2016-2020, registered at the national level, a downward trend of their total number was observed, so that in 2016 there were 3.39 million holdings, approximately 19% more than in 2020.

Analyzing agricultural holdings and the used agricultural area returned to an average agricultural holding, it was noted that 2.81 million agricultural holdings that do not have legal personality used approximately 7.81 million hectares. However, it was observed that, on average, the agricultural surface used by an agricultural holding is approximately 52.53 hectares.

At the same time, it should be mentioned that 25.1 thousand holdings that have legal personality used an area of approximately 5 million hectares (4.98 million hectares), and the used agricultural area that returned on average to a single holding was 1,620, 5 hectares (Table 2).

Table 2. Agricultural holdings and the average used agricultural surface per agricultural holding, by legal status

The legal status of agricultural holdings	TOTAL agricultural holdings (Number)	Farms that used agricultural land (Number)	The agricultural area used (ha)	The used agricultural area which return on average (ha)	
				Per agricultural holding	Per an agricultural holding that used agricultural land
Agricultural holdings without legal personality	2,861,673	2,826,368	7,816,660.3	52.53	53.15
Agricultural holdings with legal personality	25,394	25,128	4,946,168, 29	1,620.55	1,633.04

Source: National Institute of Statistics [7].

Continuing to analyze the data, however, from the point of view of the size of the used surface, it was possible to note that most farms were smaller than 0.5 ha, however, representing a fairly high share, around 37 % of the total holdings at the national level.

On the other hand, from the perspective of the legal framework, holdings that were not considered legal entities, and that had an area smaller than 0.5 hectares, represented a weight of 37% (1.05 million) of the total holdings.

A very small share (0.002%) is owned by large holdings, those with a physical size of over 1,000 hectares.

At the same time, the highest share is owned by holdings that have legal personality and are between 100 and 500 hectares in size (Figure 1).

After more than 30 years after gaining land ownership rights, 96% of the number of agricultural holdings in Romania are smaller than 10 hectares, while 71% of them are agricultural holdings with an area of less than 2 hectares. Consequently, the current agricultural sector in Romania is extremely polarized, being made up of two main categories of entities, with different characteristics and different functionalities.

They refer to small-scale agricultural holdings, whose production is reduced, both quantitatively and qualitatively, directed mainly toward own consumption.

The second category refers to large agricultural holdings, which own approximately half of the agricultural land, where there is mechanized production, being oriented toward the commercialization of the entire production obtained (Figure 2).

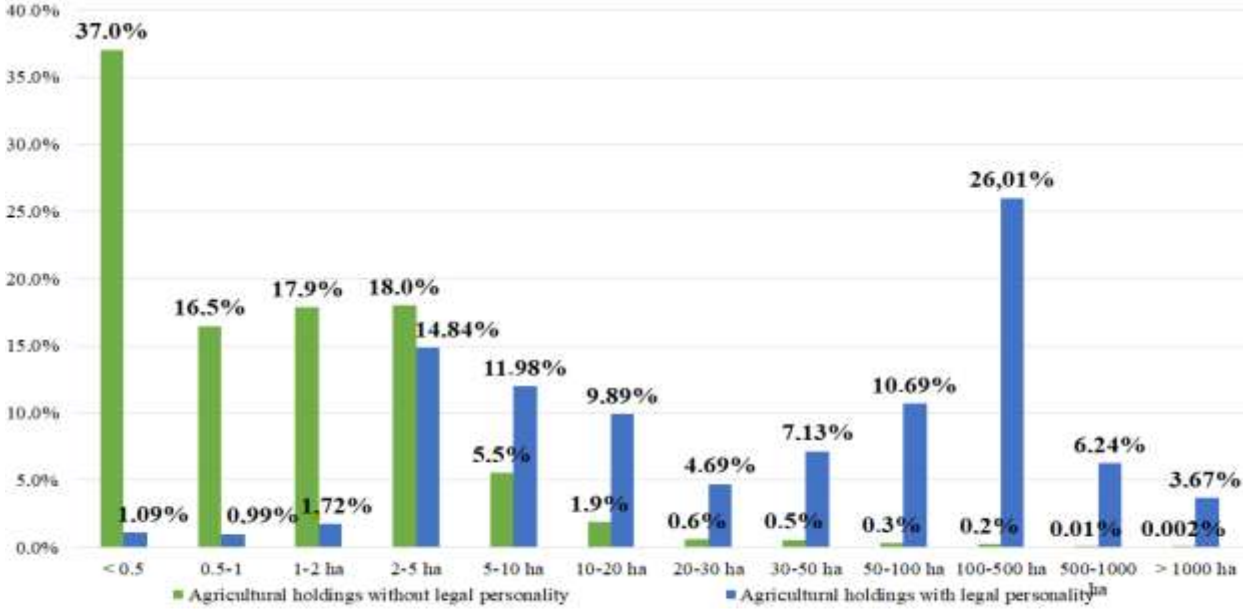

Fig. 1. The percentage of agricultural holdings, by classes of the size of the agricultural area used, according to the legal status of the agricultural holdings
Source: National Institute of Statistics [7].

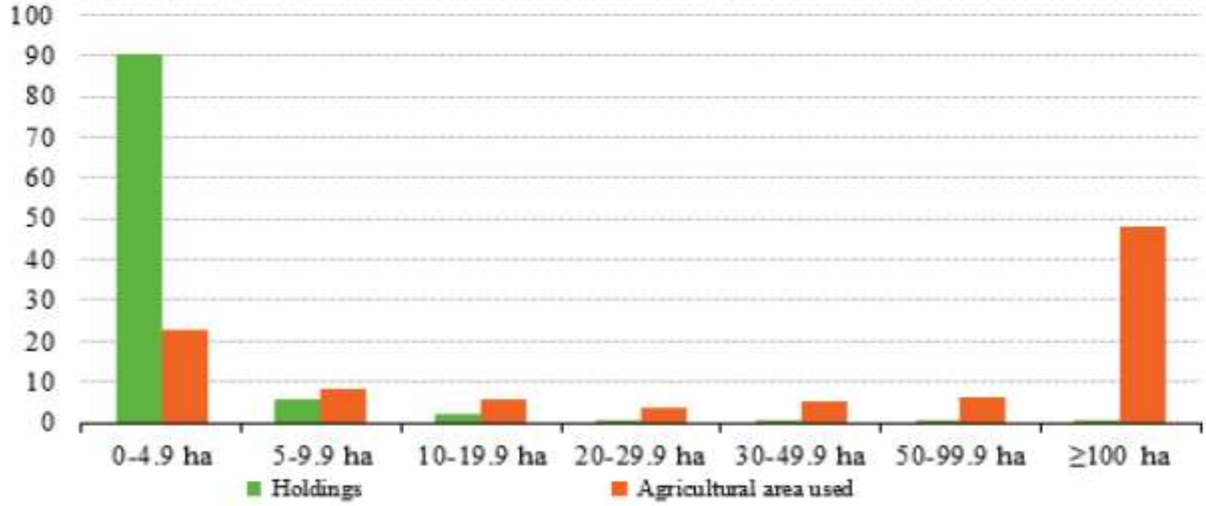

Fig. 2. Distribution of Romanian farms and the agricultural area used according to the size of the farm (%, 2020)
Source: National Institute of Statistics [7].

Thus, for the sector of medium-sized agricultural holdings, maintenance of them is still observed, and even for the near future, there do not seem to be any prospects of increasing their number, given that the analyzes and developments of the last period indicate an extensive process of pooling and growth of large holdings [12].

Farms < 5 hectares represent around 91% of all agricultural holdings in Romania and hold just under a quarter of the used agricultural area (22.8%). The fact that almost a quarter of the total area is allocated to holdings <5 hectares contributes to the understanding and explanation of some negative aspects, which over time have caused catastrophic effects on Romania. Among these aspects are the high degree of poverty in the country's rural areas, the precarious level of education, the lack of

adequate living conditions, all of which lead to a poor quality of life.
Analyzing agricultural holdings under 10 hectares, we note that they represent approximately 96% of all holdings present in Romania, while they exploit only 31% of the used agricultural surface.

On the other hand, 21% of the agricultural area is used by medium farms, with physical sizes between 10 and 100 ha. This category of holdings represents only 3.5% of the total number of existing holdings.

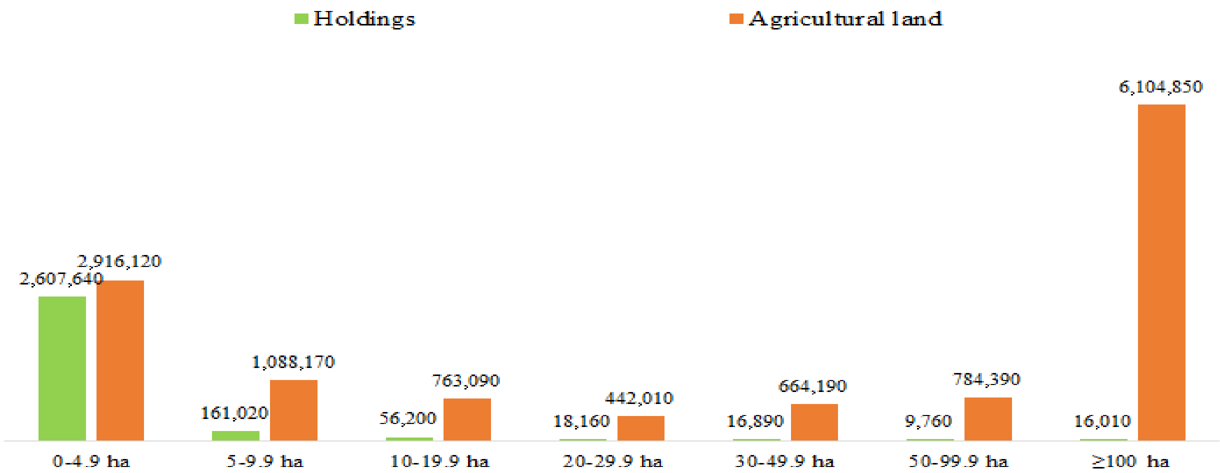

Fig. 3. Distribution of the number of Romanian farms and the agricultural area used according to the size of the farm (no, 2020)
Source: National Institute of Statistics [7].

The excessive polarization existing in Romania is generated by the existence of a very small number of large holdings, but which own more than half of all agricultural land. Also, despite the low percentage of large holdings (0.5% of the total), it was observed that they use almost half of the agricultural area, indicating that large farms, from an economic point of view, are much more efficient, compared to other categories of holdings.
However, at the EU level in terms of areas, 64% of agricultural holdings had a used agricultural area of less than 5 hectares. Small farms are very important in the country's economy because they contribute to reducing the level of poverty in the countryside, through the additional income obtained but also through the fact that there is an additional flow of food.
In the opposite direction from the perspective of the scale of production, 53.4% of all agricultural area used by the EU was worked by 3.6% of farms, having a physical size of 100 hectares or even more (Figure 4).
The distribution of holdings in this way is quite important for countries like Romania, because it is known as the country with the highest number of small holdings (under 5 hectares), approximately 9 out of 10 farms being smaller than 5 hectares (2 .6 million holdings < 5 hectares).
Taking into account the fact that at the level of the European Union, most farms were between 0 and 5 hectares, a short analysis was also carried out at the level of each member state, in order to highlight the discrepancy between them. Thus, it was observed that in countries such as Malta (96.6% of the total number of farms registered in Malta), Cyprus (87.5%), Greece (74%), Portugal (73%), etc., there were predominantly small farms (Figure 5).

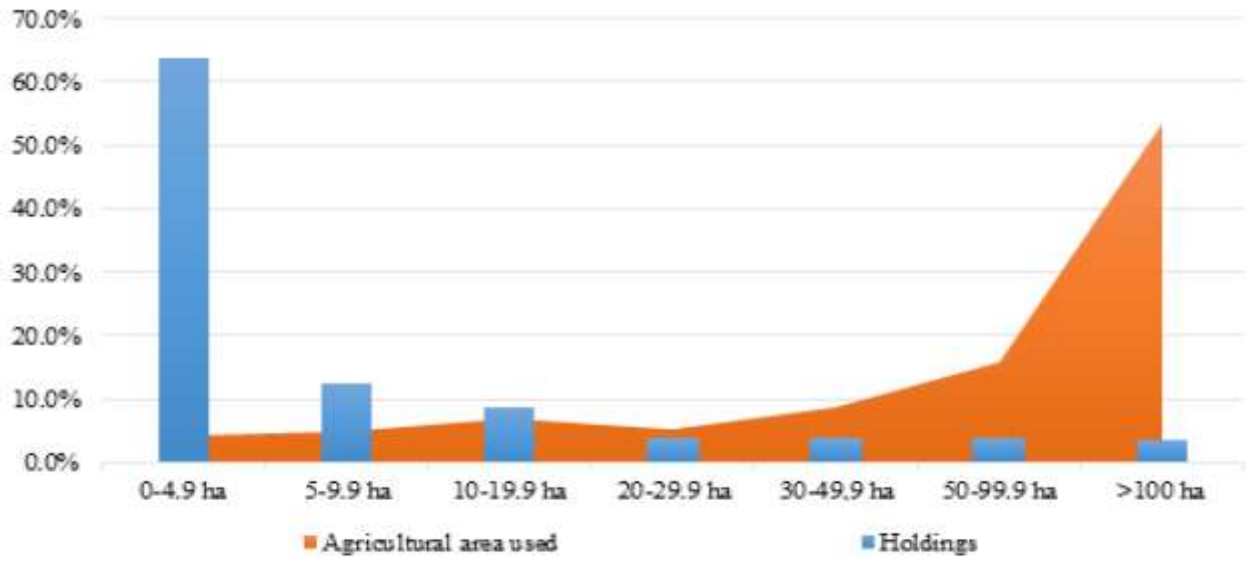

Fig. 4. Distribution of European Union farms and used agricultural area by farm size (%, 2020)
Source: Eurostat statistical database processing [5].

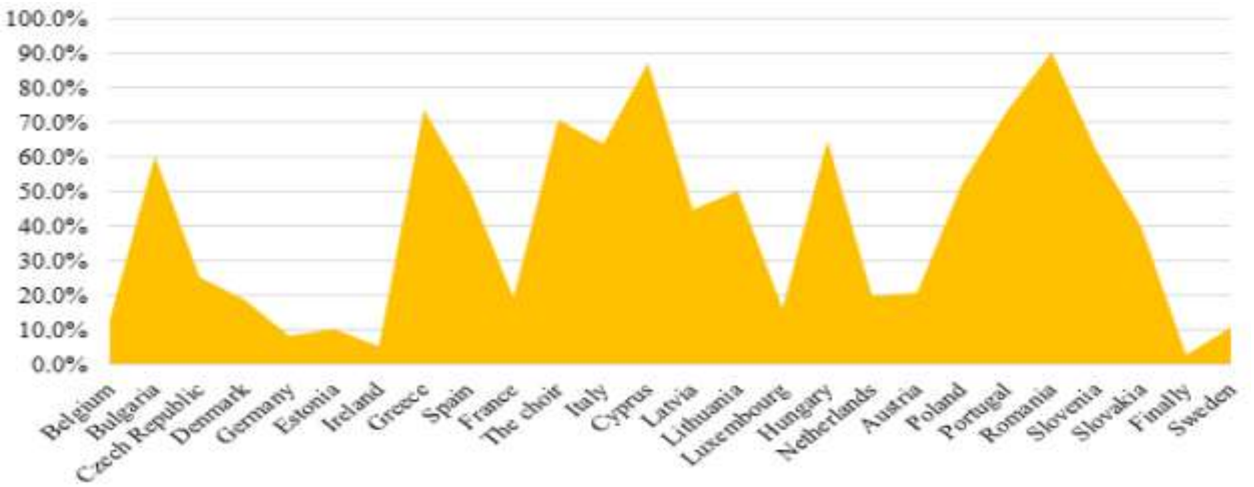

Fig. 5. Distribution of farms with physical size < 5 ha in EU countries (%, 2020)
Source: Eurostat statistical database processing [5].

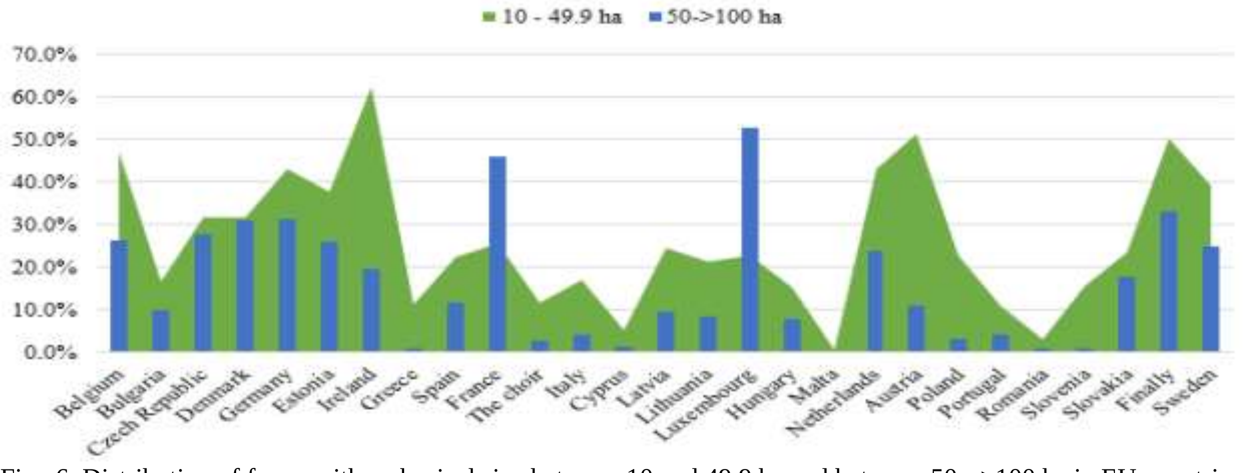

Fig. 6. Distribution of farms with a physical size between 10 and 49.9 ha and between 50 - >100 ha in EU countries (%, 2020)
Source: Eurostat statistical database processing [5].

However, medium-sized holdings, between 10 and 49.9 hectares, are in a slightly more delicate situation, because of the total number of holdings in the EU as a whole (9.07 million holdings), they hold a percentage only 16.4% and use about a quarter (21%) of the EU-27 agricultural area. The most such holdings are in Poland (298 thousand holdings), followed by Spain and Italy with 13.8% and 13.1% respectively (Figure 6).
In other words, the rest of the holdings, those between 50->100 hectares, are largely found in Luxembourg (53.7%), Finland (39%), the Netherlands (35%), and even Germany (33%) and France (32%).

CONCLUSIONS

The initially proposed goal was fulfilled and this study completed the results from the previous studies.
It also contributed to the expansion of the current specialized literature and the need for future research.
Following the analysis, it is concluded that in Romania, in 2020, approximately 2.87 million agricultural holdings were registered, most of them being agricultural holdings without legal personality (99.1%). Agricultural holdings in Romania with a size of less than 10 hectares have a weight of 96%, of which 71% are represented by holdings with a size less than 2 hectares.
Observing from the perspective of EU countries, a large number of small farms are also found in Malta (96.6% of the total number of farms in Malta), Cyprus, Greece, Portugal, etc., while for medium farms (those between 10 and 49.9 hectares) the situation is different and more delicate because, out of the total holdings of 9.07 million holdings, registered at EU level, they hold a share of 16.4% and use approximately a quarter (21%) of the EU agricultural area -27.

REFERENCES

[1]Bohataret, V.M., Bruma, I.S., 2015, Regional changes in the agricultural holdings structure in Romania during the 2002-2010 period (Mutatii regionale in structura exploatatiilor agricole din Romania in perioada 2002-2010) In Book: "Perspective ale agriculturii si dezvoltarii rurale prin prisma noi Politici Agricole Comune 2014-2020", pp.473-488. Editura Academiei Romane (Prospects of agriculture and rural development in the vision of CAP 2014-2020, PP.473-488, Romanian Academy Publishing House.
[2]Brumă, I. S., Bohatereţ, V.M., 2015, The implications of the agricultural holdings with the legal entity when using the agricultural lands in Romania, Agrarian Economy, and Rural Development - Realities and Perspectives for Romania, 6th Edition of the International Symposium, November 2015, Bucharest, The Research Institute for Agricultural Economy and Rural Development (ICEADR), Bucharest, pp. 105-112.
[3]Burcea, M., Micu, M.M., 2011, Size and characterization of agricultural holdings in Romania reported in EU 27, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.11(1).
[4]Dumitru, E., Micu, M.M., Tudor, V.C., 2019, Conceptual Approaches Regarding The Romanian Rural Area, Scientific Papers-Series Management Economic Engineering in Agriculture And Rural Development, Vol. 19(2):121-127.
[5]Eurostat Database, 2023, Farms and farmland in the European Union - statistics, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Farms_and_farmland_in_the_European_Union_-_statistics, Accessed on 20.05.2023.
[6]Gucek, A., 2020, Family farma (Obiteljsko poljoprivredno gospodarstvo), Doctoral dissertation, University North. University center Koprivnica. Department of Business and Management.
[7]National Institute of Statistics of Romania, 2022, Press Release No.74.27 March 2022, https://insse.ro/cms/sites/default/files/com_presa/com_pdf/rga_2020r.pdf, Accessed on 20.05.2023
[8]Regulation (EC) no. 1166/2008 of the European Parliament and of the Council of November 19, 2008, regarding structural surveys in agriculture and the survey regarding agricultural production methods and the repeal of Regulation (EEC) no. 571/88 of the Council. https://eur-lex.europa.eu/legal-content/RO/TXT/PDF/?uri=CELEX:32008R1166&from=EN, Accessed on May 20, 2023.
[9]Romanian Parliament, Law No. 37/2015 on the classification of farms and agricultural holdings, by type of general type of agricultural activity.
[10]Sterie, C., Dumitru, E.A., 2020. Research on the evolution of the number of agricultural holdings in the period 2002–2016. Scientific Papers. Series Management, Economic Engineering in Agriculture and Rural Development, 20(3), pp.579-582.
[11]Tachianu, A.V., Marcuta, A., Marcuta, L., 2022, Study on the evolution of the size of agricultural holdings in Romania and the UE in the period 2007-2018. Scientific Papers Series Management Economic

Engineering In Agriculture And Rural Development, 22(1), pp.655-661.
[12]Țăra, S., 2020, Romanian agrarian structure after thirty years, Journal of Community Positive Practices, XX(4) 2020, 3-24.

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DEVELOPMENT OF RAISEDBED MACHINE FOR SMALL-SCALE FARMERS TO IMPROVE WATER USES EFFICIENCY IN IRRIGATED ECOSYSTEMS

Atef SWELAM[1], Ahmed EMARA[2], Tarek FOUDA[3]

[1]Office of Innovation, UN-FAO, Rome, Italy. E-mail: atef.swelam@fao.org, previously: International Center for Agricultural Research in the Dry Areas (ICARDA), Cairo, Egypt
[2]Helwan University, Faculty of Engineering-Mataria, Mechanical Power Engineering Department, Egypt. Emails: aaarazek@gmail.com
[3]Tanta University, Faculty of Agriculture, Agriculture Engineering Department, Tanta, Egypt. Emails: tfouda628@gmail.com

Corresponding author: tfouda628@gmail.com

Abstract

The locally manufactured small-scale agricultural machinery in Egypt has recently acquired high importance in order to localize technology and innovation at the farm level. This study aims to design a cost-effective multi-seed planting raisedbed machine to rationalize water use and enhance land productivity in the Nile Delta of Egypt. The small farmers will adopt this technique to enable water, energy, seeds, and effort saving. The design of the machine went through a systematic process of tests to ensure that the design fit for purpose considering a set of design criteria such as soil type, crop type, and varieties as well as seeds size, planting rates, roads networks, farm sizes, cost-effectiveness, and available existing traction forces. The analyses using SolidWorks, a solid modelling computer-aided design and engineering application program, and Ansys simulation software were carried out to the loads and stresses subjected to different parts of the machine in order to identify the proper thickness and materials to manufacture the machine. Based on the stress and strain analysis, the machine structure and its components were designed. The main components of the machine include the main skeleton, seed drill box, planter seed box, feeding chambers, and cells as well as a feeding tube, gearbox, ditchers, ground-driving wheel and transmission mechanism, and mounting triangle. After building the machine components, various investigations were performed by subjecting the used materials to ascending loads to analyze shearing force, normal stress, shear stress, strain, and strength analysis in a micro meshes scale in all machine components. These tests enabled the identification of deformations, equivalent elastic strain, and Safety factor on different machine parts. The simulated values of the machine's parts in thicknesses and dimensions were in good correspondence and consistency with the actual design values. The model showed that the boundary conditions were accurate and rational, and it would provide a scientific basis for the optimum design of the raisedbed machine under multiple and interlinked loads.

Key words*: *laying hens, carbon footprint, egg production, methane, nitrous oxide, carbon dioxide equivalent

INTRODUCTION

World's population is constantly increasing and creating pressure on agrifood demand thus leading to increasing the importance of food production. One of the ways to increase food production is the agricultural mechanization and the agrifood industry. The agricultural sector is facing several challenges, amongst is lack of skilled and cost-effective labour to efficiently and timely carry out agronomic practices. Therefore, agricultural mechanization can significantly contribute to overcoming these challenges. Agricultural mechanization aims to perform efficiently and effectively several agricultural operations in a short time with less labour and energy. Agricultural mechanization is an important input to agricultural production in reducing the cost of farming and maximizing the utilization of inputs (seeds, fertilizer, chemicals, and water). It is also improving the quality of the yield and reducing drudgery in farm operations [6].
Sowing techniques and types of seeding machines play an important role in seed placement and seedling emergence which ultimately affect crop growth and grain yield.

In crop production systems, seed germination and crop establishment potential are primarily determined by the soil conditions and land preparation that exist immediately prior to planting (tillage depth, land leveling, soil salinity, the quality of the seed, and seedbed environment) as well as weather influences during the establishment period. To successfully establish crops under the conditions that are likely to exist at planting, the sowing machine should be able to open furrows, properly places the seeds in the targeted place with appropriate soil cover, firm the seedbed, and perform other functions as needed such as weed and pest control [3].

Generally, the planter is made up of a frame that includes seed hoppers, a precision measuring device, a bed forming, and a power transmission system. Most of the planters are mounted and get the draught from a tractor, and the drive to the seed metering mechanism is transmitted from the ground drive wheel via chain and sprockets or from the tractor's PTO. There are some studies conducted on wheat planting in beds such as a manufactured planter designed by [15] which can sow wheat on pre-established broad beds and seeding while simultaneously establishing beds. Raisedbed farming systems (RBs) combine the majority of the elements of conservation agriculture leading to encouraging results under various environmental conditions. The RBs have the potential to reduce soil compaction and restore physically degraded soil structure as well as water saving and crop yield increasing while reducing the risk of water logging [19].

The agricultural machine is a device that performs mechanical movements to transform energy, materials (e.g. seeds, fertilizers, chemicals) and information (e.g. digital extension or automated machinery) to facilitate the agronomic practices. These machines consist of parts which are designed collectively then manufactured separately thereafter assembled in a systematic process. The parts are partially or completely combined into nodes then these nodes assembled in units that have a common functional purpose. Complex components may include several simple nodes (sub-nodes) for example; a gearbox includes bearings and shafts with gears mounted on them [25]. Agricultural machine constructions used for crop planting are exposed to a very corrosive environment while used in the field. Non-uniform corrosion deterioration can have a substantial impact on the function of different machines' structural elements and devices, thus on the machine's performance. Therefore, the most prevalent kinds of corrosion such as pitting, soil reaction, and general corrosion may be identified during the machine design stage [5]. In order to avoid or minimize machine performance deficiency, the electrical and mechanical characteristics of iron must be investigated and properly identified in the subject of material science (steels).

Developing and testing of agricultural machines become a complex process that should be well-studied. Due to agricultural areas expansion, the locally-customized agricultural machines become the main factor to increase agricultural production. Agricultural machines developed and tested in some countries are not necessarily to provide same performance with the same results in another location. Therefore, local conditions such as climate, soil, energy source, operators, and machine purposes all should be considered as these factors could influence the operational functions and capacity of those machines. Thus, developing, testing, and evaluating those machines are important under local conditions [1].

The ideal machinery can have obtained by several designs and manufacturing changes as emphasised by [7], [9] and [2] which led to many shortcomings including backward design methods, low design accuracy and efficiency, incapable pre-assembled parts and interference with assembly tests, and un-intuitive graphical expression. They explained this by indicating that the above-mentioned problems, machinery parts, and components for parametric modelling and virtual design should be adopted by parametric modelling software to resolve the former design problems. In their research, they studied components of the single-line potato harvester using the three-dimensional modelling software SolidWorks based on the practical problems of potato production.

The mechanical strength of compacted material is defined as the compressive strength/stress of the composites at maximum loading [14]. Stress stability refers to a body's or system's capacity to return to a previously established steady state after being perturbed. It also refers to a body's ability to re-establish equilibrium at the moment of any distortion [16]. SolidWorks software program and ANSYS are used to analyse the stress, strain, and deformation forces and ensure accurate machine design. Furthermore, ANSYS is a general-purpose modelling tool used to solve a wide range of mechanical problems theoretically. These challenges include static/dynamic, linear, and nonlinear structural analysis, heat transport and fluid problems, as well as acoustic and electromagnetic difficulties [12]. SolidWorks is an industrial standard for three-dimensional solid modelling, automated design, engineering analysis, and product preparation for any complexity and purpose.

Three SolidWorks primary system configurations are available depending on the type of work under investigation, namely; SolidWorks standard, professional, and premium [17]. Nishit [11] studied the Machine's chassis designed using ANSYS analysis and SolidWorks software programs. The structural material characteristics were employed in their study because most manufacturing materials are either cast iron or structural steel. The highest equivalent elastic strain they found was 2.4973e-005 m/m, while the minimum was 3.1335e-008 m/m. The greatest major elastic strain observed was 1.9219e-005 m/m, whereas the minimum was 6.0353e-009 m/m. The greatest total deformation is 37.539 m, while the minimum total deformation is 5.1243e-002 m.

A fracture is the spread of micro-fractures/cracks within specific parts of a material caused by excessive/residual stress created in the sample. A material point of fracture is a point on the stress-time curve where the sample separates into sections due to near and different fractures within specified portions of the material under the action of increasing load in a compression test. The yield point is a stress-time point. Above the proportionality area, there is a curve where a rapid rise in unit stress does not correlate to a comparable unit increase in time [4]. A model material's stress stability might suggest a rise in stress that corresponds to an equivalent increase in time. The stress/time relationship in such compacted material could not accommodate fracture and rupture points up to the yield point [13].

The current study focused on the design, testing, and evaluation of a small-scale multi-function raised bed machine using SolidWorks and ANSYS software programs to support small farmers to rationalize water use and enhance water consumption and land productivity in irrigated agriculture.

MATERIALS AND METHODS

The concept of raisedbed planting is nothing new for Egypt-delta farmers; it has been used a long time ago. The ancient Egyptians, simply, were making furrows and planting seeds on top of the beds. Raisedbed planting has a better performance as there is less need to apply water to the whole field, leading to decreased water losses. Planting wheat on the ridges insures good aeration of the roots, better use of solar radiation, efficient use of fertilizer, and easier weed control and other agricultural practices. Nowadays, the Nile Delta farming system is an intensified agriculture; farmers are widely using raisedbed planting for several seasons utilizing the same farm layout of the previous crops to save time and land preparation costs for the next crop. This is a cost-effective way of conservation farming. The current planting technology ensures the proper implementation of the raisedbed dimensions and saves the seeds and farming time.

Design of the Raised Bed Multi-Crops Planting Machine

Small farm mechanization in Egypt is a difficult process due to economic concerns when purchasing and operating farm machinery. Small farm size in the Nile Delta requires simple machines to do hard work in a short time due to intensive agriculture practices in very fragmented lands. The selection of an appropriate machine is a critical factor for sustainable use under Nile Delta's conditions. So it has to be thoughtfully and carefully selected. The key factors associated with machine selection for the Nile Delta are: 1) the machine size is suitable for fragmented small farms, 2) the cost-effective machine is suitable for poor-resources communities, 3) the machine weight is suitable for clay soil to avoid soil compaction and 4) the machine operation is in passive energy mode.

The scope of this work was to simplify the mechanized raised-bed planting to accelerate the farmers' adoption of raised-bed planting subsequently, save the applied water, and enhance water productivity. The existing machines are unsuitable for farm size in the Nile Delta. So, the key objective is to design, develop, and test a cost-effective raised bed machine for small/medium size farms in the Nile Delta. The use of the developed machine showed that the raised-bed system as an irrigation water-saving technique has dramatically reduced water losses and water applied and significantly improved crop yields. The raised-bed multi-crop planting machine was designed using SolidWorks software considering the following factors:

-Cost-effective compared to the existing machines

-Passive energy operation suitable for more land types.

-Locally manufactured with available spare parts in the local market

-Suitable for small and medium farm sizes of the Nile Delta

-Suitable for intensive canopy cover crops (e.g. wheat, berseem, rice, and other crops) and interspaced crops (e.g. corn, sugarbeet, fababean, and other crops)

-Minimum mechanical/movable parts with simple and easy to maintain

-Simple metering system and easy to maintain

-Quick adjustable sprocket set customized for each seed rate, seed size, and crop type

-Land wheel rubber tires for less traction force, less drive wheel slippage, and better seed spacing

-Tractor mounted for easy cultivation

-Suitable for any tractor type/capacity

The dimensions and shape of the raised-bed machine shown in Figures (1 to 14) demonstrating the final prototype design of the machine.

Stress, Strain, and Strength Analysis

After performing the machine design, the prototype machine was investigated through ANSYS 18.1 software program to analyse the structural material properties because most of either cast iron or structural steel is used as a fabrication material. Mesh hexahedral mesh with 1,045,708 nodes with a maximum cell size of 1 mm and a minimum cell size of 0.15 mm. The time required to tackle this challenge is 240 hours. The material employed in the analysis is structural steel as shown in Fig. 15.

Material Data

The Structural steel was used to build the machine parts (Figure 1) with specifications shown in Table (1).

Table 1. Structural Steel Constants

Items	Value
Density	7.85e-006 kg/mm^3
Isotropic Secant Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	4.34e+005 mJ kg^-1 C^-1
Isotropic Thermal Conductivity	6.05e-002 W mm^-1 C^-1
Isotropic Resistivity	1.7e-004 ohm mm

Source: Authors' determination.

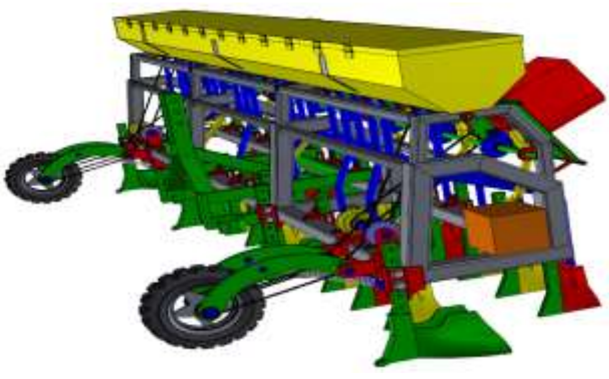

Fig. 1. Raisedbed Machine (RBM)
Source: Authors' determination.

The Raisedbed Machine (RBM) Design and Structure

The RBM consists of the main structure, two seed boxes, feeding cells, feeding tubes, vents of the MRB machine, ditchers, driving wheels and transmission system, and mounting triangle.

(1)The Main Structure

The primary structure is separated into two sections:

(A)Lower Base Chassis:

This is the most solid section of the machine, carrying the machine's entire load of components, including seeds, vents, and ditchers that formulate the beds and farrows. The cross-section of the lower base of the main skeleton was designed as a square section from steel type ST-37 with dimensions of 80 x 80 mm with a thickness of 8 mm that is solid enough to accommodate the potential loads without bending or twisting the chassis. It also provides a uniform distribution of traction forces from the tractor to the rest of the various sections. ST-37 was chosen in accordance with the German common produced quality standards DIN17100 and complies with Egyptian regulations. This steel well withstands welding. The yield stress is greater than 235 Mpa and the tensile stress (maximum stress) ranges between 360 and 510 Mpa, making this type of steel quite safe in that design. It corresponds to the following codes: EN: S235JR, JIS: SS400, ASTM: A283C, and UNI: FE360B.

(B)Upper Chassis:

A square section beam with dimensions of at least 40 x 40 mm and a thickness of 5 mm of ST-37 iron was considered for the upper chassis. It is firmly welded into the body of the lower chassis. This chassis carries seed boxes as well as feeding and transmission gears as shown in Figure 2.

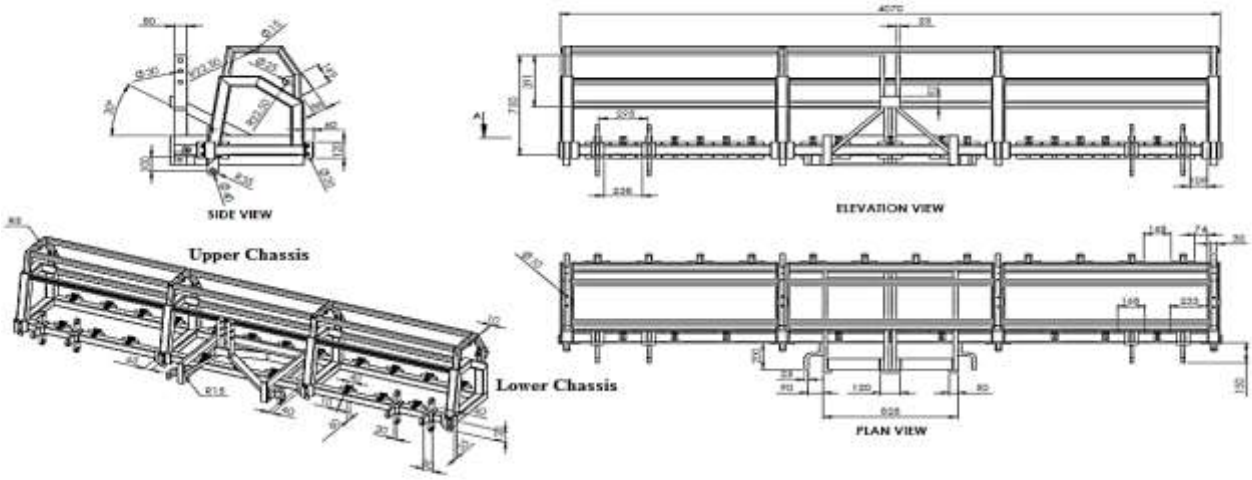

Fig. 2. The main structure of the machine’s lower and upper chassis.
Source: Own determination.

(2)Seeding Boxes

The machine contains two independent seeding boxes constructed of steel sheets with thicknesses of 3 mm with a volume capacity enough to load the needed seeds amount to at least 4 acres in one filling. The boxes are adequately coated with paint to protect them from corrosion. The seed boxes' dimensions and specifications are described as follows:

(A) Seed-Drill Box:

The dimensions of this box are 4110 x 410 x 295mm in length, width, and depth respectively as shown in Figure 3. This seeding box is used for small seeds with modest dimensions and sizes and for intensive crop plantings such as wheat, barley, clover, and sesame. Before planting starts, this box is filled with an adequate amount of seeds (approximately 0.5 m3). The box is triangular in outside shape, with a cony shape from inside to maintain seeds directed to the metering system of growth. The box's bottom is outfitted with three Plexiglas sections (external gauges) that allow the driver or farmer to continually monitor the seed level in the tank as shown in Figure 3.

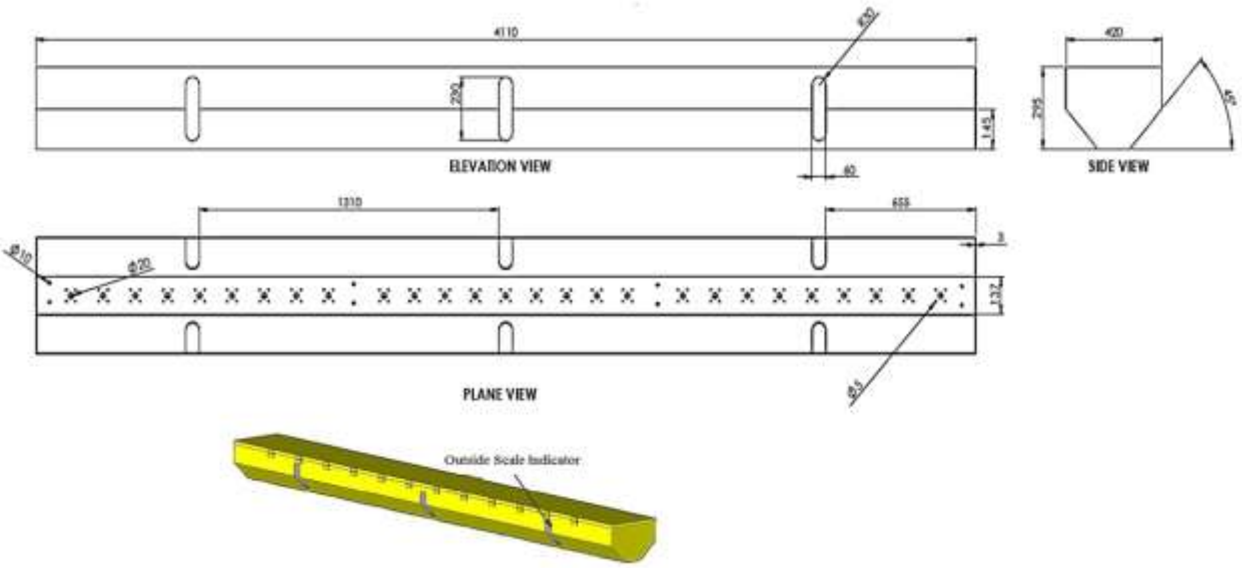

Fig. 3. Seeds Box for Small Seeds in dimensions and sizes
Source: Authors' determination.

(B)Planter Box:

It is used to sow large seeds for interspaced crops such as beans, corn, and sugarbeet. It is a distinct set of nine buckets with a capacity of 20 liters each. It nourishes the matching seeds' transfer gear. All buckets are constructed with a semi-circular, 20 cm diameter stream from the bottom to allow seeds directed toward the metering system without leaving any seeds in the bottoms of the boxes as shown in Figure 4. Figure 5 shows a combined image of the two large and small seed boxes. The design addresses the separation of motion transmission for the feeding gears of the other box. This allows operating the planter metering system separately from the seed-drill metering system (Figure 6).

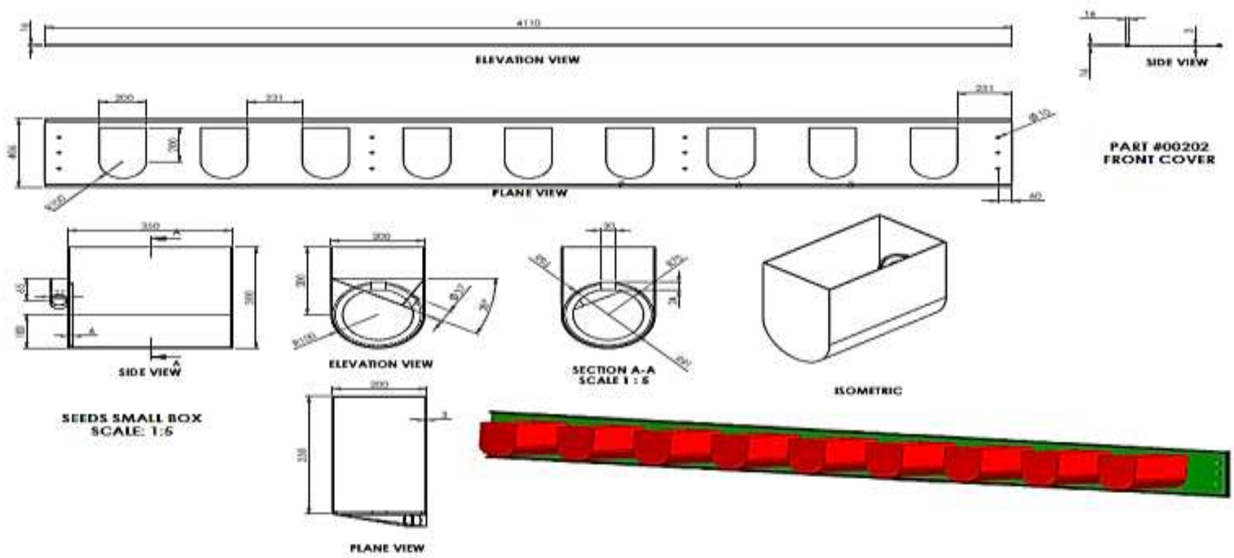

Fig. 4. Large Seeds Box for Big Seeds in Dimensions and Sizes
Source: Authors' determination.

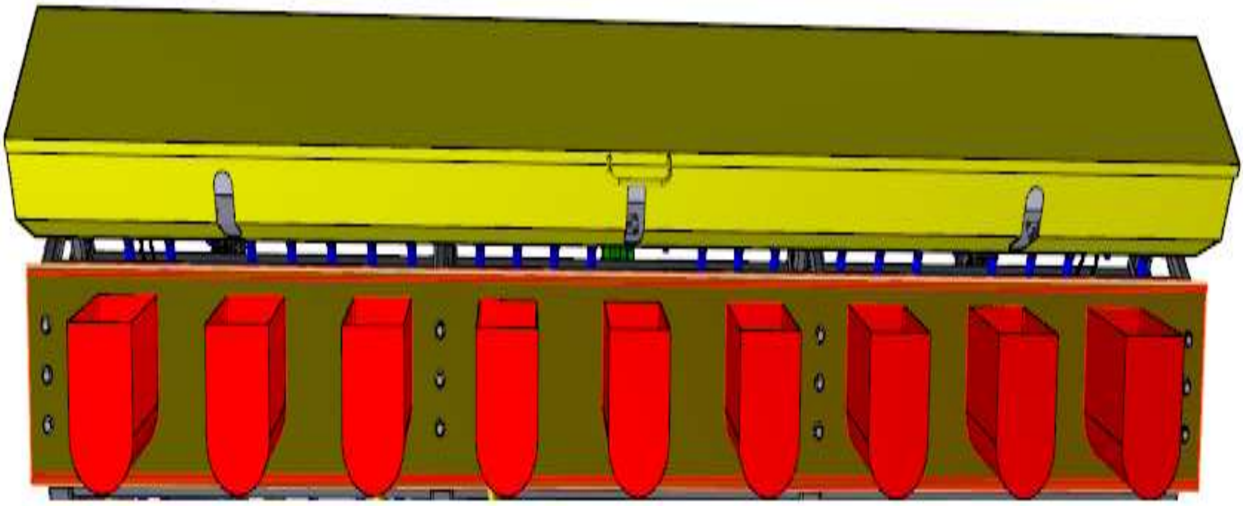

Fig. 5. A combined image of two large and small seeds boxes
Source: Authors' determination.

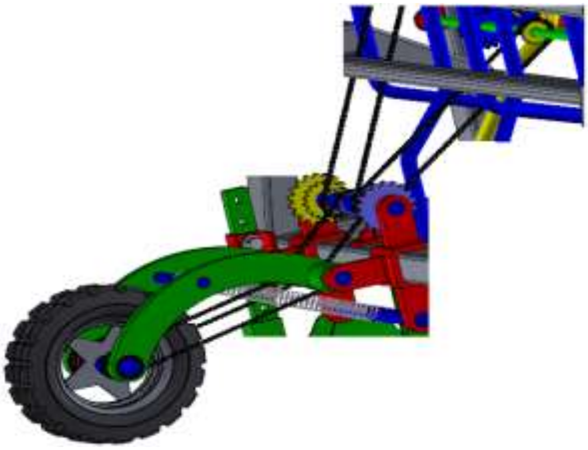

Fig. 6 Feeding Gears Set.
Source: Authors' determination.

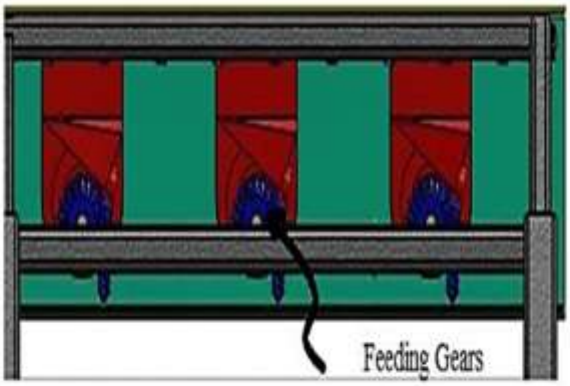

Fig. 7. Feeding Gears.
Source: Authors' determination.

(3)Feeding Cell

It is a set of gears, Fig. 7, with a fixed number of teeth estimated based on the diameter of the transmission wheel powered by soil friction and making interstitial distances within the soil between each, the seeds are inserted.

(4)Feeding Tube

It is a collection of hoses (plastic springs) with widths ranging from 2 to 3 inches (Fig. 8) that are used to swiftly convey seeds from the feeding set to the agricultural vents. It is broken into two sections as follows:

1-The hoses used to transfer the seeds from the little seeds box are the same number as the sowing seed vents, which are 21 in total, divided into three groups of seven vents for each. Farmers may also adjust the density of germination by closing the aperture of one of the hoses with a hand grip.

2-Hoses were used to transport seeds from the enormous seed box, and only nine were separated into three groups and planted on three terraces

(5) Seeds Cultivation Vents or Flakes (Seeds Liner) Stairs

The number of these seed liners is 21 vents made of iron and placed in three groups, with each group consisting of seven crumbs for each terrace, which is spread in two phases, with three in front and four in back, as shown in Fig. 9.

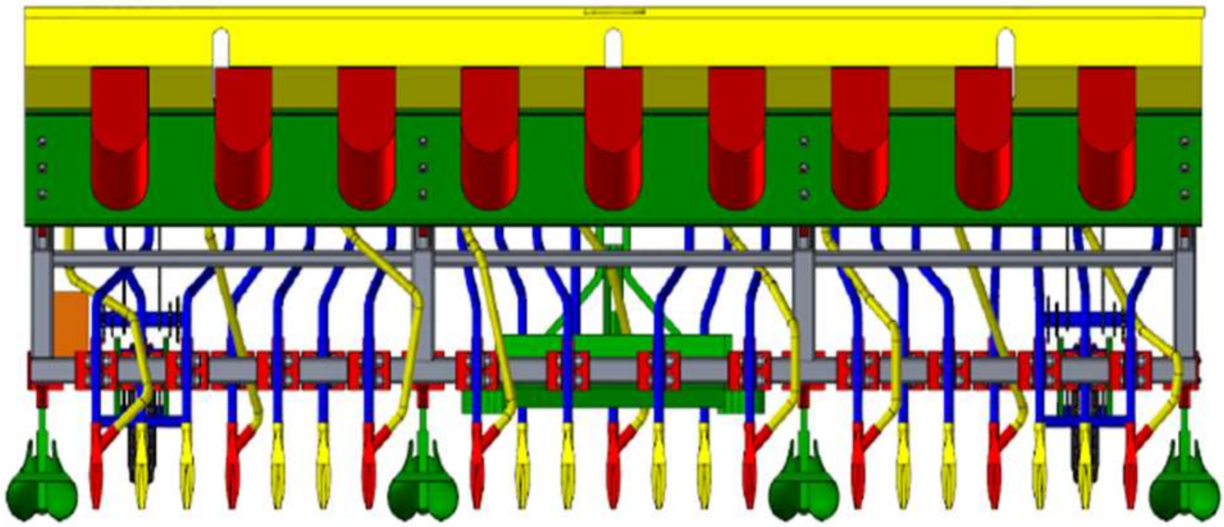

Fig. 8. Transmission hoses of seeds connected to the feeding gears.
Source: Authors' determination.

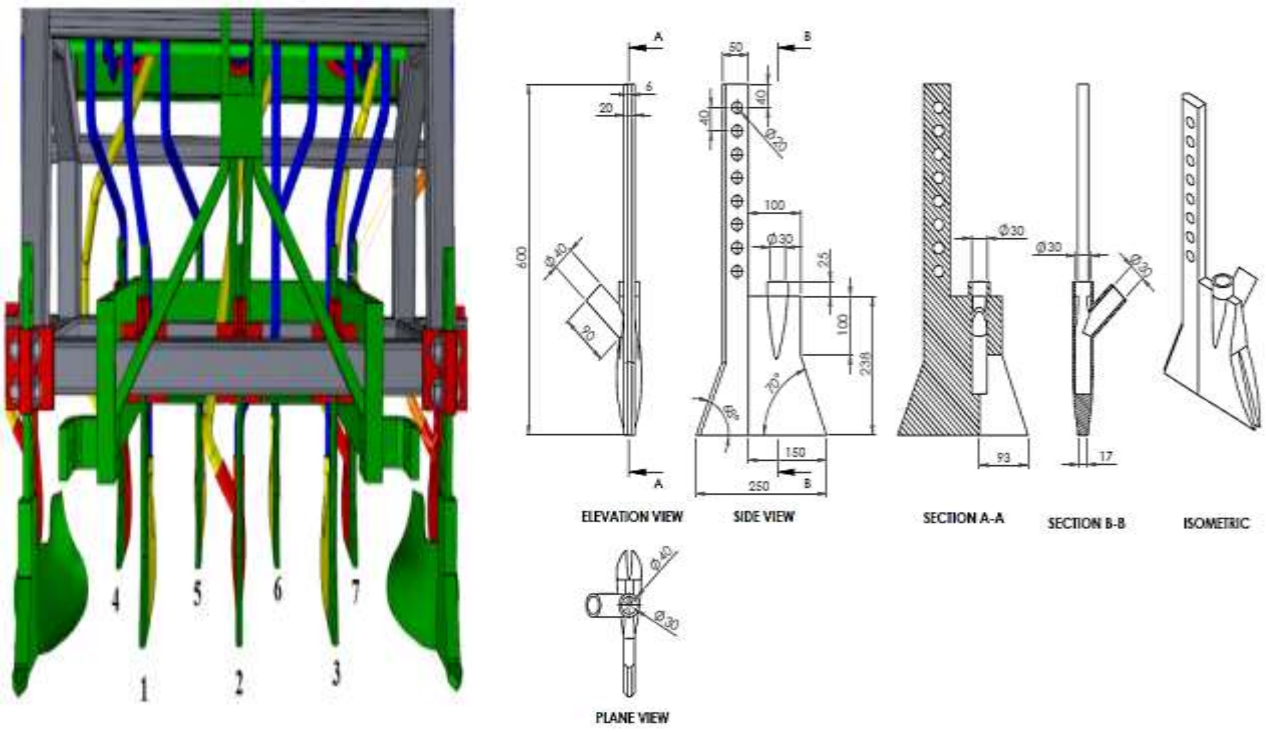

Fig. 9. Seeds cultivation vents and Seeds liner (left) structure
Source: Authors' determination.

(6)Ditchers (Farrows Openers)

The machine has four ditchers to be able to formulate three beds and four farrows, each with two sides of iron with a thickness of at least 7 mm that meet together at an angle of 86° when covering the gaps that allow penetrating the soil and opening the ditches, as illustrated in Figure (10). It is not suggested to use an MRB machine for unattended soil ploughing in order to avoid damaging the vents or failing to completely shut them, which would indicate a flaw in the cultivation process

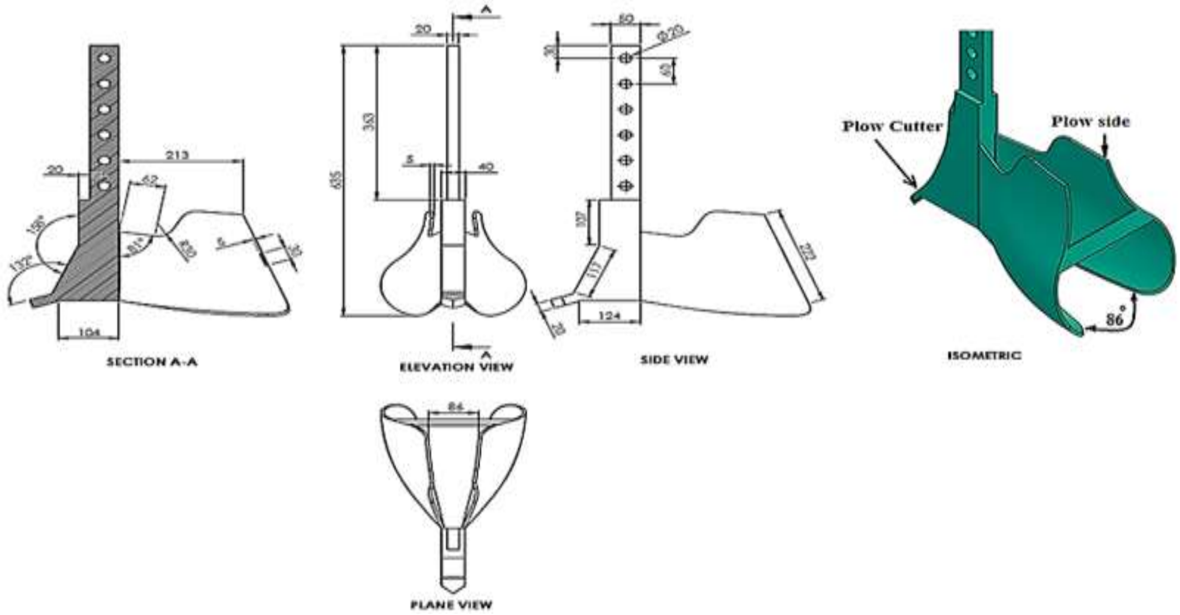

Fig. 10. The ditcher vents (farrow opener)
Source: Authors' determination.

As shown in Fig. 11, the distance between ditchers is 130 cm as recommended by previous research conducted by Swelam et al (2016) who identified the optimum dimensions of the raised bed in clay soils for several crops mainly wheat, clover, cotton, and fababean.

(7)Wheels and Transmission Set

The number of wheels turned by soil friction is estimated based on the number of terraces to be prepared, which defines the overall length of the machine (a wheel for every two terraces and about 416 mm diameter). The rate of movement and speed was modified to meet the number of seeds to be fed, as shown in Figures (12 and 13). The gears were also connected to big and small grain sowing boxes in two sets. Each group had three gears that controlled the density of grown seeds.

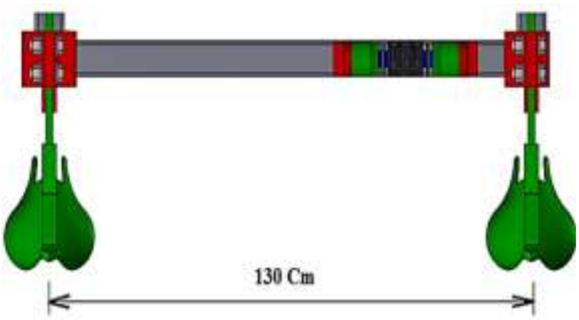

Fig. 11. Soil Light Plows
Source: Authors' determination.

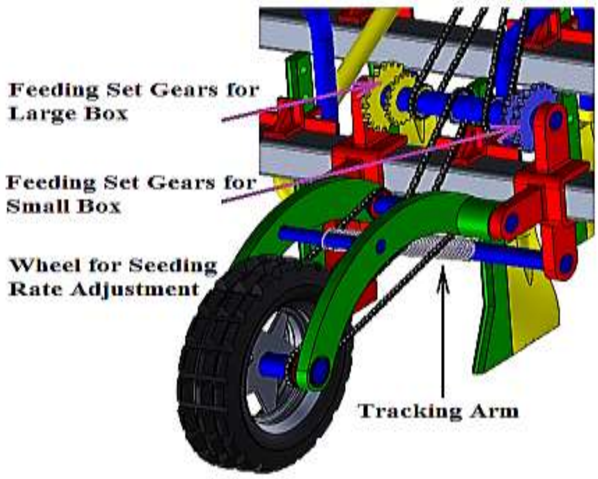

Fig. 12. A 3D schematic drawing of the set of gears and driving wheel.
Source: Authors' determination.

Traction Arm

It is made of steel (ST-37) with a thickness of not less than 25 mm to withstand the weight of the machine as well as the additional loads such as seeds' weight and soil resistance. It is designed in two levels to fit the small and large tractors and help us to control the level of planting seeds in the soil. The upper and middle holes are utilized to manage the load. The bottom and Center holes are used to adjust depth. The three holes are used to modify the distance that the plow and pits penetrate the soil based on soil resistance so that the waterways are suitably lightened and the seeds are well buried inside the soil, as illustrated in Fig. 14.

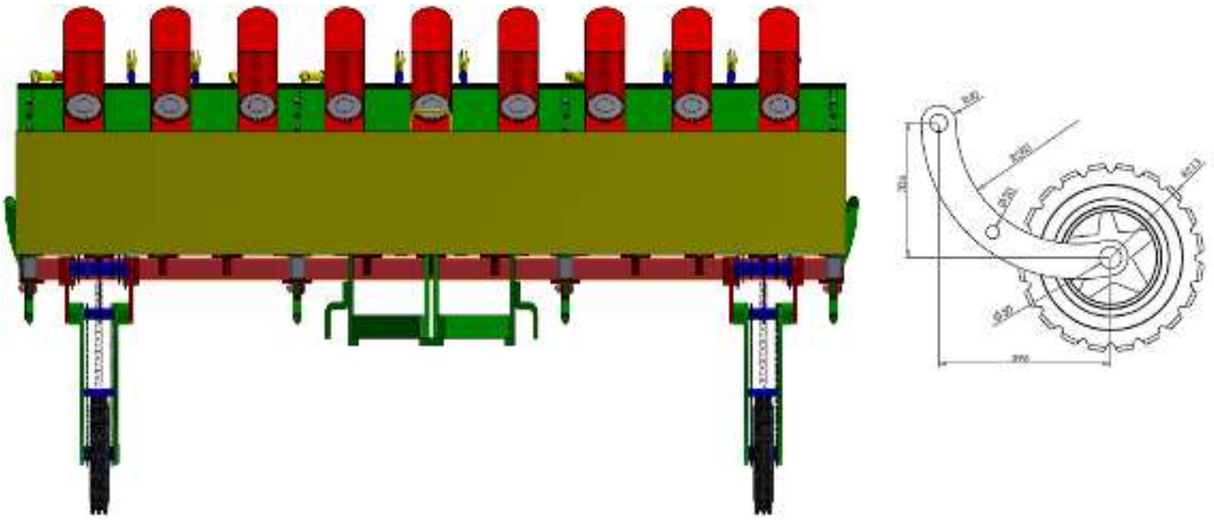

Fig. 13. Driving Wheels
Source: Authors' determination.

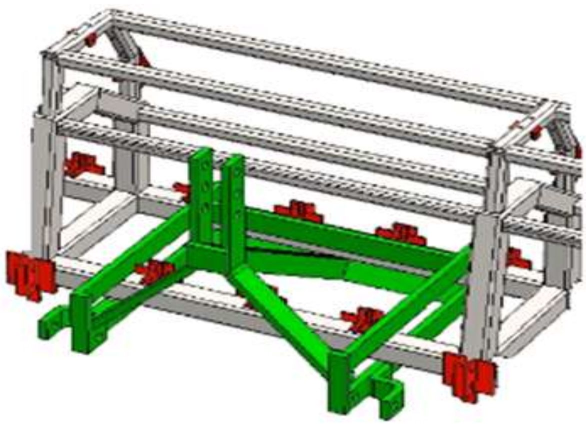

Fig. 14. Traction arm and tractor attachment Source: Authors' determination.

Engine Power and Specifications

MRB is suitable for different kinds of tractors. Large tractors are preferred so that they can carry or move the machine easily during planting or while moving from one place to another. The proper specifications for the tractor engine needed to tow the machine are shown in Table 2.

Table 2. The specification of the tractor engine

No.		
1	Compression ratio	19.5: 1
2	Number of cylinders	4
3	Displacement	2,523 cm^3
4	Maximum Power	49.5 horsepower (36.4 kW) at 2,800 rpm
5	Engine Type	diesel engine

Source: Authors' determination.

MRB Characteristics

It is characterized by suitable size for the agricultural areas intended to be used in both small and large field capacities and also transferred from one place to another without problems. Also, MRB control is easy in driving and guiding during the cultivation through the use of the appropriate tractor during the seeds distribution and concealment properly. The amount of seeds used during agriculture is reduced by up to 50%, which has a significant yield on users, enabling them to grow the best seeds even if the price increases. Ideal and regular distribution of seeds on the available land area with the possibility of controlling the intensity of agriculture is according to the desire of the farmer and the nature of the cultivated land by changing the distance between the seeds of sowing.

The efficiency of water use is improved where water saving rates reach 30% of the total water used in regular agriculture, where water can reach the seeds directly, quickly, and rationally, especially in countries where water is scarce. Saving time and the effort exerted in the process of agriculture leads to the increase of cultivated areas and good use of the agricultural season. The number of employed workers is significantly decreased with higher accuracy of the cultivation process and the productivity of agricultural crops increases as a result of ensuring good and sound agriculture according to the MRB usage.

MRB machine is one of the safest machines for the agricultural tractor driver or farmer with ease of use, operation, and maintenance and the machine is eco-friendly as it does not produce any residues or harmful gases to the environment, whether during the process of manufacturing or during the operation or maintenance.

RESULTS AND DISCUSSIONS

The simulated results shown in this part are presented for the MRB in the next main parameters as follows: Total Deformation, Equivalent Elastic Strain, Equivalent Stress, Shear stress, Normal stress, Maximum Shear Stress, and Safety factor. These parameters are selected because they explicitly cover the characteristics for MRB design and testing to be available for future computational and experimental discussions. The 3D model was created by SolidWorks 2016 while the model is meshed by Ansys- 18. Structural Steel is the material used in analysis with Compressive Yield Strength, Tensile Yield Strength, and Tensile Ultimate Strength equal 250, 250, and 460 MPa respectively. Young's Modulus was 2.e+005, Mpa Bulk Modulus 1.6667e+005 Mpa Tensile Yield Strength 250 Mpa [21].

Mesh Generation

In Fig. 15, Mesh hexahedral mesh with a total number of nodes equals 1045708 and has Max. Cell size 1 mm and Min. cell size 0.15 mm. For bounding box dimensions X, Y, and Z were 4070, 80, and 80mm. Meshing is the most critical and persuasive parameter in any model of simulation

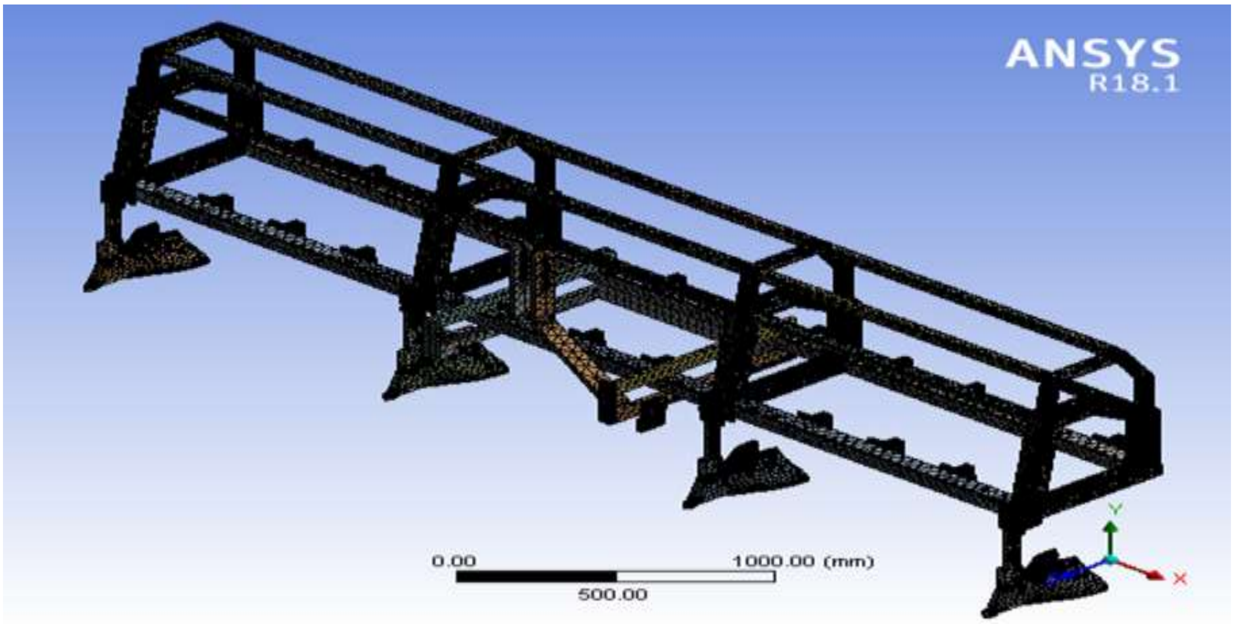

Fig. 15. Mesh generation (Total number of nodes 1045708).
Source: Authors' determination.

The selection of Hexahedron mesh provides higher accuracy and efficiency, in the results, than Tetrahedron for the identical number of nodes. Therefore, it is the recommended type for structural design applications. However, it may not be applied for all geometries especially complex ones where Tetrahedron is more suited but it is enough for MRB design simulation.

Moreover, generating Hexahedron mesh usually requires modifying and dividing the geometry into different sweepable faces through CAD modification variations or Virtual Topology. This may sometimes omit some important features or generate low-quality mesh, if not carefully applied, which is a common case if it is intensely used to force the generation of a certain method and solution rather than just simplifying the simulated model [20].

Total Deformation

Figure 16 shows the maximum range of the total deformation of 1.9706 mm. Deformation in continuum mechanics is transforming a body from a reference configuration to a current configuration. A configuration is a set containing the positions of all particles of the body. Deformation may be caused by external loads, body forces (such as gravity or electromagnetic forces), or changes in temperature, moisture content, or chemical reactions. Finally, the maximum nominal total deformation equals 0.68 mm which is favourable and in the safe range. Strain is considered a description of deformation in terms of relative displacement of particles within a body, excluding rigid body motion. Various equivalent choices can be made to represent the strain field, depending on whether the strain field is defined in the initial or final configuration of the body, and whether the metric tensor or its dual is considered.

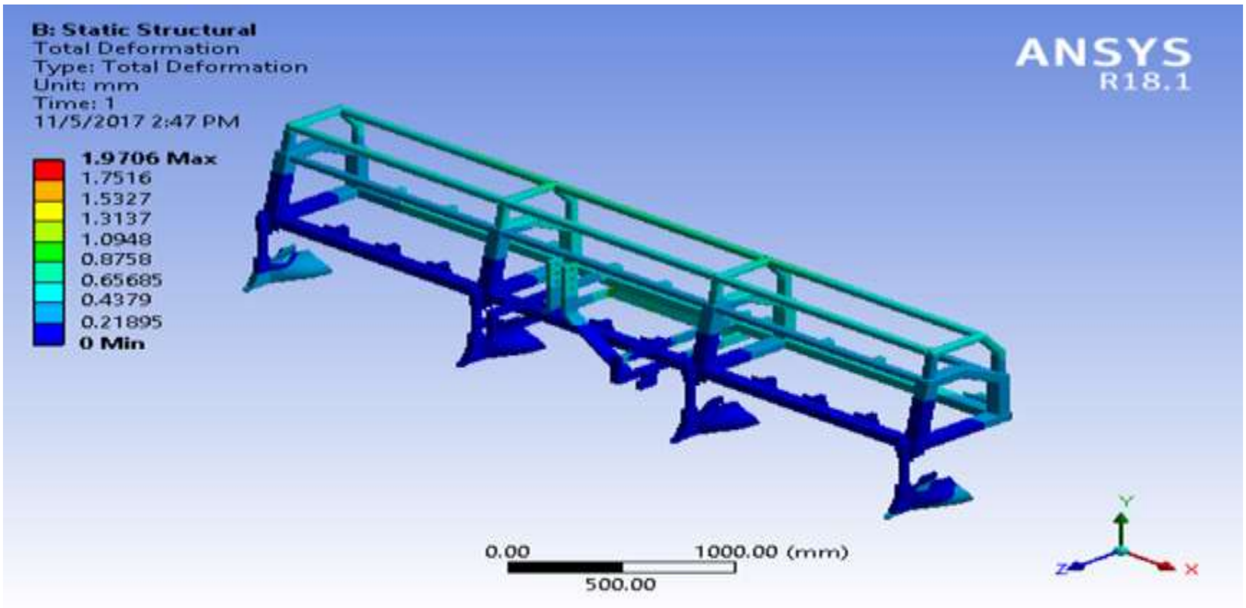

Fig. 16. Total deformation
Source: Authors' determination.

Equivalent Elastic Strain

Figure 17 shows the maximum Equivalent Elastic Strain is 0.0012312 m/m and the minimum Equivalent Elastic Strain is 2.0263 e-8 mm/mm. The internal Strain within metal is either elastic or plastic in type. In the case of elastic strain, this is observed as a distortion of the crystal lattice while the plastic strain is observed by the presence of dislocations; the displacement of part of the crystal lattice. Most quasi-brittle materials exhibit different properties under tension and compression due to their high heterogeneity and anisotropy. Elastic strain energy density can be decomposed into two parts: tensile stress and compressive stress. This allows for better exclusion of spurious failures in compression parts and more accurate crack paths and structural responses [22].

A material can fully recover its original shape after unloading if the induced stress is below the yield point of the material in the elastic response. From the point of view of metals, this behaviour is due to the stretching of chemical bonds between atoms, not breaking.

The elasticity is due to the elongation of this atomic bond, so it is fully recoverable. Moreover, these elastic strains tend to be small. The nominal equivalent elastic strain is 0.0001368 mm/mm. The higher strain locations are at the connection places while all body is in the safe range.

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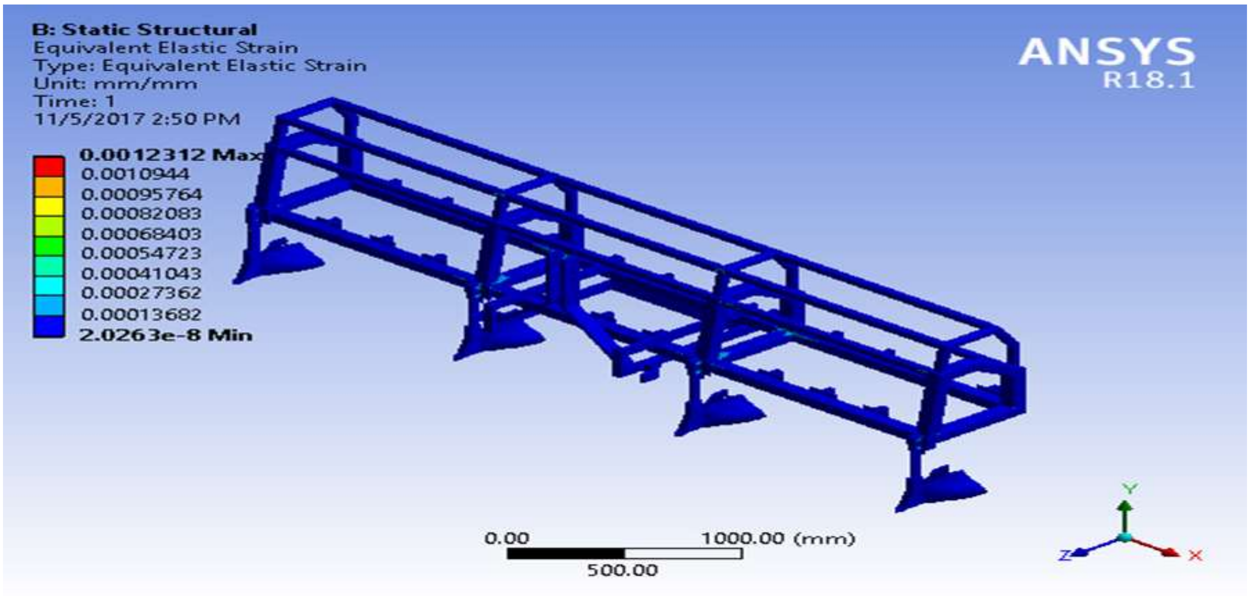

Fig. 17. Equivalent elastic strain
Source: Authors' determination.

Von- Mises Stress

Figure 18 shows the von- Mises stress distributions. As the material properties of damaged models are interpolated by von Mises stress to build the well-posed optimization model, Von Mises stress-strain plays an important role in the numerical simulations for the ductile fracture of structural metallic materials with a large plastic strain [8, 10]. The maximum von-Mises stress equals 226.34 MPa and the minimum equivalent stress is 0.0035538 Mpa. The highest value of the total deformation and the equivalent stress are not reaching near to the critical state.

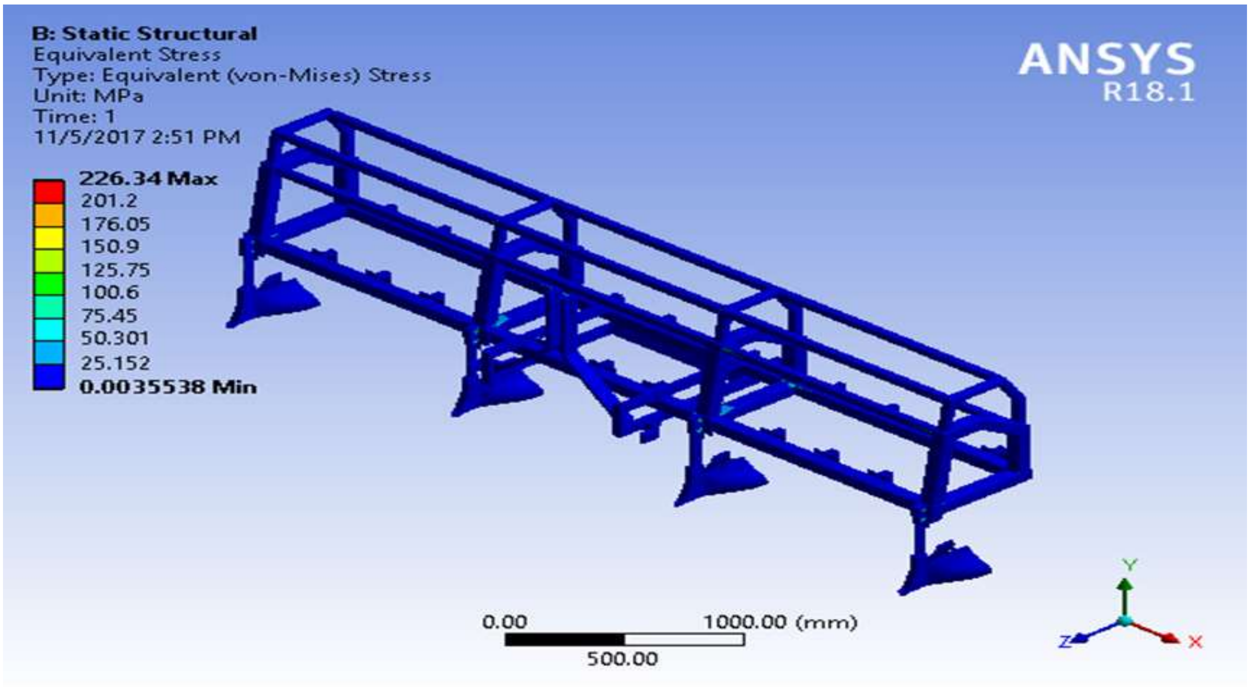

Fig. 18. Equivalent stress
Source: Authors' determination.

Shear stress

The shear stress is regularly denoted as the stress component that coplanar with a material cross-section. This type of stress arises from the force vector component that parallels the cross-section. The presented design shows an overall good agreement with the simulated results. The couple of both chassis beams cross sections and thickness are enough to withstand the shear capacity. The shear capacity of the webs of steel beam is an important performance factor utilized by the steel structures [18]. This shear strength can be affected by the corrosion when the effective thickness is reduced [24]. The elastic anisotropy of a single crystal has a decisive influence on the dispersion of the stress distribution, while the elastic modulus of each crystal direction determines the mean stress of the grain. Furthermore, shear stresses are shown to deviate from the normal distribution with higher anisotropy and be better approximated by a lognormal fit [23].

Figure 19 shows the shear stress allover the whole steel structure and the maximum range is 48.021 MPa as well as the minimum shear stress range is -76.358 Mpa. The whole tractor arm and the two chassis (upper and lower) are in the safe pattern

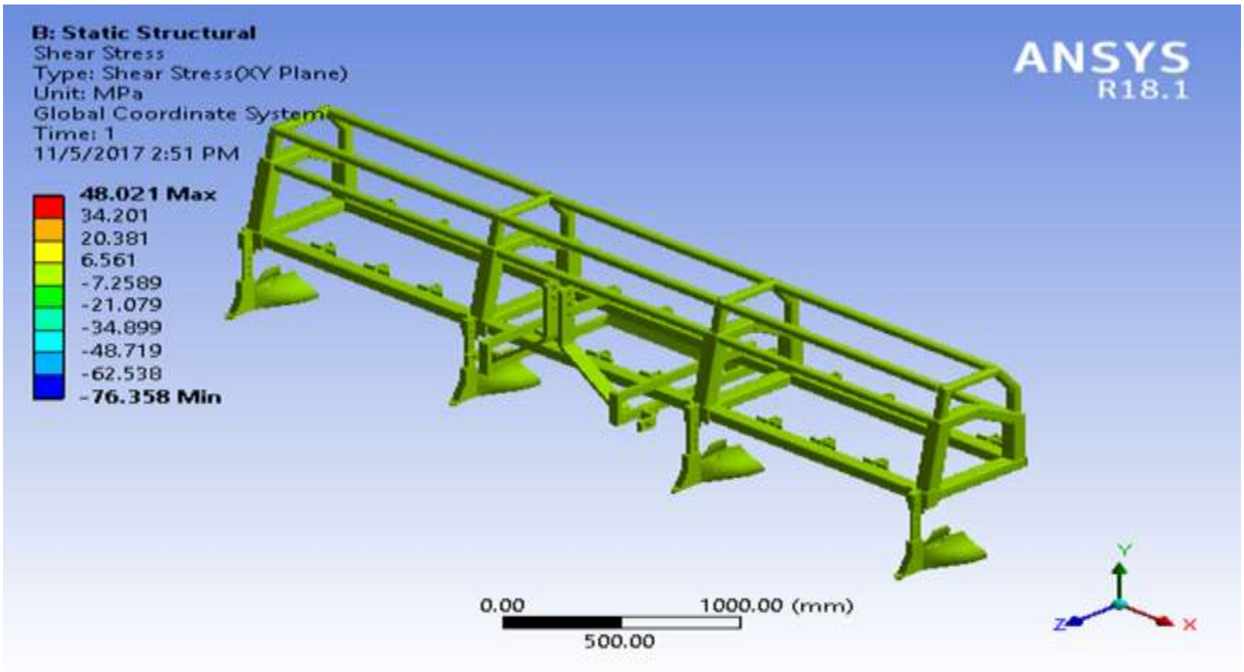

Fig. 19. Shear stress
Source: Authors' determination.

Normal stress

Any external force acts perpendicular to a certain cross-sectional area of any object or body induces a stress in those objects or body recovers its original shape.

The stress produced by the perpendicular action of a force on this given area is called a normal stress.

This normal stress arises from a perpendicular force vector.

The normal stress is subdivided into two stresses; tensile stress and compressive stress. In the tensile stress, the force acts perpendicular to the sectional area of the object, pulling it to stretch from its original shape while in the compressive stress; the force acts perpendicular to the surface area of the object, pushing and compressing it to deform its shape.

Figure 20 shows that the maximum normal stress is 44.528MPa and the minimum normal stress is -44.177Mpa.

The ditchers' fixation locations have the higher normal stress while this stress is in a safe range against deterioration.

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Shear stress arises from shear forces, which are pairs of equal and opposite forces acting on opposite sides of an object.

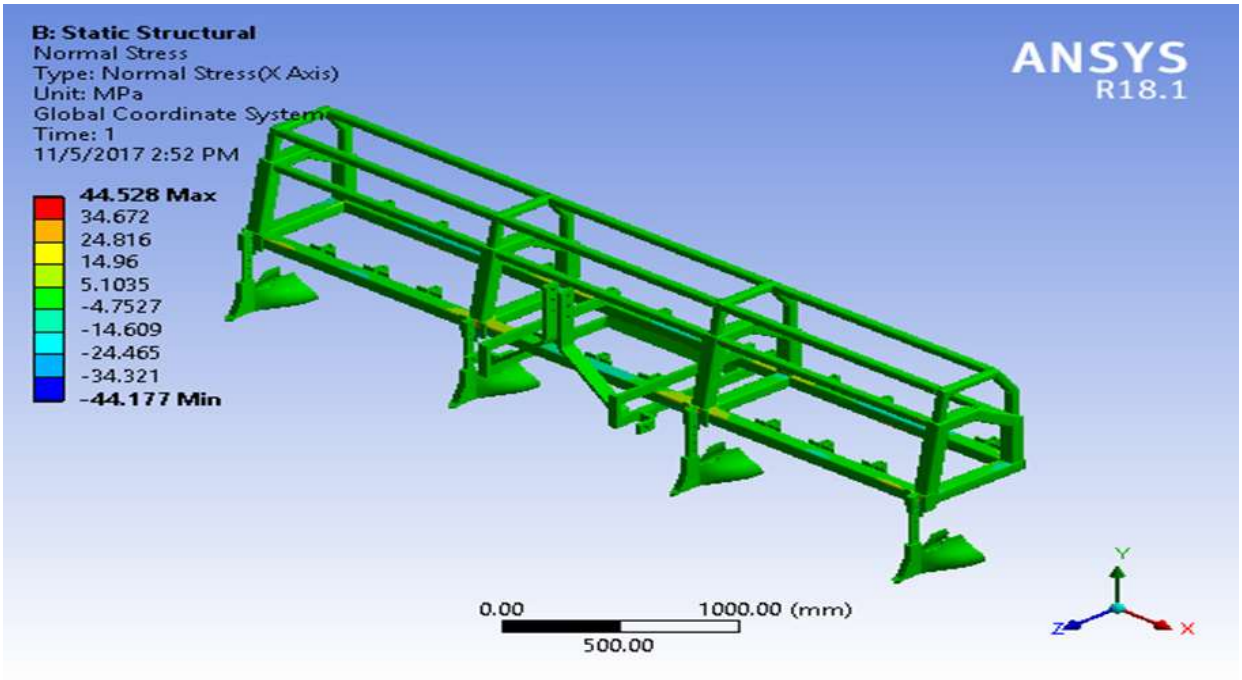

Fig. 20. Normal stress
Source: Authors' determination.

Figure 21 shows the Maximum shear stress which has a maximum value of 130.54 MPa and the minimum value of Maximum shear stress as 0.0019034 Mpa. The same fixation locations have also higher values of the maximum shear stress which are still in a very safe range

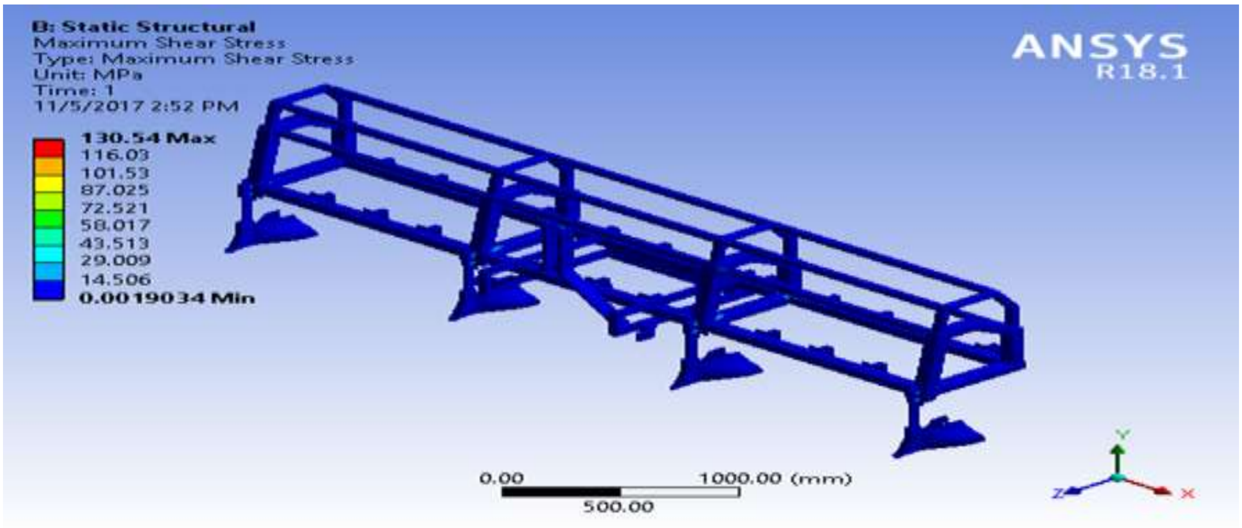

Fig. 21. Max. Shear stress
Source: Authors' determination.

Safety factor

Factor of safety is describing the load carrying capacity of a system beyond the expected or real loads and is demonstrating how much stronger is the system than it usually needs to be for an planned load. Furthermore, it is a constant value intended as a minimum target for system design. Safety factor is often calculated using a detailed analysis because the comprehensive testing is impracticable on many design models or prototypes, but the structure's ability to carry that load must be determined to a reasonable accuracy. Many design systems are persistently created much stronger than needed for normal usage to allow for misuse, unexpected loads, emergency situations, or dreadful conditions.

The safety factor is a ratio of absolute structural strength (capacity) to actual applied load, which is considered a measure of the reliability of a particular design. It is a design factor of safety or required factor of safety. The realized factor of safety must be greater than the required design factor of safety. Figure 22 shows the safety factor which lies between the maximum of 15 and the minimum factor of 1.1045. Safety factor reaches more than 10 and up to 15 in this case which is very safe for this design issue

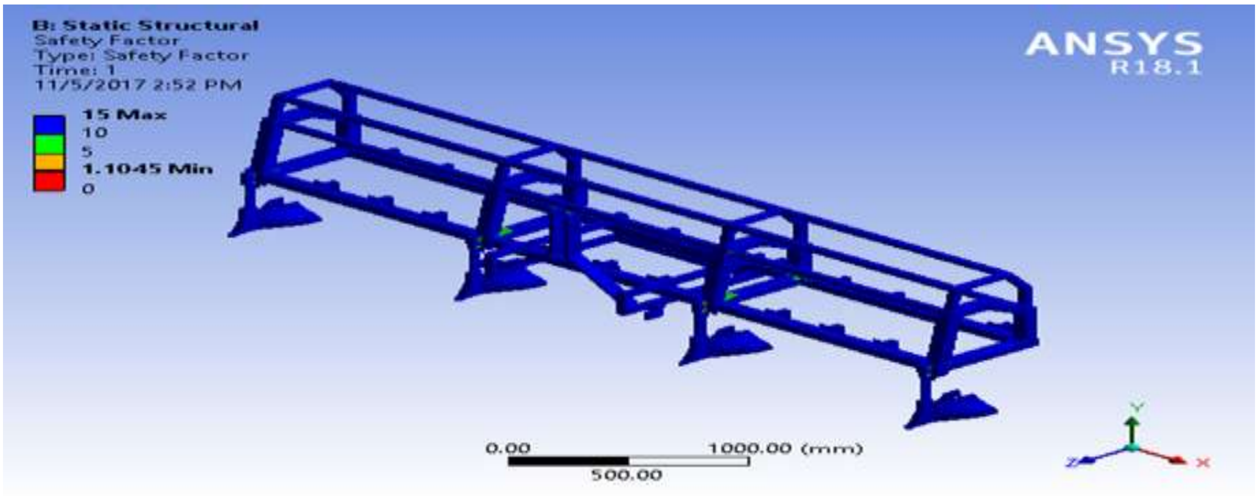

Fig. 22. Safety factor
Source: Authors' determination.

CONCLUSIONS

MRB design prototype provides a cost-effective, passive energy operation, and local manufacturing opportunity. It is suitable for small and medium farm sizes as well as for intensive canopy cover crops and interspaced crops.

The raised bed multi-seed planting machine is designed in SolidWorks software. The Bounding Box dimensions of the of raised bed machine X, Y, and Z are 4070, 80, and 80mm. The SolidWorks design is analysed through ANSYS analysis software. For the analysis, the structural material properties are selected because most of either cast iron or structural steel is used as a fabrication material. Structural Steel is the material used in analysis with Compressive Yield Strength, Tensile Yield Strength, and Tensile Ultimate Strength equal 250, 250, and 460MPa respectively. Young's Modulus is 2e+005 Mpa, Bulk Modulus is 1.6667e+005Mpa and the Tensile Yield Strength is 250 MPa.

The maximum Equivalent Elastic Strain is 0.0012312 m/m and the minimum Equivalent Elastic Strain is 2.063e-8mm/mm while the nominal Equivalent elastic strain equals 0.0001368 mm/mm. MRB machine is also very safe from risky stresses (Normal or Shear). The safety factor was 1.1045 relative to the maximum of 15. The maximum value of the total deformation is 1.9706 mm and the minimum total deformation is 0 m while the maximum nominal total deformation equals 0.68 mm which is favourable and in the safe range.

REFERENCES

[1]Abhise, N., Ramachandran, M., 2019, Design and Numerical evaluation of crankshaft of diesel engine for total deformation and strain", IOP Conference Series: Materials Science and Engineering, Vol. 810, 2019.

doi:10.1088/1757-899X/810/1/012010. Accessed on 8.10, 2023.

[2]Awad, M., Fabricated Prototype of Raised-Bed Planter for Wheat, Journal of Soil Sciences and Agricultural Engineering, 7(12), 921-927, 2016. Accessed on 8.10.2023.

[3]Ding, F., Wu, X., Gao, W., Xiang, P., Yu, Z., 2022, "Damage ratio strength criterion for cast iron", Journal of Materials Research and Technology, 18, 5362-5369, May–June 2022.

[4]Fadl, M., 2023, Theoretical Study of Combustion Characteristics for Turbulent Premixed Flames Issuing from a Swirl Stabilized Burner, Helwan University, 2023.

[5]Gehrig,, F., Wicht, D., Krause, M., Böhlke, T., FFT-based investigation of the shear stress distribution in face-centered cubic polycrystals, International Journal of Plasticity, Vol. 157, October 2022.

[6]Gorbatyuk, S. M., Veremeevych, A.N., Albul, S.V., Naumova, M. G., 2014, Elements of machines and fundamentals of machine design Publisher: NUST MISIS and team of authors, https://www.researchgate.net/publication/338981170. Accessed on 8.10.2023.

[7]Goyal, S.K., Prabha, Singh, S.R., Rai, J.P., Singh, S. N., 2014, Agricultural mechanization for sustainable agricultural and rural development in eastern up - a review, Agriculture for Sustainable Development 2(1):192-198.

[8]Ibrahim, M. M., Amin, E., Farag, A., 2008, Developing a multipurpose digger for harvesting root crop digger, Misr J. Agric. Eng., 25(4), 1225–1239, 2008.

[9]Liu, Y., Jia, B., Li, X., Hong, W., 2013, Characteristic of nutrients and evaluation of heavy metal contamination on sediments among Xinpo pond Nandu River in Hainan province, Transactions of the Chinese Society of Agricultural Engineering, 29(3), 213–224.

[10]Mary, O. O., Ebenezer, O. O., Samson, O. A., Olaoluwa, O. O., 2020, Electrical And Mechanical Properties Of Iron-Ceramic Composites, International Journal of Scientific and Technology Research Vol.9 (1), 3489-3493, 2020. http://www.ijstr.org/final-print/jan2020/Electrical-And-Mechanical-Properties-Of-Iron-ceramic-Composites.pdf. Accessed on 8.10.2023.

[11]Mohd Aras, M. S., MdZain, Z., Kamaruzaman, A. F., Ab Rashid, M. Z., Ahmad, A., Mohd Shah, H. N., Abazis, F., 2019, Design and development of remotely operated pipeline inspection robot, In Proceedings of the 11th National Technical Seminar on Unmanned System Technology 2019 (pp. 15-23), Springer, Singapore, 2021.

[12]Murray, J. R., Tullberg, J. N., Basnet, B. B., 2006, Planters and their components: types, attributes, functional requirements, classification and description, No. 435-2016-33740.

[13]Sharma, A. S., Mishra, N., Biswas, K., Basu, B., 2013, Fretting wear study of Cu–10 wt% TiB2 and Cu–10 wt% TiB2–10 wt% Pb composites", Wear, 306(1-2), 138-148.

[14]Sheikhzadeh, M., Sanjabi, S., 2012, Structural characterization of stainless steel/TiC nanocomposites produced by high-energy ball-milling method at different milling times, Materials & Design, 39, 366-372.

[15]Shen, M. J., Wang, X. J., Li, C. D., Zhang, M. F., Hu, X. S., Zheng, M. Y., Wu, K., 2014, Effect of submicron size SiC particles on microstructure and mechanical properties of AZ31B magnesium matrix composites, Materials & Design (1980-2015), 54, 436-442.

[16]Smita, N. S., Thakaree, S.H., Ramteke, R.T., 2018, Raised bed planting through broad bed furrow", International Journal of Agricultural Engineering Vol. 11(2), 400-408.

[17]Stolarski, T., Nakasone, Y., Yoshimoto, S., 2018, Engineering analysis with ANSYS software, Butterworth-Heinemann.

[18]Wang, H., Liu, J., Wen, G., Xie, Y.M., 2020, The robust fail-safe topological designs based on the von Mises stress", Journal of Finite Elements in Analysis and Design, Volume 171, April 2020.

[19]Wang, J., Poh, L.H., Guo, X., 2023, Localizing gradient damage model based on a decomposition of elastic strain energy density, Journal of Engineering Fracture Mechanics, Volume 279, 17 February 2023.

[20]Wang, Y., Li, G., Wang, Y., Lyu, Y., 2021, Simplified method to identify full von Mises stress-strain curve of structural metals", Journal of Constructional Steel Research, Volume 181, June 2021.

[21]Yang, D., Hao, X., Li, J., Li, Y., Jia, J., 2009, Virtual design and experiments of four-row mounted potato planter based on solid works", Journal of Agricultural Mechanization Research, 10, 75–78 (in Chinese with English abstract).

[22]Yang, X., Jia, J., Tong, J., and Liu, J., 2006, Associated Design for Assembly of Typical Parts of Agricultural Machinery", Journal of Computer-Aided Design & Computer Graphics, 18(1), 156–159 (in Chinese with English abstract).

[23]Yegül, U., Eminoglu, M.B., Orel, O., Colak, A., 2014, Determination of Equivalent Stress and Total Deformation in Different types of Harrows", Journal of Agricultural Machinery Science, 10(1), 65-71.

[24]Zhao, Z., Li, G., Liu, J., Wang, B., Gao, Y., 2023, Post-buckling shear capacity of the corroded end panels of H-shaped steel beams", Journal of Thin-Walled Structures, Volume 184, March 2023.

[25]Zhao, Z., Tang, L., Zhang, N., Cai, Q., Mo, S., Liang, B., 2021, Shear capacity of H-shaped steel beam with randomly located pitting corrosion, Journal of Applied Ocean Research, Volume 115, October 2021.

ASSESSMENT OF SOIL LOSSES COSTS IN CROP ROTATION DUE TO WIND AND WATER EROSION RISKS

Valerii TARASOV[1]. Vasyl HROMYAK[1], Valerii KOLIADA[1], Olha KOLIADA[2]

[1] National Scientific Center "Institute for Soil Science and Agrochemistry Research n. a. O. N. Sokolovsky" NAAS, 4 Chaikovska Street., Kharkiv, 61024, Ukraine, Phone: 057/7041669, E-mails: super_tvi1947@ukr.net, hvmluga@rambler.ru, koliadavalerii@gmail.com
[2]State Biotechnological University, MSE, 44 Alchevskikh Street, Kharkiv, 61002, Ukraine, Phone: 057/7003888, E-mail: olyakolyadapovh@gmail.com

Corresponding author: koliadavalerii@gmail.com

Abstract

The results of soil losses management studying due to wind and water soil erosion crops rotations proposed based on methodologies of NSC "Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky". The main purpose of our research was to assess the soil losses under influence of wind and water erosion in crop rotation. The works were planned to determine how erosion types correspond to crops or having the same effect on a similar field parts in the crop rotation of Ukrainian Eastern Steppe part. It was also planned to compare soils losses in similar gradations (allowable, slight, moderate, high) with the following analysis of the differences in the manifestation dynamics under different agricultural crops (fallow, winter crops, barley, oat, corn for grain, corn for silage, millet, peas), and different parts of fields. It is proposed when determining the erosion risk of the territory, the areas of such soils must be protected by such crops with minimal losses from the destructive effects of wind erosion and surface runoff. It is possible to state the cumulative manifestation of erosion and deflation on the territory of the region, but it is impossible to separate the contours of eroded and deflated soils in detail, therefore, in erosion situations proposed to obtain separate influence of each erosion (wind and water) on already eroded or erosionally hazardous lands.

Key words**:** *soil runoff, deflation, losses, modeling, management, crop rotations, forest shelterbelts*

INTRODUCTION

The soil surface on agricultural lands is constantly changing. The contours of eroded and deflated soils are created over a long period of time, first of all, on areas of soils that are dangerous for erosion and deflation. Their location in agricultural landscapes has both a natural and a technological basement. Erosion dynamic depends on the relief of the area and the type of land use. The most unprotected areas from deflation are located on open, unobstructed areas, most often on watersheds and on windy slopes. The erosively dangerous soils of Ukraine are not protected from the destructive action of surface runoff, therefore they are located on convex and long slopes, as well as along the thalwegs of the hydrographic network. Accordingly, the interpretation of M.I. Zaslavskyi [16], erosion-dangerous lands are those where the combination of natural conditions creates an opportunity for the manifestation of accelerated erosion during their economic use without the necessary anti-erosion measures. It is appropriate to take into account that the most dangerous method of soil cultivation is continuous tillage. But when considering the territory of agricultural production of Lugansk region, it can be noted that in previous years, in the second half of the 20th century, a system of protective forest plantations (PFP) as shelterbelts was created in the farms, which functions until now. The available PFP have a different level of system organization, but these are long-term anti-erosion plantations that, with age, form a favorable background for the sustainability of agro-landscapes. Because of this, when determining erosion-dangerous soils on working areas of continuous plowing, it is necessary to take into account the specific features of modeling the simultaneous manifestation of both water and wind erosion in the conditions of the Lugansk region. In addition, it should be remembered that the lands of agricultural production included tillage lands, fallow, and sometimes virgin areas. Because of this, it is advisable to apply erosion-hazardous soils on a modern cartographic basis in a differentiated manner, depending on the type of land use and the type of erosion. The materials of methodological approaches that are most suitable for practical implementation, which can be used for mapping eroded soils on agricultural production lands, are presented in the works of I. P. Kovalchuk [4], N. Velickovic, M. Todosijevic, D. Šulic [15], which justified general mapping methods. Much attention was paid to the mapping of eroded lands as a result of water and wind erosion by such scientists as V. O. Bilolipskyi [1], V. O. Bilolipskyi, S. Yu. Bulygin [2], P. V. Bolstad, T. Stowe [3], M. A. Nearing [10]. O. O. Svitlychny, S. G. Chorny. [11]. H. Teng, R. A. Viscarra Rossel, Z. Shi, T. Behrens, A. Chappell, E. Bui [14], C. Zhang, E. A. McBean [17].

The main purpose of our research was to assess the soil losses under influence of wind and water erosion in crop rotation. The works were planned to determine how they (erosion types) correspond to each other or having the joint effect on soil losses in the crop rotation of Ukrainian north-eastern part.

MATERIALS AND METHODS

Research was conducted in 2018 year on the territory of the former state farm near the village of Chuginka, Luhansky district, Luhansk region. In the 70-s of the last century, the farm was an experimental one for the introduction of soil protection technology of agricultural cultivation. crops and the first, regarding the introduction of no-till soil cultivation. On this object, images searches were performed, available cartographic material was studied, and potential soil losses due to erosion and deflation were determined in the section of working areas under agricultural crops with the help of appropriate models, methods and methodologies, whose were used to determine areas with erosion-hazardous soils.

The lower limit of the categories of erosion-dangerous arable soils was determined by the author's calculation method of V. I. Tarasov [12], which states down to establishing isohypsometric points in which the amount of soil erosion on arable land does not exceed the lower values of the regional scale of the corresponding categories: I - the zone of formation of surface runoff and soil erosion, which is compensated by the speed of cultural soil formation; II – soil run off (deflation) up to 5 t/ha; III – soil run of 5-12 t/ha; IV – run of 12-20 t/ha, V – > run of 20 t/ha.

Soils of the 1st category were allocated in the upper part of the slope. It is separated from the upper watershed line by the height of the slope drop of up to 5 m with the steepness of the slope < 0.75º. The soils of other zones were classified as erosion-dangerous. They were calculated depending on the steepness of the slope and soil losses in accordance with this steepness. The soils cover of site was represented by chernozems of various degrees of erosion, sod soils and outcomes of parent materials. Zonal soils are ordinary chernozems, partially-shortened with low-humus content. They situated on the plateau of areas between watersheds. Slightly eroded chernozems are located on the slopes of the watersheds of the northern and western expositions. On the slopes of the southern and eastern expositions, there are medium and highly eroded; on the terraced slopes – chernozem soils are saline. In the ravines, the soil cover is represented by chernozem eroded, ravine and sod eroded soils. Sod eroded soils are located on the southern exposition slopes.

According to quantitative indicators of soil organic matter, the average soils humus content was on the level of 4.11%. Soil quality score points was calculated according to authors results, which determines the level of their fertility and the conditions for planning crop yields in conditions of wind and water erosion. To determine potential soil losses from deflation, we used the Bocharov-Shiyaty model in the modification of the NSC "ISSAR named after O. N. Sokolovsky" (NSC ISSAR) [8]. Calculation of soil losses during wind storm erosion was performed using the mathematical and statistical model of A.B. Lavrovsky [9].

RESULTS AND DISCUSSIONS

According to research data of Institute for Soil Science and Agrochemistry Research named after O. N. Sokolovsky [9], the norm (Po) of the manifestation of erosion was considered to be the value of the soil lost through erosion for a year, which is equal to 0.1% of the capacity of the upper humus genetic horizon (H) of a full-profile (non-eroded) soil. For example, typical chernozem has a thickness of H = 42 cm. That is, this amount of losses can be compensated in the course of cultural soil formation.

Thus, the definition of contours or zones of erosion-dangerous soils is performed by the calculation method, with the help of existing mathematical models. At the same time, it is necessary to observe the rule that it is not necessary to spread the effect of mathematical models beyond the zone for which they were developed [8].

As mentioned above, to determine the potential soil losses from deflation, we used the Bocharov-Shiyaty model in the modification of the NSC ISSAR, which is presented with detail in the Methodological recommendations for forecasting the occurrence of wind storms in Ukraine, published in 2010 [9] and which has included: conditional potential soil losses; soil lumpiness; amount of stubble or plant residues on the soil surface; coefficients depending on the genesis, physical and physico-chemical properties of the soil and the type and amount of plant residues; coefficient of destruction of aggregates; terrain influence coefficient; coefficient of deflationary stability of rural and urban areas with crops; coefficient expressing the level of the field protection by forest shelterbelts; coefficient of influence of additional soil protection measures; average multi-year number of hours with a dust storm; average maximum wind speed during dust storms of 20% coverage; speed of the air flow in the Air Aerodynamic Installation-3, which is equal to 13.5 m/s (23 m/s on the vane height).

Calculations according to this method were performed separately for each field, taking into account the available agricultural background and the protection of the field by PFP in form of forest shelterbelts (Table 1).

Table 1. Potential wind erosion soil losses on crop rotation fields in experiment

Field	Part	Crop	Field area, ha	Protected with forest belts, %	Potential soil losses	
					t/ha	from field, t
1	2	3	4	5	6	7
I	1	Black fallow	100.40	16.62	12.67	1,272.45
	2	Black fallow	38.50	35.00	9.88	380.38
II	1	Winter crop	70.90	8.18	2.08	147.77
	2	Winter crop	40.60	0.00	2.27	92.16
	3	Winter crop	21.80	0.00	2.27	49.49
III	1	Corn for grain	62.70	38.00	8.62	540.35
	2	Corn for grain	94.20	0.00	13.90	1,309.38
IV	1	Barley	16.30	32.00	1.75	28.49
	2	Oat	65.00	2.97	2.49	162.08
	3	Millet	46.50	38.00	1.59	74.09
	4	Barley	13.60	15.00	2.18	29.71
	5	Barley	20.70	21.00	2.03	42.03
V	1	Corn for silage	109.40	9.10	12.91	1,412.11
	2	Corn for silage	51.20	0.00	14.20	727.04
VI	1	Peas	95.10	9.10	2.18	207.47
	2	Peas	51.40	5.00	2.28	117.19
VII	1	Winter crop	141.30	0.00	2.27	320.75
	2	Winter crop	32.30	15.83	1.91	61.71
VIII	1	Sunflower	123.80	29.23	11.04	1,366.73
	2	Sunflower	23.20	11.90	13.74	318.85
	3	Sunflower	33.90	15.83	13.13	445.10
Total			1,252,80	12,90	7.27	9,105.32

Source: Authors' results.

At the final stage, the calculation of the amount of soil loss from water and wind

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erosion was carried out with an analysis of the stability of the soil. soil deflation and erosion processes within the limits of crop rotation.

The results of the calculations show that the fields of the existing crop rotation are the most vulnerable to dust storms. Extrusion of soil on them depends on two main factors: agricultural background and protection of the territory by forest shelterbelts, which varies from 0 to 38%. Since in most cases dust storms occur in early spring (from the end of February - beginning of March), soil losses depend on the coverage of its surface. The average calculated protection of land by forest shelterbelts in field crop rotation is 12.9%, while potential soil losses amount to 7.27 t/ha. Based on the data of the given calculations, a corresponding cartogram (Fig. 1) was constructed, which characterizes the deflation risk of the fields.

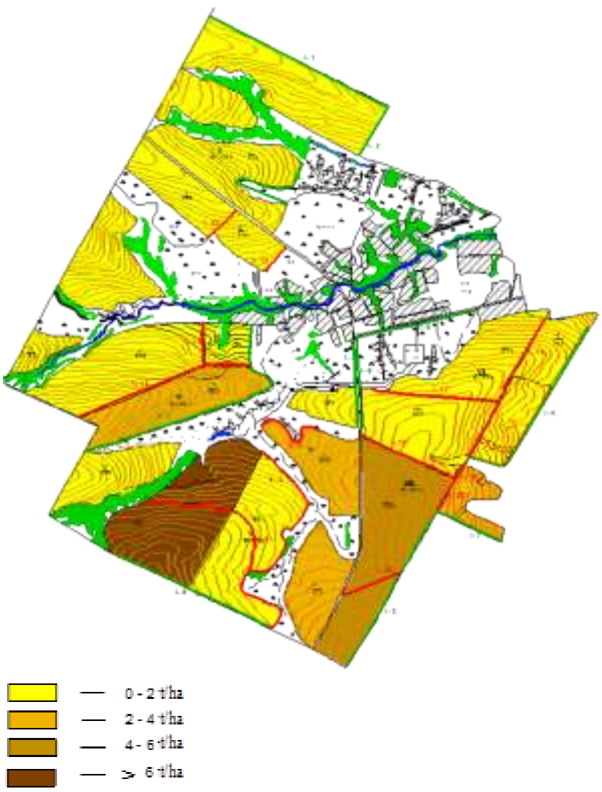

Fig. 1. Wind erosion soil losses cartogram
Source: authors interpretation of results.

According to the Institute for Soil Science and Agrochemistry Research, allowable soil losses from deflation should not exceed 2 t/ha [8]. Since soil losses within field crop rotation significantly exceed permissible limits, they can be classified as erosion-dangerous. This situation requires an increase in the protection of rural areas by applying some agrotechnical measures or additionally created field protection forest shelterbelts.

Calculation of soil losses during rainfall storm erosion was performed using the mathematical and statistical model of A.B. Lavrovsky [7], which has the form:

AR = 10-3 X2,7E (5,0 - 0,04Xc - 0,1 Xh + 0,1Xcc) Xs Xt Xob Xe...........................(1)

where:

AR - amount of soil loss, t/ha; XE – weighted average kinetic energy of the erosive part of heavy rainfall, kJ/m^2; Xc – physical clay content, %; Xh – humus content, %; Xcc – carbonate content ($CaCO_3$), %; Xs – steepness, degree; Xt – terrain factor, м; Xob – openness of the background, %; Xe – efficiency factor of some soil protection measures, %.

The average amount of rainfall energy for the zone for a certain period is determined by adding up the probability-weighted average energy values of the maximum daily precipitation:

$$X_E = \frac{E_1F_1 + E_2F_2 + ... + E_nE_n}{F_1 + F_2 + ... + F_n} \kappa J / m^2$$
....(2)

where:

E1, E2, En – energy of torrential precipitation of a certain security, kJ/m^2; F1….Fn – probability, %.

The energy of the erosive part of heavy rainfall was determined by the equation:

$E=23.1\ I^{0,21}$...(3)

where:

E – energy of the erosion-dangerous part of heavy rainfall, kJ/m^2; I – average intensity of the erosive part of the rainfall, mm/min.

The influence of soil properties in the models is reflected by three leading factors: the content of physical clay (Xc), humus (Xh) and carbonates (Xcc). The use of basic properties makes it possible to quickly take into account the susceptibility to storm erosion of soils.

The models take into account the weighted average steepness of the slopes (Xα):

$$X_a = \frac{\alpha_{11}L_1 + \alpha_2 L_2 + ... + \alpha_n L_n}{L_1 + L_{\ 2} + ... + L_n}$$

....(4)

where:

Xα – weighted average slope (section), degree; α – slope of elementary homogeneous area, degree; L – length of an elementary homogeneous section, m.

The influence of the weighted average value of the slope, corrected by the relief factor (Xri) - the shape of the slope and exposition. The latter are expressed by the corresponding values taking into account the ratio of the length of the slopes (L, m) to the width of the site (B, m). Before determining the amount of soil loss from wind erosion, an information table (field) is compiled for each plot (field) of the crop rotation. However, in order to determine the amount of fine soil carried outside the field, calculations were made of the amount of deposited fine soil in the forest shelterbelts.

Potential soil losses from rainfall under the existing organization of the territory amount to 4.17 t/ha, or 5,213.82 t in total For this purpose, the formula of V.I. Tarasov [7] was used:

W =10 [0.99(Wn + 1/0)0.69 – 1.0] (1.98 – 2.04k) sin β ....(5)

where:

W - mass of fine soil deposited in the forest shelterbelts, t/ha; Wn - mass of fine soil removed from the higher slope, kg/m^2;

Wn = AR Sn / 10·Sл; ....(6)

where:

Sn - field area, ha; Sл - area of the forest shelterbelts, ha; k - flow coefficient in the shelterbelts; sinβ - sine of the angle between the drainage line and the forest shelterbelts. The coefficient of runoff in forest shelterbelts is adopted on the basis of field experiments with manual raining on various elements of the terrain. At the same time, a rain generating device (patent 62336 A) was used [13]. Results of potential soil losses from rainfall presented in Table 2.

Table 2. Potential water erosion soil losses on crop rotation fields in experiment

Field	Part	Crop	Field area, ha	Soil losses, t	
				from 1 ha	from field
1	2	3	4	5	6
I	1	Black fallow	100.40	6.54	656.14
	2	Black fallow	38.50	6.89	265.33
II	1	Winter crop	70.90	3.55	251.56
	2	Winter crop	40.60	1.90	77.30
	3	Winter crop	21.80	4.02	87.54
III	1	Corn for grain	62.70	6.02	377.65
	2	Corn for grain	94.20	4.78	449.99
IV	1	Barley	16.30	3.18	51.91
	2	Oat	65.00	3.35	217.50
	3	Millet	46.50	3.36	156.14
	4	Barley	13.60	2.97	40.41
	5	Barley	20.70	4.05	83.84
V	1	Corn for silage	109.40	5.35	585.09
	2	Corn for silage	51.20	3.59	183.88
VI	1	Peas	95.10	2.77	263.36
	2	Peas	51.40	1.33	68.21
VII	1	Winter crop	141.30	2.61	369.45
	2	Winter crop	32.30	2.87	92.80
VIII	1	Sunflower	123.80	4.31	533.54
	2	Sunflower	23.20	6.30	146.06
	3	Sunflower	33.90	7.55	256.11
Total			1,252.80	4.17	5,213.82

Source: Authors' results.

The results of calculations show that potential soil losses from 1 ha vary from 1.33 to 7.55 t, on average by crop rotation - 4.17 t/ha. It should be noted that the land of field crop rotation is located on a flat surface or on slopes with a steepness of up to 3º. But most of the fields have a slope length of more than 800 m, so the potential soil erosion exceeds the ecologically acceptable limit of 2.0 t/ha. Such crops as fallow and row crops are more susceptible to leaching, where leaching varies from 3.59 to 7.55 t/ha. Based on the results of soil loss calculations, a corresponding cartogram was also constructed (Fig. 2).

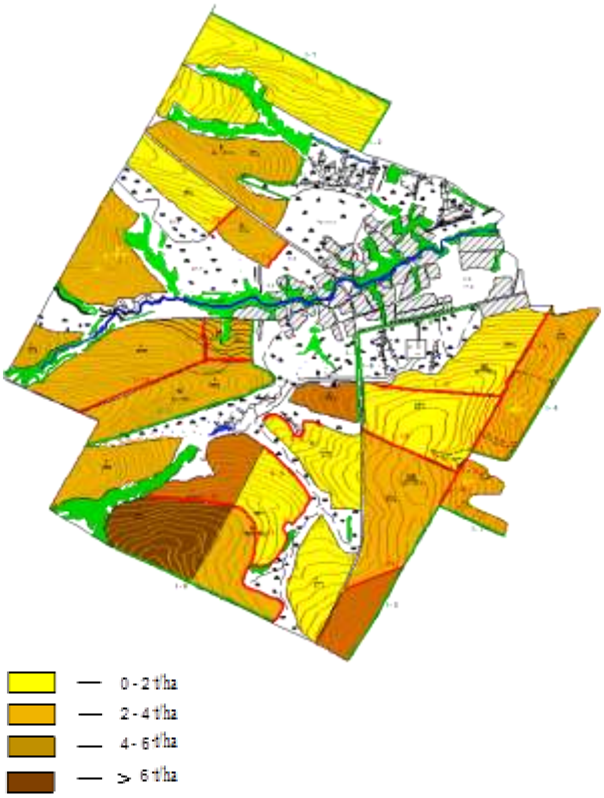

Fig. 2. Water erosion soil losses cartogram.
Source: authors interpretation of results.

The results of the experiments and calculations showed risk of individual fields part both from the point of view of runoff processes and the processes of soil deflation.
Quantitative calculations of soil losses costs restoration for the humus content removed from the soil as a result of water and wind erosion were carried out taking into account the actual costs of organic fertilizers in 2019 year. Based on the fact that 0.08 tons of humus were formed from 1 t of organic manure in the Steppe zone of Ukraine, to restore 1 t of humus, it is necessary to apply about 12.5 tons of manure (1 ton / 0.08 = 12.5 tons). According to the research of Kucher A. I. and the authors, in 2019 [5, 6], at the cost of organic fertilizers 250 UAH/t and the costs of their application 124 UAH/t, the total amount was 374 UAH/t. Taking into account the official inflation, it is possible to determine the estimated actual amount at the present moment - 586 UAH/t or, for example, 5,860 UAH/ha for an application of 10 t/ha. Thus, the cost of restoring of 1 t humus is 7,325 UAH. The information below obtained as the results of calculations of the restoration costs of humus that removed has been presented in Table 3 (water erosion) and Table 4 (wind erosion).

Table 3. Costs of humus losses restoration due to water erosion according to fields parts and crops, UAH

Field	Part	Crop	Soil losses t/ha	Humus losses t/ha	Costs of restoring humus losses (water erosion)	
					UAH/ha	UAH/ field
1	2	3	4	5	6	7
I	1	Black fallow	12.67	0.5207	3,814.40	382,965.61
	2	Black fallow	9.88	0.4061	2,974.45	114,516.25
II	1	Winter crop	2.08	0.0855	626.20	44,397.55
	2	Winter crop	2.27	0.0933	683.40	27,746.06
	3	Winter crop	2.27	0.0933	683.40	14,898.13
III	1	Corn grain	8.62	0.3543	2,595.12	162,713.75
	2	Corn grain	13.90	0.5713	4,184.70	394,198.67
IV	1	Barley	1.75	0.0719	526.85	8,587.67
	2	Oat	2.49	0.1023	749.63	48,726.16
	3	Millet	1.59	0.0653	478.68	22,258.69
	4	Barley	2.18	0.0896	656.31	8,925.75
	5	Barley	2.03	0.0834	611.15	12,650.74
V	1	Corn silage	12.91	0.5306	3,886.65	425,199.76
	2	Corn silage	14.20	0.5836	4,275.02	218,880.84
VI	1	Peas	2.18	0.0896	656.31	62,414.64
	2	Peas	2.28	0.0937	686.41	35,281.53
VII	1	Winter crop	2.27	0.0933	683.40	96,564.49
	2	Winter crop	1.91	0.0785	575.02	18,573.14
VIII	1	Sun-flower	11.04	0.4537	3,323.67	411,470.94
	2	Sun-flower	13.74	0.5647	4,136.53	95,967.50
	3	Sun-flower	13.13	0.5396	3,952.88	134,002.80
Total			7.27	0.2650	1,940.96	2,740,940.68

Source: Authors' results.

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Table 4. Costs of humus losses restoration due to wind erosion according to fields parts and crops, UAH

Field	Part	Crop	Soil losses t/ha	Humus losses t/ha	Costs of restoring humus losses (wind erosion)	
					UAH/ha	UAH/ field
1	2	3	4	5	6	7
I	1	Black fallow	6.54	0.2688	1,968.92	197,679.17
	2	Black fallow	6.89	0.2832	2,074.29	79,860.02
II	1	Winter crop	3.55	0.1459	1,068.75	75,774.67
	2	Winter crop	1.9	0.0781	572.01	23,223.58
	3	Winter crop	4.02	0.1652	1,210.25	26,383.48
III	1	Cor grain	6.02	0.2474	1,812.37	113,635.36
	2	Corn grain	4.78	0.1965	1,439.05	135,558.97
IV	1	Barley	3.18	0.1307	957.36	15,605.01
	2	Oat	3.35	0.1377	1,008.54	65,555.27
	3	Millet	3.36	0.1381	1,011.55	47,037.22
	4	Barley	2.97	0.1221	894.14	12,160.31
	5	Barley	4.05	0.1665	1,219.28	25,239.16
V	1	Corn silage	5.35	0.2199	1,610.66	176,205.94
	2	Corn silage	3.59	0.1475	1,080.80	55,336.78
VI	1	Peas	2.77	0.1138	833.93	79,306.67
	2	Peas	1.33	0.0547	400.41	20,580.89
VII	1	Winter crop	2.61	0.1073	785.76	111,027.90
	2	Winter crop	2.87	0.1180	864.04	27,908.33
VIII	1	Sun-flower	4.31	0.1771	1,297.56	160,637.66
	2	Sun-flower	6.3	0.2589	1,896.66	44,002.56
	3	Sun-flower	7.55	0.3103	2,272.98	77,054.16
Total			4,17	0,1708	1,251.40	1,569,773.11

Source: Authors' results.

The highest losses of soil from wind erosion were on the crops (t/ha): black fallow (9.88-12.67) and sunflower (11.04-13.74), corn (12.91-14.20). Lowest allowable losses (t/ha): millet – 1.59, barley – 1.75, winter wheat – 1.91. The highest soil losses from water erosion were calculated for the crops (t/ha): sunflower (6.30-7.55), black fallow (6.54-6.89) and corn (5.35-6.02). Lowest allowable losses (t/ha): millet – 1.59, peas – 1.33, winter wheat – 1.90.

When analyzing the cost of losses of soil organic matter due to water and wind erosion, a similar trend was maintained. The highest cost of humus losses restoration in soil (UAH/ha) as a result of water erosion was observed on variants with the most open soil surfaces under the cultivation of technical crops - corn (2,595.12-4,275.02), sunflower (3,323.67-4,136.53) and black fallow (2,974.45-3,814.40). The lowest cost of humus losses restoration in soil (UAH/ha) was fixed for millet (478.68) and barley (526.85). In the case of humus losses costs for lands restoration due to wind erosion, this trend was also preserved for some extent. The highest ones humus losses restoration costs (UAH/ha) were observed for variants with black fallow (1,968.92-2,074.29), sunflower (1,297.56-2,272.98) and corn (1,080.80-1,812.37). The lowest value of humus loss restoration cost (UAH/ha) was observed for variants with peas (400.41) and winter wheat crop (572.01). The rest of studied in experiment crops were having average values of soil losses from erosion and required average values of costs for humus content restoration.

CONCLUSIONS

When determining the erosion risk of the territory, the areas of eroded or erosionally hazardous soils must be protected by crops with potentially minimal soil losses from the wind erosion and surface runoff. The highest and lowest values of humus loss restoration costs should also be considered.

For areas with black fallow and technical crops (such as sunflower, corn for grain or corn for silage) some monitoring plots should be organized to observe soil erosion dynamics. The specified features of these crops are suggested to be taken into account when planning crop rotations and soil tillage, assessing the risks of highest costs of humus losses restoration because of erosion processes.

It is also important to state the cumulative manifestation of wind and water erosion on the territory of the region, but it is difficult to separate the contours of eroded and deflated soils in detail, therefore, in cases of erosion situations we propose to obtain separate influence of each erosion on already eroded or erosionally hazardous lands.

REFERENCES

[1]Bilolypskyi, V.A., 1998, Ekologichni pidkhody do formuvannya funktsionalnyh modeley hruntovodookhoronnyh ahrolandshaftiv (Ecological approaches for the formation of functional models of soil and water protection agrolandscapes). Bulletin of Agrarian Science, Vol. 1. 28–34. (In Ukrainian).

[2]Bilolipskyi, V.A., Bulygin, S.Y., 2009, An Ecological and Hydrological Analysis of Soil- and Water-Protective Agrolandscapes in Ukraine. Eurasian Soil Science, Vol. 42 (6), 682-692.

[3]Bolstad, P.V., Stowe, T., 1994, An evaluation of DEM accuracy: elevation, slope and aspect. Photogrammetric Engineering and Remote Sensing, 60: 1327-1332.

[4]Kovalchuk, I.P., 2013, Eroziyni protsesy Zakhidnoho Podillya (Erosion processes of Western Podillia). Kyiv-Lviv: League-Press. 2013. 296 p. (In Ukrainian).

[5]Kucher, A., 2017, Estimation of effectiveness of usage of liquid organic fertilizer in the context of rational land use: a case study of Ukraine. Przeglad Wschodnioeuropejski. 2017. Vol. VIII. No. 2, 95–105.

[6]Kucher, A. V., 2015, Economic aspects of evaluation of organic fertilizers. Natural agricultural production in Ukraine: development problems, development prospects: Mater. international science and practice conf. (Dnipropetrovsk, October 22–23, 2015). Dnipropetrovsk: RVV DDAEU, 2015, 173–175. (In Ukrainian).

[7]Lysetsky, F. N., Svetlichnyi, A.A, Cherny, S.G., 2012, Sovremennyye problemy eroziovedeniya (Recent developments in erosion science), Book edited by Svetlychnyi A. A. Belgorod: Constanta, 2012. 456 p. (In Russian).

[8]Metodyky i normatyvy proyavu i nebezpeky eroziyi (Methods and standards for the manifestation and danger of erosion)/ Methodical manual. Kharkiv 2000. 64 p. (In Ukrainian)

[9]Metodychni rekomendatsiyi z prohnozuvannya proyavu vitrovykh bur v Ukrayini (Methodological recommendations for forecasting the occurrence of wind storms in Ukraine). Kharkiv, 2010. 32 p. (In Ukrainian)

[10]Nearing, M.A., 2013, Soil erosion and conservation, in: Environmental Modelling: Finding Simplicity in Complexity: Second Edition. pp. 365–378.

[11]Svitlichny, O.O., Chorniy, S.G., 2007, Osnovy eroziyeznavstva (Fundamentals of erosion studiing): Textbook. Sumy: VTD "University book", 2007. 266 p. (In Ukrainian).

[12]Tarasov, V.I., 1988, Otsenka stokoreguliruyushchey roli lesnykh polos (Melioratsiya i vodnoye hozyaystvo). Evaluation of the runoff-regulating role of forest belts. Land reclamation and water management. 1988. No. 7, 54-55. (In Russian).

[13]Tarasov, V.I., Zubov, O.R., Kolesnikov, Y. I., Polulyakh, M.M., 2003, Doshuvalna ustanovka dlya vyvchennya eroziї gruntiv (Rain installation for the study of soil erosion. Patent 62336A. Bull. No. 12, 2003 (In Ukrainian).

[14]Teng, H., Viscarra Rossel, R.A., Shi, Z., Behrens, T., Chappell, A., Bui, E., 2016, Assimilating satellite imagery and visible-near infrared spectroscopy to model and map soil loss by water erosion in Australia. Environment Modelling and Software. 77, 156–167.

[15]Velickovic, N., Todosijevic, M., Šulic, D., 2022, Erosion Map Reliability Using a Geographic Information System (GIS) and Erosion Potential Method (EPM): A Comparison of Mapping Methods, BELGRADE Peri-Urban Area, Serbia. Land 2022, 11, 1096.

[16]Zaslavsky M.N., 1983, Eroziovedeniye (Erosiology) A textbook for students of geography. and soils. specialist. universities. Moscow: Higher. School 1983. 320 p. (In Russian).

[17]Zhang, C., McBean, E.A., 2016, Estimation of desertification risk from soil erosion: a case study for Gansu Province. China. Stochastic Environmental Research and Risk Assessment. 30, 2215–2229.

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THE EFFICIENCY OF RAISING PIGLETS UNDER DIFFERENT SYSTEMS OF THEIR FEEDING

Oleksandr TISHCHENKO[1], Serhii LUHOVYI[2], Mykola POVOD[1], Oleksandr MYKHALKO[1], Tetyana VERBELCHUK[3*], Serhii VERBELCHUK[3*], Vira KOBERNIUK[3]**

[1]Sumy National Agrarian University, Department of Feed Technology and Animal Feeding, 160, H. Kondratiiev Street, Sumy, Ukraine, Phones: +38(099)2601594, +38(095)5488087, +38(066)2871386, E-mails: ptichka307@gmail.com, oleksandr.mykhalko@snau.edu.ua, nic.pov@ukr.net
[2]Mykolaiv National Agrarian University, Department of genetics, animal feeding and biotechnology, St. Georgy Gongadze, 9, Mykolaiv, Ukraine, Phones: +38(095)3343415, E-mails: lugsergey23@gmail.com
[3]Polissia National University, [*]Department of Technology of Processing and Quality of Livestock Products, [**]Department of feeding, animal breeding and biodiversity conservation, Staryi Boulevard, 7, Zhytomyr, Ukraine, Phone: +38(098)2482590, +38(098)2482590, +380671697709, E-mail: ver-ba555@ukr.net, verba5551@ukr.net, kobernukvera@gmail.com

Corresponding author: snau.cz@ukr.net

Abstract

The article studied the productivity indicators, the effectiveness of the use of feed and medical and preventive means, as well as the economic indicators for the rearing of piglets using dry feeding (from self-breeders), wet feeding (from automatic feeders), liquid feeding (prepared in containers for a building for rearing) and portioned liquid feeding (prepared at each individual automatic feeder). Better indicators of piglet productivity were found with liquid feeding and portioned feeding of piglets by hydration during feeding in the automatic feeder. In liquid feeding, piglets had 4.34–20.62% better average daily and absolute growth, 3.42–15.24% higher weight at the end of the period, but were 0.03–0.53% worse in terms of preservation than analogues using dry and wet feed. When using a liquid feeding system with feed mixture in containers designed for one room, the productivity indicators proved to be lower compared to feeding with portion feeding systems, but they outperformed the animals with dry feeding by 15,6% in terms of average daily and absolute gains and by 11.43% in terms of weight at the end of rearing, and they outperformed analogues consuming moistened feed in the feeder by 10.77% in terms of average daily and absolute gains and by 7.81% in terms of weight of piglets at the end of rearing. Piglets consuming wet feed during rearing were inferior to their liquid-fed counterparts in terms of key productivity indicators, but showed better productivity levels than their dry-fed peers.

Key words: *distribution of fodder, feeding, rearing of piglets, liquid fodder, dry fodder*

INTRODUCTION

A key role in raising pigs is played by rational and balanced feeding, which includes not only the correct composition of rations and the creation of an effective feed base, but also the use of modern highly efficient feeding systems [6, 22, 26].

The study of the aspects of feeding pigs enables a drastic increase in their productivity, especially in young animals in fattening, through a scientifically based balancing of rations in terms of energy content and the number of nutrients and biologically active substances [3, 24]. However, even an optimally high energy level and a balanced ration with biologically complete protein through essential amino acids (lysine, methionine, cystine, tryptophan, threonine), macro- and microelements and biologically active substances do not ensure 100% implementation of the fattening program if the producer does not pay the necessary attention to the feeding systems [11, 19, 25]. The organization of pig feeding in today's sense is a set of complementary and appropriate technologies that can be used in the context of the selected type of feeding, provided that appropriate equipment is available and appropriate methods are followed [23, 33].

Today, there are two main types of pig feeding: liquid, dry, and less frequently, wet feeding in various combinations of water and feed. Until recently, most pig farms preferred dry feeding. This type of feeding was believed to be associated with lower costs for installation and maintenance of equipment [4] and to provide better sanitary and hygienic conditions for the farm [10]. Such a statement is valid only in relation to feeding with granulated compound feed. Modern equipment for dry fodder distribution through feeders combined with drinkers is relatively easy to maintain. It also reduces feed losses and pollution. In addition, modern equipment allows any feed dosing regime and ensures free access for pigs to feed [28]. Feeders of all leading manufacturers are equipped with feeding nipples or nipple drinkers. With their help, pigs can independently determine what consistency of feed to eat. A phase feeding system can be used with dry feeding, but not to the same extent as with liquid feeding. This is due to the limited choice of ready-made rations and the technical capabilities of the facilities [13]. However, pigs eat dry feed much slower than wet feed, which complicates their hierarchical relationship due to the longer duration of the feeding process [1]. Liquid feeding of pigs has been around since ancient times, as food waste traditionally formed the basis of pig feed, even in the era of small-scale pig production [21, 24]. A sharp increase in the number of pigs and the transition to industrial pig farming led to a need for a constant supply of large quantities of feed, which led to the development of technology for obtaining freeze-dried rations. The leader in liquid fattening of pigs among European countries is Ireland (90% of the herd), followed by Germany, Denmark and Holland (up to 50% of the herd). The United States and Canada remain supporters of dry feeding, while liquid feeding systems have been developed in the southwestern United States in recent years and already cover 20% of the pig herd [18, 26]. It should be noted that the advantages and disadvantages of dry feeding are clearer, while there is some lack of information on liquid feeding. Among the main advantages of liquid feeding is the possibility of using cheap waste from the food industry. Considering that 70% of expenditure in pig meat production is on feed, production costs can be significantly reduced by using cheap products in the composition of complete and balanced rations for pigs [21]. Other benefits include: significantly higher consumption of liquid feed compared to dry feed (by 5% or more) [14], improvement in feed conversion (up to 10%) [12], increase in live weight gain by up to 6% [7], faster attainment of slaughter live weight [30], reduction in feed losses [5]. According to published work [6], pigs fed liquid feed consumed it to a greater extent and achieved a higher pre-slaughter weight, higher average daily gains, and had higher meat content in the carcass (14%) than pigs fed dry feed. The liquid feed also met their physiological needs to a greater extent than the dry feed in the post-weaning piglets. In addition, the components included in the liquid ration contain lactic acid bacteria, which ferment the feed mixture, lowering its pH value and thus have a preservative effect. Lactic acid prevents the reproduction of pathogenic microflora in the feed [17, 32]. Modern automated liquid feeding systems, which are currently widely used in European countries, make it possible to ensure the preparation and highly precise dosed distribution of feed to the animals with minimal labour. With liquid feeding, it is also possible to reduce production costs by using cheap food waste [2, 34]. The disadvantages of liquid feeding include the following: high initial investment and qualified personnel are required for process management [29], as the risk of losses can be high if the technology is violated in any of the phases, then the hygienic condition can deteriorate if regulations are violated when cleaning the feed pipe systems [9, 21]. It was also reported that there was no likely difference in feed conversion between groups of pigs receiving different types of feed based on moisture [20] An alternative but less common way of preparing feed for growing piglets is to moisten dry feed in feeders. Piglets eat this feed better than dry feed but slightly worse than liquid feed, which also results in higher average daily gains for the animals compared to animals eating granulated dry feed mixes. The degree of feed digestibility is higher with liquid feeding than with wet or dry feeding. Feed conversion is higher than with dry feeding. Feeding young, growing animals in a moistened multiphase procedure followed by liquid feeding contributed to the formation of a certain consumption mode and mechanism of nutrient assimilation in piglets, resulting in more intensive accumulation of intramuscular fat [31]. However, other researchers have reported that feed consistency has no effect on nutrient digestibility in pigs [15], and the effect of wet feed on piglet growth during rearing has not been scientifically proven [16]. Thus, feeding piglets in the growth phase can be done with dry, wet, and liquid feeds, but each of these feeds has its own positive and negative effects on the growth intensity of the animals. Each type of feed is provided by different feeding systems, which differ in technological and organizational aspects and require an unequal amount of labor and financial resources for equipment, maintenance and ensuring efficient production [3, 4, 6, 24, 27]. The scientific study of the results of the use of different feeds, different systems of preparation and supply of growing plants with feed mixtures is constantly carried out and is characterized by diverse conclusions, which do not always coincide. Therefore, further research on the influence of the feed type on the growth of piglets is still urgently needed. Thus, the objective of the experiment is to investigate the relationship between the growth intensity of English-breed piglets and the use of dry, liquid, and wet feeds, as well as various methods of preparation and transportation under the conditions of an industrial pig enterprise.

MATERIALS AND METHODS

The materials for the study were piglets raised by half-breed sows of the Landrace and Large White English breed and boars of the synthetic terminal line PIC 337 of the English company PIC. The object of the study was the productive qualities and efficiency of piglet rearing under different systems of transport and distribution of feed. To conduct the study, four groups of 1,200 piglets each were formed according to the scheme of the experiment (Table 1) in the commercial breeder (No. 2) of LLC "Globinsky Pig Complex", Poltava region, Ukraine.

Table 1. Scheme of the experiment

Indicator	Groups			
	I (control)	II	III	IV
The number of piglets in the group	1200	1200	1200	1200
The number of piglets in pen	150	150	150	150
The method of transporting feed to feeders	Dry compound feed and chain-disc conveyor	Dry compound feed and mechanical, chain-disc conveyor	Liquid compound feed and hydraulic transportation through pipelines using clean water	Dry compound feed and pneumatic transportation using compressed air
A method of preparing a portion of fodder	Without preparation	Preparation in the feeder of the feed machine by the pigs	Preparation in hopper mixers provides liquid feed for each technological group separately.	Feed preparation in a mini-mixer for each individual pen.
Method of feeding fodder	Dry	With moistening in the feeder with the help of sprinklers	Liquid	Liquid
Feeding front for 1 piglet in pen	2.5 centimeters	2.5 centimeters	16 centimeters	16 centimeters

Source: Own calculations.

The animals of all groups were weighed separately when leaving the breeder and after setting up the pens in the breeding workshops. Two control pens were provided in each experimental group for weighing the animals, which was done individually on the day of introduction into the experiment and at the time of changeover to the next feed recipe for 41 days and after completion of rearing for 70 days of life.

Piglets in all experimental groups were kept under identical conditions, 150 each in a 6 x 8.5 m pen with a warm floor of 0.1 m^2 per animal. Ventilation in all rearing rooms was done with negative pressure through exhaust roof fans and supply air valves. Manure removal was done at the expense of a periodic vacuum gravity system from the trays under the grid floor twice during the growing season.

The filling was performed using 8 height-adjustable nipple fillers and 8 cup fillers placed at a height of 20 cm above the floor.

The animals were fed with fully rational granulated feed produced by LCC "Globynsky Compound Feed Plant", Poltava region, Ukraine. From the day of weaning until reaching an average weight of 9 kg, piglets were fed pelleted pre-stage feed, which was also used during the weaning period. Thereafter, the piglets were switched to cheaper pre-starter feed, which was fed until the piglets reached a weight of 12 kg. After that, the piglets were switched to starter feed, which they received for 70 days of life until the end of the rearing period. The difference between the control and experimental groups was the type of feeding and the distribution of the feed for the piglets.

From the first day of rearing, control group I animals received a dry feed from the American Hog Slat feeders (Photo 1). The feed front was 2.5 cm per piglet that was in the vending pen. The number of feeding places in each automat was 24. The feed was transported to the feeders by a chain and pulley conveyor. The filling of the self-loading bunkers was controlled automatically. In the first days after weaning, to accustom the piglets more quickly to feed intake, the mixed feed was added to the main feeders four times a day and scattered on a solid part of the floor. The piglets were also given a mixture of one part mixed feed and three parts warm acidified water in portable drinkers six times daily. The mixed feed, which the piglets were to learn to eat, was taken from the same bunkers as the feed for the self-feeders. Accounting for the consumed fodder was carried out automatically based on the information obtained from the torsion scales on which the fodder storage hoppers were installed.

Photo 1. Conditions of keeping piglets of group I.
Note: 1 – pipeline, 2 – distribution pipeline, 3 – feeder
Source: processed photo of LLC “Globinsky Pig Complex”

The piglets of experimental group II were kept in the same complex under similar conditions in terms of housing, feeding, maintenance of microclimate, and manure removal (Photo 2). The piglets were fed from Tubomat-type feeders at a ratio of one feeder per 30 piglets. The feed front was also 2.5 cm per animal. The feed transport and distribution in the feeders' hoppers were similar to the animals in the control group. Each feeder was equipped with two feed spreaders, with the help of which the piglets moistened the dry feed in the troughs of the feeders to the desired moisture level. In the first week after being housed in the nursery, the piglets in this group were fed via the floor and the temporary feeders like the animals in the control group. Feed accounting was done automatically using sensors on the torsion scales of the storage bunkers.

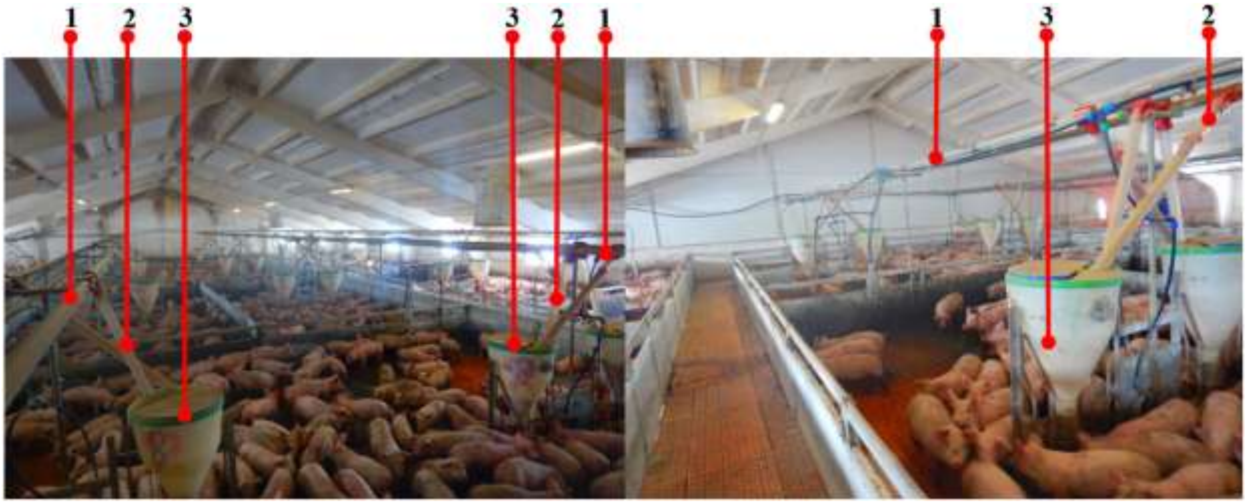

Photo 2. Conditions of keeping piglets of group II.
Note: 1 – pipeline, 2 – distribution pipeline, 3 – feeder
Source: Source: processed photo of LLC "Globinsky Pig Complex".

The animals in experimental group III were kept in similar pens as the first two groups (Photo 3) in the rearing facility (No. 4) with similar systems for maintaining the microclimate, manure removal and watering. Piglets were fed from the first day of rearing with liquid feed mixtures based on the appropriate mixed feed formulas mixed in the feed tanks of the feeding system Hydro Mix Pro of the Big Dutchman company, which consists of two mixing hoppers Mish Tank with a volume of 2 m^3, a tank for waste water, a Waser Tank with a volume of 1.2 m^3 and a Fresh Waser Tank with a volume of 10 m^3. A tank for mixed feed for a barn with 1200 animals. To manage the feed kitchen in automatic mode, the Big Farm Manager computer control system was used, which monitors the distribution, consumption of feed and filling of the feed tanks. This system also records both the dry feed and the supplementary feed added to the piglets' diet. The ratio of dry compound feed to water with tank mixers was automatically maintained at the level of 1 to 2.8 kg. The distribution of the feed portion dispensed from the hopper of the mixer was carried out by means of water transport to the pneumatic valves of the automatic feeder. The feed portion determined by the control system of the feed kitchen was pressed into the feed pipe, where it was transported to the appropriate valve of the corresponding pen with the help of a stream of clean water. By opening the valve, the feed enters the animal feeder. The level of the feeder was monitored by the level sensor. When the feeder was full, it was activated and the feeding system dispenses another portion of the feed. The feed front in this system was 16 cm per head. Feed accounting was done via the feed kitchen management system for each feeding. The frequency of filling the feeders was 12 times per day.

Photo 3. Conditions of keeping piglets of group III.
Note: 1 – pipeline, 2 – distribution pipeline, 3 – feeder
Source: Source: processed photo of LLC "Globinsky Pig Complex".

The piglets in group IV were housed in a rearing facility (No. 3), where they were kept under identical conditions for maintaining the microclimate, manure removal and feeding, also in pens on a slatted floor with a partially warm floor. The feed was transported to the drinkers, distributed and fed to the piglets in this group from the first day of the experiment using the Spotmix II feeding (Schauer, Austria).

With this system, a feed portion calculated for a pen was put into a micromixer, to which microdoses of probiotics, medicines, acidifiers or other active ingredients were added specifically for the corresponding pen at the request of the control processor.

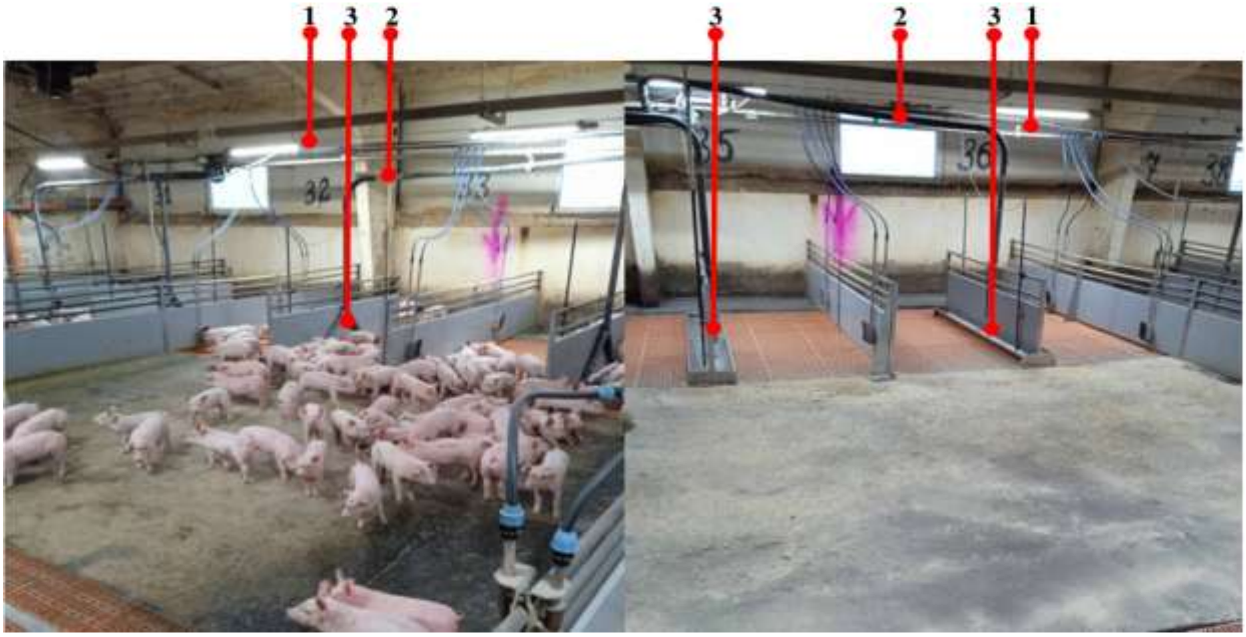

Photo 4. Conditions of keeping piglets of group IV.
Note: 1 – pipeline, 2 – distribution pipeline, 3 – feeder
Source: Source: processed photo of LLC "Globinsky Pig Complex".

This feed portion was then passed in dry form through piping by means of compressed air and a system of rotary joints to a separate feeder, where it was moistened as it was discharged from the piping system to a moisture level that was uniquely determined by the feeding controller.

The feeding front was 15 cm per piglet. The number of feedings was 12 times a day. Feed accounting was carried out by the control system at each mixing and unloading of feed into the pipelines.

The keeping of piglets in the experiment period was humane and in accordance with the policy of Council Directive 86/609/EEC [8]. Data analysis was finished using MS Excel 2016. The reliability of deviations from the average was assessed using the Student's t-test.

RESULTS AND DISCUSSIONS

As shown in Table 2, the weight of the piglets was practically the same when they were housed for rearing, ranging from 0.02 to 0.7 kg. In addition, the piglets were almost the same age when they entered the nursery. In the studies, the age of sows at the end of rearing and at the transition to fattening was almost the same. However, the weight of the piglets during this period differed significantly between the groups with different feeding systems. In our opinion, this was due to the unequal growth intensity of piglets under different feeding systems. The highest average daily weight gain during the rearing period was recorded by the animals of experimental group IV – 446.5 g, which was 18.6 (4.3%) g ($p < 0.05$) higher than in the animals of the experimental group III, by 60.2 (15.58%) g ($p < 0.001$) in comparison with the animals of the experimental group II and by 76.3 g (20.6%) ($p < 0.001$) in comparison with the piglets of the control group. At the same time, piglets in experimental group III were 57.8 g ($p < 0.001$) heavier than their counterparts when fed dry food and 41.6 g ($p < 0.01$) when fed wet food. The latter, in turn, had an advantage of 16.1 g in average daily gains over their peers in the control group.

The higher growth intensity led to inequalities between the animals of the experimental groups in the indicators of absolute growth. The highest value of this indicator was found in the piglets of the experimental group IV, which were transported, dosed and distributed using the portion feeding system Spotmix II. They exceeded the analogs of the experimental group III by 2.04 kg, those of the second experimental group by 2.95 kg, and those of the control group by 3.74 kg for this indicator.

The unequal absolute growth, with practically equal live weight at rearing, also resulted in different weight of piglets at the end of the rearing period.

The piglets in experimental group IV, which were fed liquid feed via the Spotmix II portion feeding system, had the highest weight at this time. The piglets of this group, by live weight at the end of rearing, probably exceeded by 3.68 kg or 15.24% ($p < 0.05$) the analogues of the control group, which received dry, non-moistened feed during rearing, by 2.87 kg or 11.50% ($p < 0.001$), the analogues of the experimental group II, which consumed moistened feed in drinkers, and by 0.92 kg or 3.41% ($p < 0.05$) the piglets of the experimental group III, which were fed with liquid feed mixed in large containers, as when using the drinker Hydro Mix Pro.

The latter, in turn, exceeded the piglets of the control group by 2.76 kg or 11.43% ($p < 0.001$) and the analogues of the II experimental group by 1.95 kg or 7.81% ($p < 0.01$) for this indicator.

At the same time, their peers from experimental group II, which consumed feed moistened in the feeders, outperformed the control group animals at the transition to fattening in terms of live weight by 0.81 kg or 3.35 ($p \geq 0.05$) and were inferior to the analogues of the experimental group III by 1.95 kg or 7.81% ($p < 0.001$) and peers of the experimental group IV by 2.87 kg or 11.50% ($p < 0.001$).

Table 2. Growth intensity and survival of piglets under different feeding systems

Indicator	Groups			
	I (control)	II	III	IV
The weight of the piglets when they are placed for rearing, kg	6.01±0.096	6.03±0.114	5.94±0.123	5.95±0.092
Age of piglets when placed for rearing, days	20.4	20.4	20.2	20.42
Weight of piglets when transferred to fattening, kg	24.15±0.306	24.96±0.312	26.91±0.321***	27.83±0.296***
Age of piglets when transferred to fattening, days	69.4	69.4	69.2	69.2
Absolute growth, kg	18.14±0.276	18.93±0.216*	20.97±0.309***	21.88±0.232***
Average daily growth, g	370.2±9.2	386.3±14.1	428.0±12.9***	446.5±11.3***
Preservation of piglets, %	96.81	96.33	96.06	96.27

* – $p < 0.05$; *** – $p < 0.001$
Source: own calculations.

The preservation of piglets did not show significant variations between experimental groups and proved to be 0.03–0.74% better in dry feeding than in liquid and wet feeding.
Thus, the best performance indicators of piglets during sprinkling were found in liquid feeding of piglets with the Spotmix II device with its batch mixing, pneumatic transport and humidification during feeding in the feeder. The animals in this group had 4.34–20.62% better average daily gains and absolute gains and consequently a 3.42–15.24% higher weight of piglets at the end of the rearing period. At the same time, they were 0.03–0.53% worse than their counterparts using dry and wet feeds in terms of animal survival during rearing.
When using a liquid feeding system with Hydro Mix Pro equipment, where the slurry was mixed in single-room containers and transported to the feeders via pipelines, the performance indicators were slightly lower compared to feeding with Spotmix II systems but outperformed the animals on dry feed by 15.6% in terms of average daily and absolute growth and by 11.43% in piglet weight at the end of the rearing period. Furthermore, piglets with this type of preparation for feed distribution and feeding had an advantage over their peers that consumed moistened feed in the feeder during rearing by 10.77% in average daily gains and absolute gains and by 7.81% in piglet weight at the end of rearing. Piglets fed wet feed during rearing were worse than piglets fed a liquid diet in terms of the main productivity indicators, but had better productivity levels than piglets fed a dry diet. With liquid feeding, piglets had a higher daily feed consumption of 0.05–0.06 kg compared to dry and wet feeding (Table 3).

Table 3. Average daily consumption and consumption of feed for different feeding systems of piglets

Indicator	Groups			
	I (control)	II	III	IV
Spent fodder per head, kg	32.5	32.6	35.0	35.2
Average daily feed consumption, kg	0.66	0.66	0.71	0.72
Feed conversion, kg	1.79	1.72	1.67	1,61
The average price of 1 kg of compound feed, EUR	0.32	0.32	0.31	0.31
Fodder cost of growing 1 piglet, EUR	10.34	10.37	10.97	11.03
Feed cost of 1 kg of gain, EUR	0.57	0.55	0.52	0.50

Source: own calculations.

This naturally led to an increase in their numbers during the rearing of 2.46–2.76 kg per piglet. However, the higher feed intake with liquid feeding resulted in higher growth intensity and consequently larger absolute gains, which contributed to an improvement in feed conversion by 0.05–0.18 kg. This indicator proved to be the best in the piglets of experimental group IV. It was 0.06 kg lower than for the animals in the experimental group

III, 0.11 kg lower than for the animals in the experimental group II and 0.18 kg lower than for the animals in the control group.

The average price of the mixed feed depends on the age at which the weight was reached between 9 and 12 kg. Reaching such weight later, when the animals were switched to cheaper feed, resulting in the average cost of compound feed being EUR 0.005 higher for the piglets in the first two groups.

Despite the lower price of the compound feed, piglets in the liquid feeding group were conspicuous by the higher cost of the compound feed consumed (feed cost) due to its greater quantity. Thus, compared to the analogues of group III, the animals of experimental group IV consumed EUR 0.06 more feed, the peers of group II EUR 0.66 and the piglets of the control group UAH 0.69. At the same time, animals in experimental group III consumed 2.46 UAH less feed than animals in experimental group IV, but EUR 0.59 and EUR 0.62 more than animals in the control and II experimental groups, respectively. Animals consuming unlimited amounts of dry and wet feed ate EUR 10.33 and EUR 10.36, respectively, EUR 0.59–0.69 less than the animals in the dosed liquid feed experimental group.

Despite the higher feed cost for the animals with their dosed liquid feed, the feed cost per 1 kg growth was EUR 0.02–0.06 lower compared to the animals consuming unlimited amounts of dry and wet feed from self-breeders and automatic feeders. Thus, in liquid feeding, the average daily feed consumption was higher by 7.56–8.19%, the feed cost per 1 head per period was higher by 5.78–6.70%, the feed cost for rearing 1 piglet was lower by 5.78–6.70%, but by 2.46–2.76% of feed consumption per 1 kg of growth and by 4.51–11.54% of feed cost.

Different methods of preparing, transporting, and distributing feed have different effects on the health status of piglets and on the economic indicators of their rearing, which was due to the different costs of the equipment itself and its ability to dose feed and medicines into the feed. As can be seen from Table 4, the depreciation costs of feeding equipment were the lowest for dry and wet feeding, as the investment in this equipment was significantly lower. For liquid feeding with mixing in feed bins, this cost per piglet was EUR 0.042–0.043 (81.91–84.69%) higher than for dry and wet feeding. The highest percentage of amortization costs for piglet feeding equipment was found for the Spotmix II liquid feeder. This device had EUR 0.021 (22.10%) more cost per animal compared to liquid feeding with Hudro Mix Pro equipment, EUR 0.063 (122.11%) compared to wet feeding from automatic feeders and EUR 0.064 (125.51%) compared to dry feeding from self–fertilizers.

The share of amortization costs in the cost of a piglet was in the range of 0.14–0.31% and was almost twice as high as in liquid feeding of piglets.

An important factor in piglet rearing was the health condition of the piglets, which has a significant impact on piglet productivity. Maintenance of this condition was done both by preventive measures and by treatment of the animals.

The various systems for transporting and distributing feed have different technical capabilities for incorporating prophylactics into feed. For example, the Spotmix II system doses and mixes the feed for each individual pen and enables more rational use of prophylactic agents in feeding. This contributed to the fact that the animals of research group IV had the lowest costs for the prevention of gastrointestinal diseases, which amounted to EUR 0.072 per piglet. In contrast, in liquid feeding with mixing in large containers, they were higher by EUR 0.060. In dry and wet feeding, this indicator was the highest at EUR 0.152 by EUR 0.019 compared to liquid feeding with Hydro Mix Pro equipment and by EUR 0.08 compared to feeding with Spotmix II equipment.

Lower costs of means for disease prevention contributed to the decrease in the share of preventive measures in the total cost of raising a piglet. Thus, it was almost twice as high in the animals of the experimental group IV compared to the animals of the other groups. This cost in terms of 1 kg growth of piglets during rearing was almost twice as low compared to animals of group III and almost three times as low compared to animals of groups I and II under liquid portion feeding (experimental group IV).

Table 4. Component costs of raising piglets under different piglet feeding systems

Indicator	Groups			
	I (control)	II	III	IV
Operational cost of raising 1 piglet, EUR	13.26	13.29	14.06	14.14
Expenses for depreciation of equipment per piglet, EUR	0.05	0.05	0.10	0.12
The share of amortization costs for equipment for feeding piglets in the total cost of 1 piglet, %	0.14	0.14	0.25	0.31
Costs for preventive measures per piglet per period, EUR	0.15	0.15	0.13	0.07
The share of costs for preventive means in the cost of rearing 1 piglet, %	1.11	1.11	0.92	0.50
Costs for preventive measures calculated per kg of growth, EUR	0.008	0.008	0.006	0.003
Costs for the treatment of 1 head of piglets during rearing, EUR	0.23	0.26	0.10	0.02
Costs for treatment of diseases during growing up EUR/kg of growth	0.012	0.014	0.005	0.001
The share of the cost of treatment of piglets in the cost of rearing 1 piglet, %	1.65	1.87	0.68	0.15
Costs for preventive and curative measures per head, EUR	0.38	0.41	0.23	0.09
Veterinary cost of 1 kg of gain, EUR	0.021	0.022	0.011	0.004
Costs for feed for piglets, preventive and medical measures per head, EUR	10.72	10.78	11.20	11.13
Fodder and veterinary cost of 1 kg of gain, EUR	0.59	0.57	0.53	0.51

Source: own calculations.

More effective preventive measures contributed to lower morbidity in piglets and, consequently, to lower costs for their treatment. For example, liquid portion feeding with the Spotmix II device (IV experimental group) proved to be almost five times lower in the cost of treating piglets compared to liquid feeding with mixing in the general container and more than ten times lower compared to dry and wet feeding. A similar trend was observed in the cost of treatment per 1 kg of weight gain.

The total cost of preventive and curative measures per animal was the highest in piglets of research group II with EUR 0.409, which was EUR 0.032 more compared to animals of the control group, EUR 0.179 compared to peers of the research group III and EUR 0.316 compared to analogues of the research group IV.

Taking into account the different growth intensity of piglets during rearing under different feeding systems and the unequal costs of prevention and treatment of diseases, the veterinary component of the cost of 1 kg of growth differed significantly between the groups. Thus, this cost was the lowest in the animals of experimental group IV, where EUR 0.004 was spent on veterinary preventive means for 1 kg of live weight gain. In contrast, this indicator was 61.1% higher in research group III. The highest veterinary costs per unit of growth were incurred by piglets in the II research group, for which 8.58% more funds were spent on veterinary preventive measures than in the control group, and by 43.87 and 59.38% compared to the III and IV research groups, respectively.

Contrary to the trend of decreasing expenditure on veterinary preventive measures, the total expenditure on feed and medical and preventive measures was higher in the piglet groups with liquid feeding. Thus, these expenses were the highest in the animals of experimental group III with EUR 11.19, while they were higher in the piglets of experimental group IV by EUR 0.071, in the animals of experimental group II by EUR 0.419 and in the peers from the control group by EUR 0.480. In the last group, the total cost of feed and medical and preventive measures was the lowest at EUR 10.71. But, taking into account the uneven growth of animals under different feeding systems, the trend of these costs per 1 kg of growth was completely different. Thus, the smallest expenses for feed and veterinary preventive measures per 1 kg of growth were found for piglets of the IV research group to be EUR 0.508, which was EUR 0.025 less compared to the analogues of the research group III and EUR 0.060 and 0.082 compared to the animals of II experimental and I control groups, respectively.

Thus, with liquid portioned feeding with the help of Spotmix equipment, the cost of one piglet after the completion of rearing, costs of equipment depreciation per piglet and their share in the cost of piglets, costs of feed and preventive and medical measures per head turned out to be the highest. At the same time, this method of distributing and feeding animals contributed to the lowest costs for preventive and therapeutic measures per 1 piglet and per unit of gain of piglets and the lowest feed and veterinary cost per 1 kg of gain. In the liquid feeding systems with feed mixture and its moistening in the general container for piglets, the cost of equipment for piglet feeding decreased by 4.77%, its share in the total cost of piglet rearing decreased by 0.06%, but the cost of preventive measures per animal increased by 45.63%, its share in the cost of piglet rearing was 47.90%, the cost of treatment of 1 piglet during rearing was 78.11%, the share of these costs in the cost of rearing and head was 78.06%, the cost of feeding piglets, preventive and curative measures per piglet by 0.64% and at 1 kg increase by 4.77% compared to the group of animals fed with liquid feed with the portion feeding system Spotmix II.

At the same time, transportation of dry feed and unlimited dry and wet feeding of piglets during rearing significantly reduced the depreciation cost of equipment by 81.91–125.51% and its share in the total cost of rearing 1 piglet was by 80.58–122.94%, by 3.23–4.48% of the cost of piglet feed, preventive and therapeutic measures per piglet. At the same time, the cost of preventive and curative measures per piglet increased significantly by 39.05–77.20%, their share in the cost of piglet rearing by 16.13–59.80%, and the cost of a piglet by 62.61–92.84% kilograms of growth compared to liquid methods of piglet feeding.

The decisive factor of modern competitive production is the yield and profitability of production. Considering the high share of feed in the cost of pork, the factor of its rational use is extremely important.

Table 5 shows the income and profitability of breeding pigs using different methods of transporting and distributing feed. As can be seen from this table, at the beginning of the experiment, with almost the same weight of piglets, their market value practically did not differ. The cost of rearing a piglet proved to be similar, although it was EUR 0.59–0.70 higher for liquid feeding compared to dry and wet feeding. At the same time, the animals gained different amounts of live weight during the rearing period and showed significant differences in this indicator at the end of the rearing period. This resulted in a difference in the market value of a piglet at the same market price for 1 kg live weight of the corresponding technological group of piglets.

It was highest in the piglets of the IV experimental group EUR 55.66. In contrast, the animals of experimental group III were cheaper by EUR 1.84 per piglet. At the same time, the animals of the control group fed with dry feed had the lowest sale value and were inferior in terms of this indicator to analogues of the experimental group IV EUR 7.36, peers of the experimental group III EUR 5.52 and to the animals of the experimental group II EUR 1.62. The latter had a market price close to that of the animals in the control group, but cost EUR 3.9 and EUR 5.74 less than the animals in experimental groups III and IV, respectively. In general, the market price of piglets raised on standardised liquid feed was EUR 3.90 to EUR 7.36 higher than animals fed unlimited dry and wet feed.

Table 5. Profitability of rearing piglets under different piglet feeding systems

Indicator	Groups			
	I (control)	II	III	IV
The cost of one piglet without value-added tax at the beginning of rearing, EUR	23.72	23.80	23.45	23.49
Cost of 1 piglet upon completion of rearing, EUR	37.41	37.56	37.83	37.84
The market value of 1 piglet without value-added tax, EUR	48.30	49.92	53.82	55.66
Income from growing 1 piglet, EUR	10.89	12.36	15.99	17.82
Profitability of growing 1 piglet, %	29.12	32.92	42.26	47.09

Source: own calculations.

Despite the lower cost of raising piglets of the first two groups, the income from their sale turned out to be significantly lower compared to animals that were fattened with liquid feeding, which was caused by their lower market value. Thus, the income from the sale of one pig in the control group amounted to EUR 10.89, while in the II group, it was EUR 1.47, in the III group by EUR 5.09, and in the IV group by EUR 6.92 higher compared to the control.

The highest profitability of rearing piglets was distinguished by indicators in the IV experimental group, 47.09%. While the profitability of production in the III group was lower by 4.84%, the II group by 14.18% and the control group by 17.98%, respectively.

Thus, under the liquid method of distributing fodder and feeding piglets to grow-out piglets, the cost of their growth-out was set to be higher by 0.73–1.15%, their market value was higher by 7.81–15.24%, and higher by 29.31–63.61 % income from the sale of 1 piglet of piglets and the profitability of raising one piglet was higher by 9.14–17.98% compared to unlimited feeding of piglets with dry and moistened fodder.

After analyzing the experimental results, we found that our conclusions regarding the increase in production costs when liquid feed was used do not agree with the reports [2, 21, 34] that talk about a positive effect of liquid feed on reducing the costs of pig production. On the contrary, we found that the cost price of piglets fed liquid and wet feed increased compared to piglets fed dry feed. This trend was explained by the higher cost of technical equipment for liquid feeding compared to the cost of technical equipment for dry feeding. At the same time, the traditional decrease in the cost price of pork due to cheaper liquid feed was not present in our experiment, as the cost of dry and liquid feed was the same.

The evaluation of piglet growth intensity using different feed types showed higher average daily gains in pigs consuming both liquid and wet feed compared to piglets consuming dry feed, which was consistent with the data [6, 7] that had previously indicated a similar effect, and not consistent with the conclusions [16] that claimed the absence of a reliable influence of feed type and moisture level on piglet growth. The use of liquid feeding systems in our study increased the average daily feed intake, which has already been confirmed by other reports [14] and indicates a higher interest in the pigs in liquid feed compared to dry feed. The report [31] of better intake of granulated dry feed moistened directly in the feeder compared to completely dry feed was not confirmed by our data. Contrary to previous reports [20] about the absence of a probable difference in feed conversion between groups of pigs receiving different types of feed based on moisture, in the current experiment we found, on the contrary, an improvement in feed conversion in piglets receiving liquid feed, which was also reported by other researchers in their experimental data [12].

The statement of scientists [9, 10, 21] about the deterioration of the sanitary condition of the pigsty when using wet feed could not be confirmed in our work, because the increase in the cost of preventive measures and the increase in the cost of treatment were observed in piglets that ate completely dry feed and dry feed followed by moistening in the feeder, and these indicators were lower in piglets fed liquid and wet feed. Usually, the deterioration of hygienic conditions in a pig house, where liquid feed was used, is detected when the technique of cleaning the equipment from feed residues is violated, so it is more likely to be a coincidence or a negligent attitude of the staff to their work [9, 21]. However, the level of preventive costs and the level of costs for the treatment of piglets is only an indirect sign characterising the sanitary and hygienic condition of the pig house, although they are often linked. The investigation of the effects of liquid feed on hygienic conditions in pig farming must therefore be examined in a further study.

CONCLUSIONS

The best performance indicators of the piglets were obtained with liquid portion feeding of the piglets from the feeder. With this feeding method, piglets had better average daily and absolute gains, higher weight at the end of rearing, but poorer preservation compared to their counterparts that consumed dry and wet feed.

When using a liquid feeding system with feed mix in containers designed for one room, piglet productivity proved to be lower compared to feeding with portioned feeding systems, but higher than that of animals fed dry feed.

When fed with moistened feed in feeders, the piglets were inferior to their liquid-fed peers in terms of dew intensity and feed conversion, but showed a better productivity level compared to their dry-fed peers.

For liquid feeding, compared with unlimited dry and wet feeding, average daily feed consumption, feed cost per 1 piglet, and feed cost for rearing 1 piglet were higher, but feed cost per 1 kg of growth and feed cost were lower.

For liquid feeding, higher cost per animal, cost of equipment depreciation and its share in piglet cost, cost of feed per animal and lower cost of preventive and therapeutic measures per animal and per unit of growth, feed cost and veterinary cost per kg of growth were found compared to unlimited dry and wet feeding.

For the liquid method of feed distribution and feeding piglets to nursery piglets, higher nursery costs, higher market value, higher income from the sale of 1 piglet, and higher profitability of raising a piglet were found compared to unlimited feeding of piglets with dry and wet feed.

REFERENCES

[1]Affentranger, P., Gerwig, C., Seewer, G.J.F., Schwrer, D., 1996, Growth and carcass characteristics as well as meat and fat quality of three types of pigs under different feeding regimes. Livestock Production Science, Vol. 45: 187–196. https://doi.org/10.1016/0301-6226(96)00011-5

[2]Bertocci, F., Mannino, G., 2023, Pearls before Swine: Plant-Derived Wastes to Produce Low-Cholesterol Meat from Farmed Pigs – A Bibliometric Analysis Combined to Meta-Analytic Studies. Foods, Vol. 12: 571. https://doi.org/10.3390/foods12030571

[3]Blavi, L., Solà-Oriol, D., Llonch, P., López-Vergé, S., Martín-Orúe, S.M., Pérez, J.F., 2021, Management and Feeding Strategies in Early Life to Increase Piglet Performance and Welfare around Weaning: A Review. Animals: an open access journal from MDPI, Vol. 11(2): 302. https://doi.org/10.3390/ani11020302

[4]Braude, R., Rowell, J., 1967, Comparison of dry and wet feeding of growing pigs. The Journal of Agricultural Science, Vol. 3(68): 325–330. https://doi.org/10.1017/S0021859600012818

[5]Buragohain, R., Bibeka, N.S., Arup, K.S., Bhuyan, R., Dowarah, R., Roychaudhury, R., Bora, A., 2019, Dry Vs. Liquid Feeding: Growth Performance, Nutrient Digestibility and Economics in Large White Yorkshire (LWY) Grower-Finisher Pigs. Int. J. Curr. Microbiol. App. Sci., Vol. 8(8): 2019–2025. https://doi.org/10.20546/ijcmas.2019.808.23

[6]Carcò, G., Gallo, L., Dalla Bona, M., Latorre, M.A., Fondevila, M., Schiavon, S., 2018, The influence of feeding behaviour on growth performance, carcass and meat characteristics of growing pigs. PLoS ONE, Vol. 13(10): e0205572. https://doi.org/10.1371/journal.pone.0205572

[7]Chae, B.J., 2000, Impacts of wet feeding of diets on growth and carcass traits in pigs. J. Appl. Anim. Res., Vol. 17: 81–96. https://doi.org/10.1080/09712119.2000.9706293

[8]Council Directive 86/609/EEC of 24 November 1986 on the approximation of laws, regulations and administrative provisions of the Member States regarding the protection of animals used for experimental and other scientific purposes.
[9]de Lange, C.F.M., Zhu, C.H., Niven, S.J., 2007, Effective application of enzymes and microbes to enhance the nutritional value of pig feed ingredients: a case for liquid feeding. Alltech symposium. May 22–23. Kentucky, Lexington, USA. 33–40. https://en.engormix.com/pig-industry/articles/effective-application-enzymes-microbes-t33761.htm Accessed on 08.05.2023.
[10]Ferrari, P., Ulrici, A., Barbari, M., 2021, Analysis of Housing Risk Factors for the Welfare of Lean and Heavy Pigs in a Sample of European Fattening Farms. Animals, Vol. 11(11): 3221. https://doi.org/10.3390/ani11113221
[11]Gaillard, C., Brossard. L., Dourmad. J.-Y., 2020, Review: Improvement of feed and nutrient efficiency in pig production through 2 precision feeding. Animal Feed Science and Technology, Vol. 268: 114611. https://doi.org/10.1016/j.anifeedsci.2020.114611
[12]Gonyou, H.W., Lou, Z., 2000, Effects of eating space and availability of water in feeders on productivity and eating behavior of grower/finisher pigs. J. Anim. Sci., Vol. 78: 865–870. https://doi.org/10.2527/2000.784865
[13]Han, I.K., Lee, J.H., Kim, J.H, Kim, Y.G., Kim, J.D., Paik, I.K., 2000, Application of Phase Feeding in Swine Production, Journal of Applied Animal Research, Vol. 17(1): 27–56, https://doi.org/10.1080/09712119.2000.9706290
[14]Hong, J.S., Jin, S.S., Jung, S.W., Fang, L.H., Kim, Y.Y., 2016, Evaluation of dry feeding and liquid feeding to lactating sows under high temperature environment. Journal of Animal Science and Technology. Vol. 58: 36. https://doi.org/10.1186/s40781-016-0118-0
[15]Hryshchenko. N.P., 2014, Udoskonalennia tekhnolohichnykh pryiomiv vidhodivli molodniaku svynei [Improvement of technological methods of fattening young pigs]. Abstract of Ph.D. dissertation. Kyiv.
http://repository.vsau.org/card.php?lang=uk&id=18798 Accessed on 08.05.2023.
[16]Isensee, P.K., Albers, S.E., Wichman, L.G., Thoma, A.L., Jang, Y.D., 2020, The effect of creep feed and diet complexity on growth performance in suckling and weaned pigs. Revista Colombiana De Ciencias Pecuarias, Vol. 33(3): 159–171. https://doi.org/10.17533/udea.rccp.v33n3a04
[17]Missotten, J.A.M., Michiels, J., Ovyn, A., De Smet, S., Dierick, N.A., 2015, Fermented liquid feed for weaned piglets: impact of sedimentation in the feed slurry on performance and gut parameters. Czech J. Anim. Sci., Vol. 60(5): 195–207. https://doi.org/10.17221/8169-CJAS
[18]Moran, C.A., 2001, Developments and benefits of liquid feeding through fermentation for the post-weaned pig. Dissertation. https://core.ac.uk/download/pdf/29818331.pdf Accessed on 08.05.2023.
[19]Mutua, F.K., Dewey, C., Arimi, S., 2012, A description of local pig feeding systems in village smallholder farms of Western Kenya. Trop Anim Health Prod., Vol. 44: 1157–1162. https://doi.org/10.1007/s11250-011-0052-6
[20]Mykhalko, O.G., 2020, Vidhodivelni yakosti svynei irlandskoho pokhodzhennia za riznoho typu hodivli [Feeding qualities of pigs of Irish origin under different types of feeding]. Visnyk Sumskoho natsionalnoho ahrarnoho universytetu. Seriia "Tvarynnytstvo" [Bulletin of the Sumy National Agrarian University. "Livestock" series], Vol. 3(42): 51–56. [in Ukrainian] https://doi.org/10.32845/bsnau.lvst.2020.3.9
[21]Mykhalko, O.G., 2021, Zalezhnist vidhodivelnykh yakostei svynei danskoho pokhodzhennia vid typu hodivli [The dependence of fattening qualities of pigs of Danish origin on the type of feeding]. Visnyk Sumskoho natsionalnoho ahrarnoho universytetu. Seriia "Tvarynnytstvo" [Bulletin of the Sumy National Agrarian University. "Livestock" series], Vol. 4(47): 99–107. [in Ukrainian] https://doi.org/10.32845/bsnau.lvst.2021.4.17
[22]Patience, J.F., Rossoni-Serão, M.C., Gutiérrez, N.A., 2015, A review of feed efficiency in swine: biology and application. J Animal Sci Biotechnol., Vol. 6: 33. https://doi.org/10.1186/s40104-015-0031-2
[23]Peng, L., Jiang, Z., 2020, Intelligent Automatic Pig Feeding System Based on PLC. Revista Científica de la Facultad de Ciencias Veterinarias, Vol. 30(5): 2479. https://link.gale.com/apps/doc/A634165257/IFME?u=anon~371a4a76&sid=googleScholar&xid=8ed21c3e Accessed on 08.05.2023.
[24]Pomar, C., Remus, A., 2019, Precision pig feeding: a breakthrough toward sustainability, Animal Frontiers, Vol. 9(2): 52–59. https://doi.org/10.1093/af/vfz006
[25]Pomar, C., Andretta, I., Remus, A., 2021, Feeding Strategies to Reduce Nutrient Losses and Improve the Sustainability of Growing Pigs. Frontiers in Veterinary Science. Vol. 8. https://doi.org/10.3389/fvets.2021.742220
[26]Povod, M.G., Mykhalko, O.G., Lykhach V.Ya., Hutyi, B.V., Povoznikov, M.H., Sokolenko, V.V., Verbelchuk, T.V., Ahunova, L.V., 2022, Vplyv zghodovuvannia vysokobilkovoho soniashnykovoho kontsentratu na zabiini yakosti svynei [The effect of feeding high-protein sunflower concentrate on the slaughter quality of pigs]. Visnyk Sumskoho natsionalnoho ahrarnoho universytetu. Seriia "Tvarynnytstvo" [Bulletin of the Sumy National Agrarian University. "Livestock" series], Vol. 2(49): 36–39. [in Ukrainian] https://doi.org/10.32845/bsnau.lvst.2022.2.6
[27]Povod M., Mykhalko O., Povoznikov M., Gutyj B., Koberniuk V., Shuplyk V., Ievstafiieva Y., Buchkovska V., 2022, Efficiency of using high-protein sunflower meal instead of soybean meal in feeding of growing

piglets. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(4): 595–602. https://managementjournal.usamv.ro/pdf/vol.22_4/volume_22_4_2022.pdf Accessed on 08.05.2023.

[28]Povod, M.G., Mykhalko, O.G., Verbelchuk, T.V., Shcherbyna, O.V., Tishchenko, O.S., 2021, Zalezhnist vidhodivelnykh yakostei svynei amerykanskoho pokhodzhennia vid riznoho typu hodivli [Dependence of fattening qualities of pigs of American origin on different types of feeding]. Visnyk Sumskoho natsionalnoho ahrarnoho universytetu. Seriia "Tvarynnytstvo" [Bulletin of the Sumy National Agrarian University. "Livestock" series], Vol. 4(47): 125–133. [in Ukrainian] https://doi.org/10.32845/bsnau.lvst.2021.4.21

[29]Schwarz, T., Turek, A., Nowicki, J., Tuz, R., Rudzki, B., Bartlewski, P.M., 2016, Production value and cost-effectiveness of pig fattening using liquid feeding or enzyme-supplemented dry mixes containing rye grain. Czech J. Anim. Sci., Vol. 61(8): 341–350. https://doi.org/10.17221/73/2015-CJAS

[30]Vázquez, N.A., Barragán, H.B., Aguila, N.C.V., Brenner, E.G., Dávila, F.S., Trejo, A.M., Ramírez, M.C., 2021, Effect of wet feeding of finishing pigs on production performance, carcass composition and meat quality. Rev Mex Cienc Pecu., Vol. 12(2): 370–385. https://doi.org/10.22319/rmcp.v12i2.5582

[31]Vdovichenko, Yu. V., Nechmilov, V. M., Povod, M. H., 2018. Produktyvnist porosiat za sukhoho, volohoho ta ridkoho typu hodivli na doroshchuvanni [Productivity of piglets in dry, wet and liquid type of feeding on rearing.]. Visnyk Poltavskoi derzhavnoi ahrarnoi akademii [Bulletin of the Poltava State Agrarian Academy], Vol. 3: 106–109. https://doi.org/10.31210/visnyk2018.03.15

[32]Xin, H., Wang, M., Xia, Z., Yu, B., He, J., Yu, J., Mao, X., Huang, Z., Luo, Y., Luo, J., Yan, H., Wang, H., Wang, Q., Zheng, P., Chen, D., 2021, Fermented Diet Liquid Feeding Improves Growth Performance and Intestinal Function of Pigs. Animals, Vol. 11: 1452. https://doi.org/10.3390/ani11051452

[33]Zhang, S., Wu, X., Han, D., Hou, Y., Tan, J., Kim, S.W., Li, D., Yin, Y., Wang, J., 2021, Pork production systems in China: a review of their development, challenges and prospects in green production. Front. Agr. Sci. Eng., Vol. 8(1): 15–24. https://doi.org/10.15302/J-FASE-2020377

[34]Zijlstra, R.T., Beltranena, E., 2022, Feeding coproducts to pigs to reduce feed cost and reach sustainable food production, Animal Frontiers, Vol. 12(6): 18–22. https://doi.org/10.1093/af/vfac067

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BENCHMARKING AS A TOOL FOR ASSESSING THE QUALITY OF RESEARCH MANAGEMENT OF STUDENTS IN AGRICULTURAL UNIVERSITIES OF UKRAINE

Olesia TOTSKA

Lesya Ukrainka Volyn National University, Department of Finance, 28 Vynnychenko Street, Lutsk, 43021, Ukraine, E-mail: Totska.Olesia@vnu.edu.ua

Corresponding author: Totska.Olesia@vnu.edu.ua

Abstract

The purpose of this article is to evaluate the quality of research management of students in agricultural universities of Ukraine using benchmarking. The external evaluation of agricultural higher education institutions (HEIs) of Ukraine was conducted on the basis of the data of the State Scientific Institution "Institute of education content modernization" and the Ministry of Education and Science of Ukraine regarding the results of the All-Ukrainian competition of student scientific papers in the fields of knowledge and specialties in 2019/2020 and 2020/2021 academic years. The leaders according to the results of participation in the II round of the competition in the analyzed period were 9 HEIs: Mykolaiv National Agrarian University (NAU), National University of Life and Environmental Sciences of Ukraine, Kharkiv Petro Vasylenko National Technical University of Agriculture, Lviv NAU, Sumy NAU, Vinnytsia NAU, Poltava State Agrarian Academy, Kharkiv NAU named after V. V. Dokuchayev, Polissia National University. They annually had more than 10 winners of the competition of various degrees. Other agricultural HEIs of Ukraine should focus on their indicators in order to improve the quality of research management of students. The obtained results enable agricultural universities not only to determine the leaders based on the number of works awarded with I, II or III degree diplomas in the All-Ukrainian competition, but also to evaluate, compared to them, their strengths and weaknesses; to get new ideas for research management of students; to plan further scientific activities taking into account the indicators of HEIs-leaders.

Key words: *benchmarking, agricultural universities, Ukraine, management quality, student research papers*

INTRODUCTION

Scientific and pedagogical workers in higher education institutions (hereinafter – HEIs), in addition to educational activities, must also engage in scientific activities, in particular, supervise the scientific work of students. But the quality of such work is different. The Ministry of Education and Science of Ukraine creates conditions for developing the intellectual potential of talented Ukrainian youth, supporting the scientific and creative work of students and cadets, stimulating their interest in research work, and mastering innovative technologies. For this purpose, the Ministry has introduced the All-Ukrainian competition of student scientific papers in the fields of knowledge and specialties, which takes place in two rounds: the first – in HEIs, the second – in basic HEIs. Students (cadets) who obtain a higher education with a bachelor's and master's degree in HEIs [11], including agrarian ones, can participate in the competition.

To analyze the quality of management of students' scientific work and its improvement in agricultural universities, it is possible to carry out an external evaluation of these HEIs using the benchmarking method. Note that Hyrylovska I. V. (2010) defines benchmarking as "improving oneself by learning from others". It allows you to answer the following questions:

– How do we work compared to others?
– What should we strive for?
– Who works best in certain areas?
– How do they manage it?
– How can we apply what others are using?
– How can we become better than the best? [3].

Benchmarking in agricultural research was used by the following scientists: Bedradina G. and Nezdoyminov S. (2021) – quality of services provided by rural tourism tour operators [1]; Ladyka V. and Lozynska I. (2019) – evaluation of the efficiency of the Lebedynska breed of dairy cows [5]; Sârbu O. (2015) – analysis of the evolution of agriculture in its many aspects, focusing on the concepts of rural development from the point of view of durability and multifunctionality [8]; Wolf C. A. *et al.* (2020) – indicators of profitability of dairy farms in the upper Midwest of the USA over time and depending on herd size [12]; Yasar A. (2023) – models of convolutional neural networks for varieties of bread wheat [13]; Zbanca A. *et al.* (2023) – economic and financial estimates of lavender cultivation [14]; Zbancă A. *et al.* (2018) – estimates and comparative economic analysis of berry cultivation in the Republic of Moldova [15].

The following researchers compared the performance indicators of agricultural HEIs: Knapczyk A. *et al.* (2018) – comparison of selected agricultural universities in Europe based on academic output [4]; Mehlhorn J. E. *et al.* (2015) – the level of entrepreneurial education in agricultural colleges and programs in Australia, New Zealand and the USA [6]; Totska O. (2023) – financing of scientific work in agricultural universities of Ukraine [10].

In addition, Totska O. L. (2022) investigated the financial aspects of the scientific activity of HEIs in the regions of Ukraine [9].

The purpose of this article is to evaluate the quality of management of the scientific work of students in agricultural universities of Ukraine using benchmarking.

MATERIALS AND METHODS

External evaluation of agricultural HEIs of Ukraine with the help of benchmarking will be conducted on the basis of the data of the State Scientific Institution “Institute of education content modernization” (2021) and the Ministry of Education and Science of Ukraine (2021) regarding the results of the All-Ukrainian competition of student scientific papers in the fields of knowledge and specialties in 2019/2020 and 2020/2021 academic years [2; 7]. The following two academic years are not included in the analysis due to the fact that the second round of the competition at basic HEIs was canceled due to reasons for ensuring the safety of the participants in the educational process, as there is a special situation in the country.

RESULTS AND DISCUSSIONS

The list of agricultural HEIs that had winners in the II round of the All-Ukrainian competition of student scientific works in the fields of knowledge and specialties in the 2019/2020 academic year is given in Table 1, in the 2020/2021 academic year – in Table 2, where in blue the data that are equal to or exceed the indicators of the previous year are highlighted, yellow – less than the previous ones.

As you can see, in the 2019/2020 academic year, the winners of the competition were students of 20 agricultural HEIs, in the 2020/2021 academic year – 21 HEIs.

18 agricultural HEIs had winners in both periods. Among them, 5 universities improved all indicators: Mykolayiv NAU, Sumy NAU, Polissia NU, Podillia State Agrarian and Technical University, Bila Tserkva NAU. The overall indicator was improved by 13 HEIs, and worsened by 5 HEIs. Separate partial indicators (the number of works awarded with I, II or III degree diplomas) improved in all HEIs, except for Stepan Gzhytskyi NU of Veterinary Medicine and Biotechnologies of Lviv. This is evidence that agricultural universities improve the quality of management of the scientific work of students.

The leaders in terms of the total number of works awarded with diplomas are clearly visible in Fig. 1.

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Table 1. Results of the participation of agricultural HEIs in the II round of the All-Ukrainian competition of student scientific works in the fields of knowledge and specialties in the 2019/2020 academic year

No	Name of the higher education institution	The number of works awarded with diplomas of the I degree	The number of works awarded with diplomas of the II degree	The number of works awarded with diplomas of the III degree	To-ge-ther
1	Mykolaiv NAU	6	17	34	57
2	National University of Life and Environmental Sciences of Ukraine (NULESU)	8	13	24	45
3	Kharkiv Petro Vasylenko NTU of Agriculture	6	13	17	36
4	Lviv NAU	5	7	23	35
5	Sumy NAU (including Hlukhiv Agrotechnical Institute named after S. A. Kovpak)	6	3	18	27
6	Vinnytsia NAU	1	4	12	17
7	Poltava State Agrarian Academy	4	8	4	16
8	Kharkiv NAU named after V. V. Dokuchayev	3	6	4	13
9	Polissia NU (Zhytomyr National Agroecological University)		3	8	11
10	Dmytro Motornyi Tavria State Agrotechnological University	1	5	5	11
11	Dnipro State Agrarian and Economic University	2	3	4	9
12	Stepan Gzhytskyi NU of Veterinary Medicine and Biotechnologies of Lviv		1	5	6
13	Podillia State Agrarian and Technical University	1	2	3	6
14	Bila Tserkva NAU	1	1	2	4
15	Separated subdivision NULESU "Berezhany Agrotechnical Institute"	1	1	2	4
16	Odesa SAU	1		3	4
17	Kherson SAU	3	1		4
18	Uman NU of Horticulture		2	1	3
19	Zhytomyr Agricultural Technical College			1	1
20	Ladyzhyn College of the Vinnytsia NAU			1	1
Together		49	90	171	310

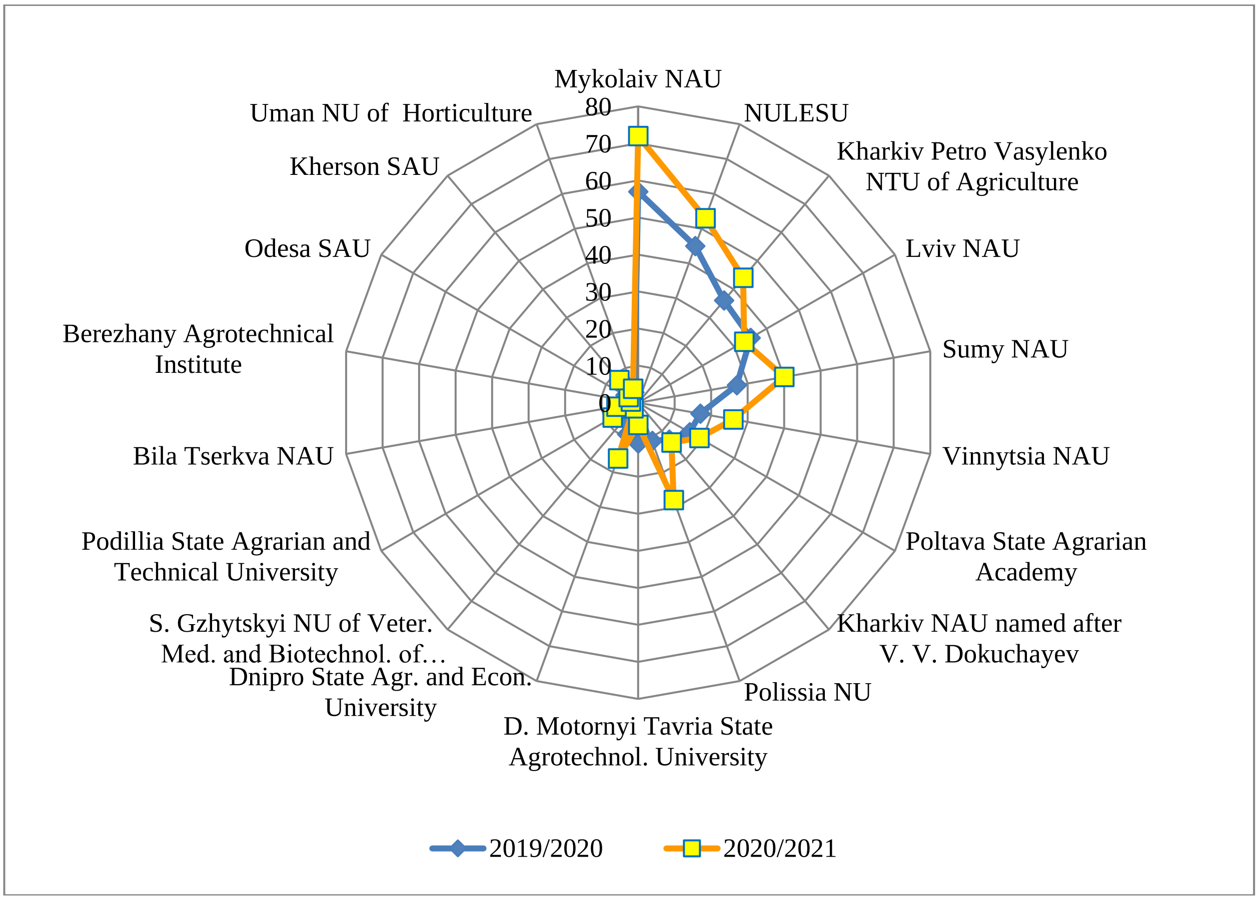
NAU – National Agrarian University, NTU – National Technical University, NU – National University, SAU – State Agrarian University.
Source: Formed by the author based on data from the State Scientific Institution "Institute of education content modernization" (2021) [2].

Table 2. Results of the participation of agricultural HEIs in the II round of the All-Ukrainian competition of student scientific works in the fields of knowledge and specialties in the 2020/2021 academic year

No	Name of the higher education institution	The number of works awarded with diplomas of the I degree	The number of works awarded with diplomas of the II degree	The number of works awarded with diplomas of the III degree	To-ge-ther
1	Mykolaiv NAU	7	21	44	72
2	NULESU	7	19	27	53
3	Kharkiv Petro Vasylenko NTU of Agriculture	6	12	26	44
4	Sumy NAU	9	11	20	40
5	Lviv NAU	2	4	27	33
6	Polissia NU (Zhytomyr National Agroecological University)	5	9	14	28
7	Vinnytsia NAU	3	1	22	26
8	Poltava State Agrarian Academy	1	6	12	19
9	Dnipro State Agrarian and Economic University	1	2	13	16
10	Kharkiv NAU named after V. V. Dokuchayev		5	9	14
11	Podillia State Agrarian and Technical University	1	3	4	8
12	Kherson State Agrarian and Economic University	1	4	3	8
13	Dmytro Motornyi Tavria State Agrotechnological University	2	2	2	6
14	Bila Tserkva NAU	1	3	2	6
15	Separated subdivision NULESU "Nizhyn Agrotechnical Institute"		4	2	6
16	Uman NU of Horticulture		2	2	4
17	Odesa NAU	1	1	1	3
18	Separated subdivision NULESU "Berezhany Agrotechnical Institute"	2			2

19	Stepan Gzhytskyi NU of Veterinary Medicine and Biotechnologies of Lviv			2	2
20	Separated structural unit "Berezhany Vocational College of the NULESU"			1	1
21	Kharkiv State Zooveterinary Academy			1	1
Together		49	109	234	392

NAU – National Agrarian University, NTU – National Technical University, NU – National University, SAU – State Agrarian University.
Source: Created by the author based on data from the Ministry of Education and Science of Ukraine (2021) [7].



NAU – National Agrarian University, NTU – National Technical University, NU – National University, SAU – State Agrarian University.
Fig. 1. Comparative diagram of agrarian HEIs of Ukraine according to the results of participation in the II round of the All-Ukrainian competition of student scientific papers in the fields of knowledge and specialties
Source: Author's development based on the data of Tables 1 and 2.

As we can see, the leaders according to the results of participation in the II round of the All-Ukrainian competition of student scientific works in the fields of knowledge and specialties in the analyzed period were 9 HEIs: Mykolaiv NAU, NULESU, Kharkiv Petro Vasylenko NTU of Agriculture, Lviv NAU, Sumy NAU, Vinnytsia NAU, Poltava State Agrarian Academy, Kharkiv NAU named after V. V. Dokuchayev, Polissia NU. They annually had more than 10 winners of various degrees. Other agricultural HEIs of Ukraine should focus on their indicators in order to improve the quality of management of the scientific work of students.

CONCLUSIONS

So, in order to become leaders among agricultural HEIs in Ukraine in terms of the quality of management of students' scientific work, it is necessary to prepare at least 10 winners of the All-Ukrainian competition. In addition, it is possible to study in which fields of knowledge and specialties they prepared their works, as well as to study the content of the works on the websites of the basic HEIs that conducted the second round of the competition.

The obtained results enable agricultural universities not only to determine the leaders based on the number of papers awarded with I, II or III degree diplomas in the All-Ukrainian competition of student research papers in the fields of knowledge and specialties, but also to evaluate, compared to them, their own strengths and weaknesses; to get new ideas for guiding students' scientific work; to plan further scientific activities taking into account the indicators of HEIs-leaders. The result of this will be the development of the intellectual potential of education seekers, stimulation of their interest in in-depth research work, and their mastery of innovative technologies. In the future, students can realize their scientific potential in further professional activities.

REFERENCES

[1]Bedradina, G., Nezdoyminov, S., 2021, Assessing the quality of services provided by rural tourism tour operators in overcoming the COVID-19 pandemic consequences in Ukraine, Scientific Papers. Series "Management, Economic Engineering in Agriculture and Rural Development", 21(3):189–198.

[2]Derzhavna naukova ustanova "Instytut modernizatsii zmistu osvity" [State Scientific Institution "Institute of education content modernization"], 2021, Pro pidsumky Vseukrainskoho konkursu studentskykh naukovykh robit z haluzei znan i spetsialnostei: Lyst IMZO vid 04.03.2021 № 22.1/10-482 [About the results of the All-Ukrainian competition of student research papers in the fields of knowledge and specialties: Letter of the IECM dated March 4, 2021 No. 22.1/10-482], https://drive.google.com/file/d/1HFuy_-M7ypkja2jvYPsGHBqBHLvRkcwh/view, Accessed on April 29, 2023. (In Ukrainian).

[3]Hyrylovska, I. V., 2010, Benchmarkinh yak nova skladova v otsiniuvanni yakosti pidhotovky kvalifikovanykh robitnykiv [Benchmarking as a new component in assessing the quality of training of skilled workers], X mizhnarodna naukovo-praktychna konferentsiia "Humanizm ta osvita" [X International Scientific and Practical Conference "Humanism and Education"], September 14–16, 2010, Vinnytsia, Ukraine, http://conf.vntu.edu.ua/humed/2010/txt/Gyrylovska.ph, Accessed on May 10, 2023. (In Ukrainian).

[4]Knapczyk, A., Francik, S., Wrobel, M., Mudryk, K., 2018, Comparison of selected agriculture universities in Europe on basis of analysis of academic output, 17th International Scientific Conference: Engineering for Rural Development, May 23–25, 2018, Jelgava, Latvia, pp. 727–732, doi: 10.22616/ERDev2018.17.N410.

[5]Ladyka, V., Lozynska, I., 2019, Benchmarking as the assessment method of efficiency the Lebedynska breed of dairy cows, Scientific Papers. Series "Management, Economic Engineering in Agriculture and Rural Development", 19(3):341–346.

[6]Mehlhorn, J. E., Bonney, L., Fraser, N., Miles, M. P., 2015, Benchmarking entrepreneurship education in U. S., Australian, and New Zealand university agriculture programs, Journal of Developmental Entrepreneurship, 20(3), doi: 10.1142/S108494671550017X.

[7]Ministerstvo osvity i nauky Ukrainy [Ministry of Education and Science of Ukraine], 2021, Pro pidsumky Vseukrainskoho konkursu studentskykh naukovykh robit z haluzei znan i spetsialnostei u 2020/2021 navchalnomu rotsi: Nakaz Ministerstva osvity i nauky Ukrainy vid 28.07.2021 r. № 865 [About the results of the All-Ukrainian competition of student research papers in the fields of knowledge and specialties in the 2020/2021 academic year: Order of the Ministry of Education and Science of Ukraine dated July 28, 2021 No. 865], https://mon.gov.ua/ua/npa/pro-pidsumki-vseukrayinskogo-konkursu-studentskih-naukovih-robit-z-galuzej-znan-i-specialnostej-u-20202021-navchalnomu-roci, Accessed on April 29, 2023. (In Ukrainian).

[8]Sârbu, O., 2015, Evolutionary benchmarks of agriculture and rural development in the Republic of Moldova, Scientific Papers. Series "Management, Economic Engineering in Agriculture and Rural Development", 15(2):327–336.

[9]Totska, O. L., 2022, Financial aspects of scientific activity of higher education institutions in the regions of Ukraine and strategy of commercialization of its results, Journal of Management & Technology [Revista Gestão & Tecnologia], Special Edition, 22:34–57.

[10]Totska, O., 2023, Financing of scientific work in agricultural universities of Ukraine, Scientific Papers. Series "Management, Economic Engineering in Agriculture and Rural Development", 23(1):829–836.

[11]Verkhovna Rada Ukrainy [Verkhovna Rada of Ukraine], 2017, Pro zatverdzhennia Polozhennia pro Vseukrainskyi konkurs studentskykh naukovykh robit z haluzei znan i spetsialnostei: Nakaz Ministerstva osvity i nauky Ukrainy vid 18.04.2017 № 605 [On the approval of the Regulation on the All-Ukrainian competition of student scientific works in the fields of knowledge and specialties: Order of the Ministry of Education and Science of Ukraine dated April 18, 2017 No. 605], https://zakon.rada.gov.ua/laws/show/en/z0620-

17?lang=uk#Text, Accessed on May 10, 2023. (In Ukrainian).
[12]Wolf, C. A., Black, J. R., Stephenson, M. W., 2020, Benchmarking upper Midwest dairy farm profitability, Agricultural Finance Review, 80(5):733–744, doi: 10.1108/AFR-02-2020-0022.
[13]Yasar, A., 2023, Benchmarking analysis of CNN models for bread wheat varieties, European Food Research and Technology, 249(3):749–758, doi: 10.1007/s00217-022-04172-y.
[14]Zbanca, A., Balan, I., Uratu, V., 2023, Investment management in the cultivation of lavender for the production of the essential oil, Scientific Papers. Series "Management, Economic Engineering in Agriculture and Rural Development", 23(1):887–894.
[15]Zbancă, A., Negritu, G., Stratan, D., 2018, Benchmarking of investment and their recoverability in the berries sector, Scientific Papers. Series "Management, Economic Engineering in Agriculture and Rural Development", 18(1):529–536.

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EFFICACY OF INSECTICIDES ON SEED ALFALFA IN THE SECOND YEAR OF LIFE

Andrii TYSHCHENKO, Olena TYSHCHENKO, Olena PILIARSKA, Tetiana MARCHENKO, Kateryna FUNDIRAT, Viktor SHARII, Vira KONOVALOVA

Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, 24 Mayatska doroga Street, sett. Khlybodarske, Odesa district, Odesa region, 67667, Ukraine, E-mails: tischenko_andriy@ukr.net, elenat1946@ukr.net, olena.piliarska@gmail.com, tmarchenko74@ukr.net, kfundirat@gmail.com, viktor.sharii@ukr.net, vera_konovalova_1990@ukr.net

Corresponding author: tischenko_andriy@ukr.net

Abstract

The aim of the study was to study the effectiveness and provide an economic assessment of the use of various insecticides against pests on alfalfa seed crops in the second year of the grass stand. The research was conducted during 2019–2021 at the experimental field of the Institute of Irrigated Agriculture of the NAAS. Treatment with insecticides was carried out: the first – in the phase of the beginning of budding, the second - before the beginning of flowering. The use of insecticides reduced the number of pests on the grass stand. The most effective in the fight against pests (with the exception of Aphis craccivora Koch) was the preparation with the active substances Chlorpyrifos, 500 g/l and Cypermethrin, 50 g/l and the consumption rate of 1.00 l/ha. The highest seed yield was obtained in the first treatment with an insecticide preparation with the active substances Chlorpyrifos, 500 g/l and Cypermethrin, 50 g/l and the consumption rate of 1.00 l/ha, and in the second treatment with preparations with the active substances Chlorantraniliprole, 200 g/l and Lambda-cyhalothrin, 50 g/l at a rate of 0.17 and 0.15 l/ha, respectively. When irrigated with this variant, the seed productivity was 635.2 kg/ha, which was higher than the control variant by 115.3 kg/ha. Under conditions of natural moisture, the seed yield was 452.5 kg/ha, and was higher than the control by 74.3 kg/ha. The lowest cost price of 0.66 €/ha and the highest conditional net profit of 1702.87 €/ha was obtained on the option: the first treatment - Chlorpyrifos, 500 g/l and Cypermethrin, 50 g/l, the second – Chlorantraniliprole, 200 g/l and Lambda-cyhalothrin, 50 g/l.

Key words: *alfalfa, seeds, insect, irrigation, economic efficiency*

INTRODUCTION

The main purpose of agriculture is the cultivation of crops, the production of food products for human consumption and domestic animals. With the increase in the population in the world and in order to meet its needs, it is necessary to increase the productivity of plants. However, unfortunately, there are pests that reduce the yield of crops intended for human consumption [6, 8, 20]. It is believed that the world produces enough agricultural products to meet the needs of the population, but the damage caused by pests of agricultural crops leads to severe economic consequences [11]. For example, in alfalfa, one of the factors that determines its seed productivity is the presence and number of insect pests. Depending on the different conditions that exist in each specific case on the grass stand, seed yield losses can reach 30–50%, and in some cases even more. However, the yield can be significantly increased by timely prevention of losses from diseases, pests and weeds [21]. Overall crop losses from insect damage have increased, largely due to changes in agricultural practices and growing technologies. Effective control of crop pests is very important to minimize damage and, as a result, economic losses, especially in recent years with an increase in the number of warm winters, which are favorable conditions for overwintering and development of pests [10]. The use of various agricultural methods, sometimes even with the use of resistant varieties, does not always provide the desired level of plant protection, and thus additional control measures in the form of the use of synthetic chemicals are necessary [2].

However, successful chemical control requires a great deal of knowledge about the effects of insecticides not only on the mortality and oviposition of insect pests (especially vectors), but also on the rate at which the insecticide affects their feeding behavior [9]. The phytosanitary condition of agrocenoses, despite the measures taken, does not improve due to the implementation of zero and minimal tillage, non-observance of crop rotation, unbalanced application of mineral fertilizers, insufficient and incorrect use of pesticides, non-observance of crop cultivation technologies [12]. According to Abate T. and Ampofo J.K.O. there is a lot of evidence that pest populations and their numbers are significantly higher in monoculture crops than in crop rotation, and growing two or more crops in the same field simultaneously increases the number of entomophages and generally keeps pest numbers low [1]. Agrotechnological methods, including site selection, crop rotation, choice of variety (hybrid) and seed material, timing and method of sowing, can to some extent reduce the number of some insect pests. For example, [4] reported a decrease in the number of aphids on wheat during early sowing. Aheer G.M. etc. [16] showed that the timing of sowing affects the population of aphids and other pests of leguminous crops. In addition, the number of pests can be regulated by the width of the row spacing and the density of plants, by weed control [18]. Forbes V.E. note that the use of mulch of straw and mustard reduces the population and number of insect pests of beans by 75% [3]. Moreover, studies have established that sloping areas and forest strips reduce wind speed, complicate the migration of aphids and, accordingly, affect their spread, which reduces the degree of damage to plants by viral diseases [13]. The fight against vector insects is a serious problem, so the choice of the most effective insecticides in the fight against them in different environments is always important [7]. Insects are a huge group of living organisms, but not many of them are harmful to crops. Insecticides used in crop production do not have a selective effect and, as a rule, destroy all entomofauna [5]. Alfalfa is often called the beginning of the food chain, because it supports not only domestic animals and humans, but also many species of wild animals and birds (more than 700) and more than 1000 species of arthropods, which are very important for the Earth's ecosystem [17, 24]. Alfalfa, grown for seeds, is severely damaged by pests, both omnivorous and specialized. The duration of cultivation and the length of the growing season, its high fodder value and the presence of conditions for overwintering pests contribute to their settlement and increase in their number [22]. According to Holoborodko S.P. etc. ecological and faunal studies conducted in the Left Bank of the Lower Dnieper of the Southern Steppe of Ukraine established and systematized the species composition of the alfalfa seed biocenosis and gave them an economic assessment. 157 types of pests [23] cause complex damage to all organs of seed alfalfa. Alfalfa crops are damaged at various stages of plant development – from seed germination to crop ripening. They cause the most tangible damage to seed crops, damaging generative organs and seeds. The species composition and number of pests of seed alfalfa are affected by weather conditions that develop during the growing season and during the wintering period. Therefore, the absence or untimely implementation of protection measures sharply reduce the seed yield and its sowing quality [21].

It should be noted that the pests that severely damage grassy alfalfa in the first year of seed use are the *Adelphocoris lineolatus Goeze.*, *Tychius flavus Berck*, *Bruchophagus roddi Guss.*, *Aphis craccivora Koch* and, in some years, the *Margaritia sticticalis*. Thus, the species composition of insect pests on grassy alfalfa, their number and harmfulness change significantly both in the zonal aspect and during the life of alfalfa in one field and during the growing season [14, 19]. However, despite the sufficient study of the species composition of entomofauna on seed alfalfa, thorough information on harmfulness, ecology and integrated protection of alfalfa crops both from a complex of pests and from individual species is extremely scarce in the literature.

The aim of the study was to study the effectiveness and provide an economic assessment of the use of various insecticides against pests on alfalfa seed crops in the second year of the grass stand.

MATERIALS AND METHODS

The research was conducted during 2019–2021 at the experimental field of the Institute of Irrigated Agriculture of the NAAS. In terms of soil and climate, it is located in the steppe zone, on the Ingulets irrigated massif.

The method of establishing a field experiment is split plots. Main areas (factor A) – moisture conditions (without irrigation (DL) and irrigation (I)); factor B – first treatment against pests: 1 – application of insecticide: 1 – Control (without treatment); 2 – Dimethoate, 400 g/l + Lambda-cyhalothrin, 50 g/l – at the rate of 1.00 l/ha + 0.15 l/ha; 3 – Imidacloprid, 200 g/l + Lambda-cyhalothrin, 50 g/l – at a rate of 0.20 l/ha + 0.15 l/ha; 4 – Chlorpyrifos, 500 g/l + Cypermethrin, 50 g/l – at a rate of 1.00 l/ha; 5 – Chlorantraniliprole, 200 g/l + Lambda-cyhalothrin, 50 g/l – at a rate of 0.17 l/ha + 0.15 l/ha.; factor C – second treatment against pests: 1 – Control (no treatment); 2 – Dimethoate, 400 g/l + Lambda-cyhalothrin, 50 g/l – at the rate of 1.00 l/ha + 0.15 l/ha; 3 – Imidacloprid, 200 g/l + Lambda-cyhalothrin, 50 g/l – at a rate of 0.20 l/ha + 0.15 l/ha; 4 – Chlorpyrifos, 500 g/l + Cypermethrin, 50 g/l – at a rate of 1.00 l/ha; 5 – Chlorantraniliprole, 200 g/l + Lambda-cyhalothrin, 50 g/l – at a rate of 0.17 l/ha + 0.15 l/ha. Wide-row sowing with 70 cm between rows. The area of the sowing area is 60 m^2, the area of the accounting area is 50 m^2, repetition three times. Alfalfa variety Elehiia. Herbaceous plant of the second year of life (spring sowing), seeds obtained from the first cutting. The species composition of harmful insects was detected during surveys, their number and the ratio of different stages were associated with the phases of plant development and weather conditions (temperature, air humidity and precipitation) using an entomological net (10 sweeps). The evaluation of the effectiveness of the terms and the frequency of chemical treatments was determined according to the method of S.O. Tribel and taking into account the economic thresholds of harmfulness [15]. Treatment with insecticides was carried out: the first – in the phase of the beginning of budding, the second - before the beginning of flowering with a mounted sprayer OH-600 with a consumption of working fluid of 250 l/ha. Statistical processing of experimental data was carried out by AgroSTAT, XLSTAT, Statistica (v. 13).

RESULTS AND DISCUSSIONS

It is known that a complex of pests is found on alfalfa crops, which differ in the features of development and the nature of plant damage. When examining the alfalfa grass stand in the second year of life (in the budding phase) before treatment with insecticides, the average number of pests was: *Adelphocoris lineolatus Goeze* – 3.0 specimens/10 sweeps of the net, *Aphis craccivora Koch* – 20.0, *Margaritia sticticalis* – 3,0, *Phytonomus transsylvanicus Petri*. (beetle/larva) – 1.0/3.0 and *Tychius flavus Berck* – 1.0 specimens/10 sweeps of the net (Table 1). It is known that the effectiveness of various insecticides against rodent and sucking pests is not the same, therefore there was a need to study the effectiveness of universal and binary mixtures of insecticides against a complex of pests.

The use of the first insecticide treatment reduced the number of pests on the grass: *Adelphocoris lineolatus Goeze* – by 70.0–93.3%, *Aphis craccivora Koch* – 93.0–97.5, Margaritia sticticalis – 80.0–96.7, *Phytonomus transsylvanicus Petri*. (beetle/larva) – 60.0–90.0/73.3–93.3 and *Tychius flavus Berck* – 76.0–94.0%, depending on the insecticide.

The use of the second insecticide treatment helped to reduce the number of pests on the grass stand. The most effective was the preparation with the active substances Chlorpyrifos, 500 g/l and Cypermethrin, 50 g/l and the consumption rate of 1.00 l/ha. This reduced the number of pests: *Adelphocoris lineolatus Goeze* – by 85.0–91.7%, *Aphis craccivora Koch* – 85.0–91.7, *Margaritia sticticalis* – 97.5, Tychius flavus Berck – 88.2–92.3 and *Bruchophagus roddi Guss* – by 92.5–96.7%, depending on the use of insecticide during the first treatment.

Table 1. The number of pests before and after the application of insecticides and their effectiveness on grass alfalfa seeds in the second year of life

Variant	The number of pests, specimens/10 sweeps of the net												Reduction of pest population, %					
	Adelphocoris lineolatus Goeze		*Aphis craccivora Koch*		*Margaritia sticticalis*		*Phytonomus transsylvanicus Petri.* (beetle/larva)		*Tychius flavus Berck*		*Bruchophagus roddi Guss*		*Adelphocoris lineolatus Goeze*	*Aphis craccivora Koch*	*Margaritia sticticalis*	*Phytonomus transsylvanicus Petri.* (beetle/larva)	*Tychius flavus Berck*	*Bruchophagus roddi Guss*
	before	after	before	after	before	after	before	after	before	after	before	after						
first insecticide treatment																		
1		4.0		25.0		4.0		2.0/5.0		2.0		0.0	-	-	-	-	-	-
2		0.9		0.5		0.6		0.4/0.8		0.3		0.0	70.0	97.5	80.0	60.0/73.3	70.0	-
3	3.0	0.5	20.0	1.4	3.0	0.4	1.0/3.0	0.2/0.4	1.0	0.2	0.0	0.0	83.3	93.0	86.7	80.0/86.7	80.0	-
4		0.2		0.8		0.1		0.1/0.2		0.1		0.0	93.3	96.0	96.7	90.0/93.3	90.0	-
5		0.3		1.0		0.3		0.2/0.3		0.2		0.0	90.0	95.0	90.0	80.0/90.0	80.0	-
second insecticide treatment																		
1-1		2.1		10.0		2.0		0.0/0.0		3.8		4.7	-	-	-	-	-	-
1-2		0.8		0.2		0.8		0.0/0.0		1.0		0.9	60.0	98.8	80.0	-	66.7	77.5
1-3	2.0	0.6	17.0	0.7	4.0	0.1	0.3/0.0	0.0/0.0	3.0	0.7	4.0	0.6	70.0	95.9	97.5	-	76.7	85.0
1-4		0.3		0.3		0.1		0.0/0.0		0.3		0.3	85.0	98.2	97.5	-	90.0	92.5
1-5		0.4		0.5		0.1		0.0/0.0		0.5		0.4	80.0	97.1	97.5	-	83.3	90.0
2-1		1.4		2.1		0.2		0.0/0.0		2.9		3.7	-	-	-	-	-	-
2-2		0.5		0.0		0.0		0.0/0.0		0.5		0.7	58.3	100.0	100.0	-	70.6	80.0
2-3	1.2	0.3	3.3	0.1	0.6	0.0	0.0/0.0	0.0/0.0	1.7	0.4	3.5	0.4	75.0	97.0	100.0	-	76.5	88.6
2-4		0.1		0.0		0.0		0.0/0.0		0.2		0.2	91.7	100.0	100.0	-	88.2	94.3
2-5		0.2		0.0		0.0		0.0/0.0		0.3		0.3	83.3	100.0	100.0	-	82.4	91.4
3-1		1.3		3.9		0.1		0.0/0.0		2.0		3.5	-	-	-	-	-	-
3-2		0.4		0.0		0.0		0.0/0.0		0.4		0.6	60.0	100.0	100.0	-	71.4	80.6
3-3	1.0	0.2	5.4	0.2	0.4	0.0	0.0/0.0	0.0/0.0	1.4	0.3	3.1	0.3	80.0	96.3	100.0	-	78.6	90.3
3-4		0.1		0.1		0.0		0.0/0.0		0.1		0.2	90.0	98.1	100.0	-	92.9	93.5
3-5		0.2		0.2		0.0		0.0/0.0		0.2		0.3	80.0	96.3	100.0	-	85.7	90.3
4-1		1.0		3.4		0.0		0.0/0.0		1.6		3.0	-	-	-	-	-	-
4-2		0.3		0.0		0.0		0.0/0.0		0.3		0.5	62.5	100.0	100.0	-	70.0	81.5
4-3	0.8	0.1	3.6	0.0	0.1	0.0	0.0/0.0	0.0/0.0	1.0	0.2	2.7	0.3	87.5	100.0	100.0	-	80.0	88.9
4-4		0.1		0.0		0.0		0.0/0.0		0.1		0.2	87.5	100.0	100.0	-	90.0	92.6
4-5		0.1		0.0		0.0		0.0/0.0		0.1		0.2	87.5	100.0	100.0	-	90.0	92.6
5-1		1.2		3.5		0.0		0.0/0.0		1.7		3.3	-	-	-	-	-	-
5-2		0.4		0.0		0.0		0.0/0.0		0.4		0.6	60.0	100.0	100.0	-	69.2	80.0
5-3	1.0	0.2	4.0	0.2	0.3	0.0	0.0/0.0	0.0/0.0	1.3	0.3	3.0	0.4	80.0	95.0	100.0	-	76.9	86.7
5-4		0.1		0.0		0.0		0.0/0.0		0.1		0.1	90.0	100.0	100.0	-	92.3	96.7
5-5		0.1		0.1		0.0		0.0/0.0		0.2		0.3	90.0	97.5	100.0	-	84.6	90.0

Source: Own results.

Usually, a low number of pests, or their absence, has a positive effect on the formation of generative organs and, accordingly, on the seed productivity of plants. However, the presence of this drug with the active substances Chlorpyrifos, 500 g/l and Cypermethrin, 50 g/l of fumigation action had a negative effect on the number of pollinating insects, which reduced the formation of beans and seeds in them and subsequently affected the productivity of plants. Under conditions of natural moisture, the seed yield was 330.5–390.6 kg/ha, and it was higher than the control by 10.5–12.4 kg/ha. Under irrigation, the seed productivity of alfalfa was 437.6–536.0 kg/ha, respectively, which was higher than the control variant by 13.0–16.1 kg/ha.

The highest seed yield was obtained in the first treatment with an insecticide preparation with the active substances Chlorpyrifos, 500 g/l and Cypermethrin, 50 g/l and the consumption rate of 1.00 l/ha, and in the second treatment with preparations with the active substances Chlorantraniliprole, 200 g/l and Lambda-cyhalothrin, 50 g/l at a rate of 0.17 and 0.15 l/ha, respectively. Under irrigation with this variant, the seed productivity was 635.2 kg/ha, which was higher than the control variant by 115.3 kg/ha. Under conditions of natural moisture, the seed yield was 452.5 kg/ha, and was higher than the control by 74.3 kg/ha (Table 2).

Table 2. Seed productivity and economic assessment of the second year alfalfa seed cultivation depending on moisture conditions and insecticide application

Variant	Seed yield, kg/ha	Saved yield, kg/ha	The cost of the obtained products, €/ha	Costs per 1 ha, €	The cost of 1 kg, €	Conditionally net profit, €/ha	Profitability level, %
DL 1-1	320.0	-	1,280.00	200.27	0.63	1,079.73	539
DL 1-2	357.7	37.7	1,430.80	224.57	0.63	1,206.23	537
DL 1-3	366.3	46.3	1,465.20	215.53	0.59	1,249.67	580
DL 1-4	330.5	10.5	1,322.00	223.17	0.68	1,098.83	492
DL 1-5	382.8	62.8	1,531.20	244.83	0.64	1,286.37	525
Average	**351.5**	**39.3**	**1,405.84**	**221.67**	**0.63**	**1,184.17**	**535**
DL 2-1	352.2	-	1,408.80	224.10	0.64	1,184.70	529
DL 2-2	393.7	41.5	1,574.80	248.70	0.63	1,326.10	533
DL 2-3	403.2	51.0	1,612.80	239.73	0.59	1,373.07	573
DL 2-4	363.7	11.5	1,454.80	247.10	0.68	1,207.70	489
DL 2-5	421.3	69.1	1,685.20	251.87	0.60	1,433.33	569
Average	**386.8**	**43.3**	**1,547.28**	**242.30**	**0.63**	**1,304.98**	**538**
DL 3-1	365.4	-	1,461.60	215.47	0.59	1,246.13	578
DL 3-2	408.6	43.2	1,634.40	240.17	0.59	1,394.23	581
DL 3-3	418.4	53.0	1,673.60	231.23	0.55	1,442.37	624
DL 3-4	377.4	12.0	1,509.60	238.43	0.63	1,271.17	533
DL 3-5	437.2	71.8	1,748.80	243.43	0.56	1,505.37	618
Average	**401.4**	**45.0**	**1,605.60**	**233.75**	**0.58**	**1,371.85**	**587**
DL 4-1	378.2	-	1,512.80	226.53	0.60	1,286.27	568
DL 4-2	422.9	44.7	1,691.60	251.30	0.59	1,440.30	573
DL 4-3	433.0	54.8	1,732.00	242.43	0.56	1,489.57	614
DL 4-4	390.6	12.4	1,562.40	249.57	0.64	1,312.83	526
DL 4-5	452.5	74.3	1,810.00	254.70	0.56	1,555.30	611
Average	**415.4**	**46.6**	**1,661.76**	**244.91**	**0.59**	**1,416.85**	**578**
DL 5-1	358.6	-	1,434.40	225.87	0.63	1,208.53	535
DL 5-2	400.9	42.3	1,603.60	250.43	0.62	1,353.17	540
DL 5-3	410.5	51.9	1,642.00	241.57	0.59	1,400.43	580
DL 5-4	370.3	11.7	1,481.20	248.77	0.67	1,232.43	495
DL 5-5	428.9	70.3	1,715.60	246.53	0.57	1,469.07	596
Average	**393.8**	**44.1**	**1,575.36**	**242.63**	**0.62**	**1,332.73**	**549**
Average	***389.8***	***43.6***	***1,559.17***	***237.05***	***0.61***	***1,322.12***	***558***
I 1-1	424.6	-	1,698.40	367.57	0.87	1,330.83	362
I 1-2	479.0	54.4	1,916.00	393.00	0.82	1,523.00	388
I 1-3	493.3	68.7	1,973.20	384.43	0.78	1,588.77	413
I 1-4	437.6	13.0	1,750.40	390.63	0.89	1,359.77	348
I 1-5	518.7	94.1	2,074.80	414.37	0.80	1,660.43	401
Average	**470.6**	**57.6**	**1,882.56**	**390.00**	**0.83**	**1,492.56**	**382**
I 2-1	474.4	-	1,897.60	392.63	0.83	1,504.97	383
I 2-2	535.2	60.8	2,140.80	418.57	0.78	1,722.23	411
I 2-3	551.2	76.8	2,204.80	410.13	0.74	1,794.67	438
I 2-4	489.0	14.6	1,956.00	415.83	0.85	1,540.17	370
I 2-5	579.7	105.3	2,318.80	423.03	0.73	1,895.77	448
Average	**525.9**	**64.4**	**2,103.60**	**412.04**	**0.79**	**1,691.56**	**410**
I 3-1	497.3	-	1,989.20	384.70	0.77	1,604.50	417
I 3-2	561.0	63.7	2,244.00	410.83	0.73	1,833.17	446
I 3-3	577.8	80.5	2,311.20	402.47	0.70	1,908.73	474
I 3-4	512.7	15.4	2,050.80	407.97	0.80	1,642.83	403
I 3-5	607.6	110.3	2,430.40	415.47	0.68	2,014.93	485
Average	**551.3**	**67.5**	**2,205.12**	**404.29**	**0.74**	**1,800.83**	**445**
I 4-1	519.9	-	2,079.60	396.50	0.76	1,683.10	424
I 4-2	586.5	66.6	2,346.00	422.83	0.72	1,923.17	455
I 4-3	604.0	84.1	2,416.00	414.47	0.69	2,001.53	483
I 4-4	536.0	16.1	2,144.00	419.77	0.78	1,724.23	411
I 4-5	635.2	115.3	2,540.80	427.53	0.67	2,113.27	494
Average	**576.3**	**70.5**	**2,305.28**	**416.22**	**0.73**	**1,889.06**	**453**
I 5-1	485.6	-	1,942.40	394.73	0.81	1,547.67	392
I 5-2	547.8	62.2	2,191.20	420.73	0.77	1,770.47	421
I 5-3	564.2	78.6	2,256.80	412.30	0.73	1,844.50	447
I 5-4	500.5	14.9	2,002.00	417.93	0.84	1,584.07	379
I 5-5	593.3	107.7	2,373.20	425.20	0.72	1,948.00	458
Average	**538.3**	**65.9**	**2,153.12**	**414.18**	**0.77**	**1,738.94**	**419**
Average	***532.5***	***65.2***	***2,129.94***	***407.35***	***0.77***	***1,722.59***	***422***

Assessment of the significance of partial differences

$LSD_{05}(A)$	61.318
$LSD_{05}(B)$	1.118
$LSD_{05}(C)$	0.719

Evaluation of the significance of the main effects

$LSD_{05}(A)$	7.080
$LSD_{05}(B)$	0.204
$LSD_{05}(C)$	0.131

Note: The cost of 1 kg of seeds – 4.00 €. Source: Own results.

At the first treatment, the highest cost price (0.81 €/kg) and the lowest conditional net profit (1,114.93 €/ha) was obtained on the control variant without the use of insecticides. The use of insecticides, during the first treatment, reduced the number of pests and increased the yield. In variant 2-1 of the experiment, by using insecticides (Dimethoate, 400 g/l + Lambda-cyhalothrin, 50 g/l), the cost price was 0.79 €/kg and the conditional net profit was 1,244.63 €/ha, on variant 3-1 (Imidacloprid, 200 g/l + Lambda-cyhalothrin, 50 g/l) – 0.74 €/kg and 1,320.20 €/ha, respectively, and on variant 5-1 (Chlorantraniliprole, 200 g/l + Lambda - cyhalothrin, 50 g/l) – 0.78 €/kg and 1,275.97 €/ha, respectively. The lowest cost price of 0.73 €/kg and the highest conditional net profit of 1,376.07 €/ha was obtained when using insecticides with the active substances Chlorpyrifos, 500 g/l and Cypermethrin, 50 g/l - at the rate of 1.00 l/ha (variant 4-1) (Table 3).

Table 3. Seed productivity and economic efficiency of alfalfa seed cultivation in the second year depending on the application of insecticides

Variant	Yield, kg/ha	Saved yield, kg/ha	The cost of the obtained products, €/ha	Costs per 1 ha, €	The cost of 1 kg, €	Conditionally net profit, €/ha	Profitability level, %
1-1	349.3	-	1,397.20	282.27	0.81	1,114.93	395
1-2	392.5	43.2	1,570.00	306.93	0.78	1,263.07	412
1-3	403.3	54.0	1,613.20	298.07	0.74	1,315.13	441
1-4	360.4	11.1	1,441.60	305.20	0.85	1,136.40	372
1-5	423.0	73.7	1,692.00	327.60	0.77	1,364.40	416
Average	**385.7**	**45,5**	**1,542.80**	**304.01**	**0.79**	**1,238.79**	**407**
2-1	387.8	-	1,551.20	306.57	0.79	1,244.63	406
2-2	435.8	48.0	1,743.20	331.57	0.76	1,411.63	426
2-3	447.8	60.0	1,791.20	322.83	0.72	1,468.37	455
2-4	400.1	12.3	1,600.40	329.60	0.82	1,270.80	386
2-5	469.6	81.8	1,878.40	335.23	0.71	1,543.17	460
Average	**428.2**	**50.5**	**1,712.88**	**325.16**	**0.76**	**1,387.72**	**426**
3-1	404.6	-	1,618.40	298.20	0.74	1,320.20	443
3-2	454.8	50.2	1,819.20	323.33	0.71	1,495.87	463
3-3	467.2	62.6	1,868.80	314.67	0.67	1,554.13	494
3-4	417.5	12.9	1,670.00	321.23	0.77	1,348.77	420
3-5	490.1	85.5	1,960.40	327.10	0.67	1,633.30	499
Average	**446.8**	**52.8**	**1,787.36**	**316.91**	**0.71**	**1,470.45**	**464**
4-1	421.4	-	1,685.60	309.53	0.73	1,376.07	445
4-2	473.6	52.2	1,894.40	334.87	0.71	1,559.53	466
4-3	486.6	65.2	1,946.40	326.10	0.67	1,620.30	497
4-4	434.7	13.3	1,738.80	332.63	0.77	1,406.17	423
4-5	510.4	89.0	2,041.60	338.73	0.66	1,702.87	503
Average	**465.3**	**54.9**	**1,861.36**	**328.37**	**0.71**	**1,532.99**	**467**
5-1	396.1	-	1,584.40	308.43	0.78	1,275.97	414
5-2	445.1	49.0	1,780.40	333.50	0.75	1,446.90	434
5-3	457.3	61.2	1,829.20	324.80	0.71	1,504.40	463
5-4	408.6	12.5	1,634.40	331.43	0.81	1,302.97	393
5-5	479.6	83.5	1,918.40	336.00	0.70	1,582.40	471
Average	**437.3**	**51.6**	**1,749.36**	**326.83**	**0.75**	**1,422.53**	**435**
Average	***432.7***	***51.1***	***1,730.75***	***320.26***	***0.74***	***1,410.49***	***440***

Note: The cost of 1 kg of seeds – 4.00 €.
Source: Own results

During the second insecticide treatment, the highest cost price of 0.85 €/kg was obtained on variant 1-4 (Chlorpyrifos, 500 g/l and Cypermethrin, 50 g/l), and the lowest conditional net profit of €1,114.93/ha was obtained on the control (variant 1-1, without the use of insecticides). The lowest cost price of 0.74 €/kg was obtained on variant 1-3 (Imidacloprid, 200 g/l + Lambda-cyhalothrin, 50 g/l), and the highest conditional net profit of 1,364.40 €/ha – by using insecticides with a.s. Chlorantraniliprole, 200 g/l and Lambda-cyhalothrin, 50 g/l (variant 1-5).

The lowest cost of 0.66 €/ha and the highest conditional net profit of 1,702.87 €/ha was obtained on variant 4-5: the first treatment -

Chlorpyrifos, 500 g/l and Cypermethrin, 50 g/l, the second – Chlorantraniliprole, 200 g/l and Lambda-cyhalothrin, 50 g/l.

CONCLUSIONS

The most effective in the fight against pests (with the exception of *Aphis craccivora Koch*) was the preparation with the active substances Chlorpyrifos, 500 g/l and Cypermethrin, 50 g/l and the consumption rate of 1.00 l/ha. But the presence of fumigation effect of this drug negatively affected the number of pollinating insects, which reduced the formation of beans and seeds in them and subsequently affected the productivity of plants, so this drug should not be used before flowering (second treatment). The highest seed yield of 635.2 kg/ha under irrigation and 452.5 kg/ha under natural moisture conditions was obtained in the variant with the first treatment with an insecticide preparation with active substances Chlorpyrifos, 500 g/l and Cypermethrin, 50 g/l, and with the second treatment with preparations with active substances Chlorantraniliprole, 200 g/l and Lambda-cyhalothrin, 50 g/l.

The lowest cost price of 0.66 €/ha and the highest conditional net profit of 1,702.87 €/ha was obtained on the variant: the first treatment – Chlorpyrifos, 500 g/l and Cypermethrin, 50 g/l, the second - Chlorantraniliprole, 200 g/l and Lambda-cyhalothrin, 50 g/l.

REFERENCES

[1]Abate, T., Ampofo, J.K.O., 1996, Insect Pests of Beans in Africa: Their Ecology and Management. Annual Review of Entomology. 41:45–73. http://dx.doi.org/10.1146/annurev.en.41.010196.000401

[2]Dhungana, S.K., Adhikari, B., Adhikari, A., Kim, I., Kim, J., Shin, D., 2020, Comparative effect of different insecticides on the growth and yield of soybeans. Plant Protect. Sci. 56:206–213. https://doi.org/10.17221/77/2019-PPS

[3]Forbes, V.E., Hommen, U., Thorbek, P., Heimbach, F., Van den Brink, P.J., Wogram, J., Thulke, H.H., Grimm, V., 2009, Ecological Models in Support of Regulatory Risk Assessments of Pesticides: Developing a Strategy for the Future. Integrated Environmental Assessment and Management. 5:167–172. doi: 10.1897/ieam_2008-029.1

[4]Gilbertson, R.L., Rojas, M., Natwick, E., 2011, Development of Integrated Pest Management (IPM) strategies for whitefly (Bemisia tabaci)-transmissible geminiviruses. In The Whitefly, Bemisia tabaci (Homoptera: Aleyrodidae) Interaction with Geminivirus-Infected Host Plants. / Ed. by W.M.O. Thompson. Springer: Dordrecht, The Netherlands. 323–356. doi: 10.1007/978-94-007-1524-0_12

[5]Godfrey, L.D., Goodell, P.B., Natwick, E.T., Haviland, D.R., Barlow, V.M., 2001, UC IPM Pest Management Guidelines: Cotton: Insects and Mites. UC ANR Publ., 3444:19–71.

[6]Katungi, E., Farrow, A., Chianu, J., Sperling, L., Beebe, S., 2009, Common Bean in Eastern and Southern Africa: A Situation and Outlook Analysis. International Centre for Tropical Agriculture. 61.

[7]Maluta, N.K.P., Lopes, J.R.S., Fiallo-Olivé, E., Navas-Castillo, J., Lourenção, A.L., 2020, Foliar Spraying of Tomato Plants with Systemic Insecticides: Effects on Feeding Behavior, Mortality and Oviposition of *Bemisia tabaci* (Hemiptera: Aleyrodidae) and Inoculation Efficiency of Tomato Chlorosis Virus. Insects, 11(9):559. doi:10.3390/insects11090559

[8]Munyasa, A.J., Chemining'wa, G.N., Kimani, P.M., Mburu, M.W., Nderitu, J.H., 2013, Evaluation of Drought Tolerance Mechanisms in Mesoamerican Dry Bean Genotypes. University of Nairobi, Nairobi. 191.

[9]Ochilo, W.N., Nyamasyo G.H., 2011, Pest Status of Bean Stem Maggot (*Ophiomyia* spp.) and Black Bean Aphid (*Aphis fabae*) in Taita District, Kenya. Tropical and Subtropical Agro Ecosystems, 13(1):91–97.

[10]Peter, K.H., Swella, G.B., Mushobozy, D.M., 2009, Effect of Plant Populations on the Incidence of Bean Stem Maggot (*Ophiomyia* spp.) in Common Bean Intercropped with Maize. Plant Protection Science, 45(4):148–155. doi: 10.17221/19/2009-PPS

[11]Spiridonov, Yu.Ya., 2017, Technology of cultivation of spring durum wheat with the use of preparations Secateurs turbo, Bariton, Falcon, Nagro and others. Agrarian scientific journal, 3:30–36. doi: https://doi.org/10.28983/asj.v0i3.47

[12]Spiridonov, Yu.Ya., 2018, Peculiarities of the influence of plant protection chemicals on the dynamics of nutrients in plants, their chemical composition and development conditions. Agrarian scientific journal, 10:37–40. https://doi.org/10.28983/asj.v0i10.606.

[13]Stoddard, F.L., Nicholas, A.H., Rubiales, D., Thomas, J., Villegas-Fernández, A.M., 2010, Integrated Pest Management in Faba Bean. Field Crops Research, 115:308–318. http://dx.doi.org/10.1016/j.fcr.2009.07.002

[14]Strizhkov, N.I., 2017, Integrated technology for the protection of field crops from diseases, pests and weeds based on biological and chemical methods. Saratov. 56.

[15]Tribel, S.O., 2001, Test methods and application of pesticides. / Ed. by S.O. Tribela. K. The world. 448.

[16]Tyshchenko, A.V., Tyshchenko, O.D., Kuts, G.M., Piliarska, O.O., Halchenko, N.M., 2021, Anti-pest

protection of two-year old alfalfa grown for seeds. Breeding and seed production, 119:170-180. https://doi.org/10.30835/2413-7510.2021.237163

[17]Tyshchenko, A.V., Tyshchenko, O.D., Lyuta, Yu.O., Piliarska, O.O., 2021, Adaptability is an important feature in plant selection. Irrigated agriculture, 75:101-109. doi: https://doi.org/10.32848/0135-2369.2021.75.19

[18]Tyshchenko, A.V., Tyshchenko, O.D., Piliarska, O.O., Kuts, H.M., Halchenko, N.M., 2021, Seed productivity of alfalfa in the first year of life depending on pest control measures. Agrarian innovations, 6:57-67. https://doi.org/10.32848/agrar.innov.2021.6.12

[19]Tyshchenko, O., Tyshchenko, A., Piliarska, O., Biliaeva, I., Kuts, H., Lykhovyd, P., Halchenko, N., 2020, Seed productivity of alfalfa varieties depending on the conditions of humidification and growth regulators in the Southern Steppe of Ukraine. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 20(4):551-562.

[20]Tyshchenko, O., Tyshchenko, A., Piliarska, O., Kuts, H., Lykhovyd, P., 2020, Evaluation of drought tolerance in alfalfa (*Medicago sativa*) genotypes in the conditions of osmotic stress. AgroLife Scientific Journal, 9(2):353-358.

[21]Vigera, S.M., 2002, Protection of seed alfalfa crops under conditions of biological and intensive farming. Plant protection, 2:6–8.

[22]Vigera, S.M., Ruban, M.B., 1997, Alfalfa seed. Agrobiological system of protection against harmful organisms. Protection of plants, 5:24–25.

[23]Vozhehova, R., Tyshchenko, A., Tyshchenko, O., Dymov, O., Piliarska, O., Lykhovyd, P., 2021, Evaluation of breeding indices for drought tolerance in alfalfa (*Medicago*) genotypes. Scientific Papers. Series A. Agronomy, LXIV(2):435-444.

[24]Vozhehova, R., Tyshchenko, A., Tyshchenko, O., Piliarska, O., Konovalova, V., Sharii, V., Fundirat, K., 2022, Economic feasibility of application of bacterial and fungal drugs on seed-used alfalfa. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(4):827-834.

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ECONOMIC EFFICIENCY OF GROWING ALFALFA FOR SEEDS BY INOCULATION WITH BACTERIAL PREPARATIONS

Andrii TYSHCHENKO, Olena TYSHCHENKO, Olena PILIARSKA, Tetiana MARCHENKO, Kateryna FUNDIRAT, Viktor SHARII, Vira KONOVALOVA

Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, 24 Mayatskadoroga Street, sett. Khlybodarske, Odesa district, Odesa region, 67667, Ukraine, E-mails: tischenko_andriy@ukr.net, elenat1946@ukr.net, olena.piliarska@gmail.com, tmarchenko74@ukr.net, kfundirat@gmail.com, viktor.sharii@ukr.net, vera_konovalova_1990@ukr.net

Corresponding author: tischenko_andriy@ukr.net

Abstract

Research on the impact of seed inoculation with various bacterial preparations on seed productivity of alfalfa varieties, symbiotic nitrogen accumulation, and root system strength was conducted in 2018–2020 at the experimental field of the Institute of Irrigated Agriculture of the National Academy of Sciences of Ukraine. The economic efficiency of growing alfalfa for seeds under inoculation with bacterial preparations was also calculated. The highest seed productivity was obtained after inoculation with a cyanobacterial drug: 456.4 kg/ha in the Unitro variety and 361.1 kg/ha in the Zoryana variety, at a cost of 0.56 €/kg and 0.70 €/kg and conditional net profit of 1571.93 €/ha and 1190.73 €/ha, respectively. The highest root mass (5.76 and 5.80 t/ha) and nitrogen fixation (222 and 228 kg/ha) were noted in the Unitro and Zoryana varieties, respectively, when the cyanobacterial preparation was used. The greatest profit from growing alfalfa for seeds in crop rotation was obtained by inoculation with a cyanobacterial preparation in the Unitro variety 1,894.40 €/ha and in the Zoryana variety 1,516.43 €/ha.

Key words**:** *alfalfa, inoculation, nitrogen fixation, root mass, economic efficiency*

INTRODUCTION

Alfalfa is a perennial fodder crop that is grown all over the world and is characterized by high biomass productivity, nutritional value and high protein content among fodder legumes. It helps to increase soil fertility [13, 30], protects soils from wind and water erosion [29, 33]. In addition, atmospheric nitrogen fixation makes it an indispensable precursor for other crops. However, the lack of a sufficient amount of seed material, due to the low yield of seeds, does not allow expanding the sown areas of this valuable fodder crop [34].

Increasing the yield of alfalfa seeds is a complex and extremely important problem that can be solved by creating high-yielding varieties and developing improved agricultural technology. Its essence consists in the addition or strengthening of conventional agrotechnical techniques that positively affect the processes of growth and development, the formation of reproductive organs and increase the yield of seeds [11, 32]. Only by creating optimal conditions for the development and growth of plants is it possible to obtain high and stable seed yields.

The root system of crops solves an important task for plants. The powerful architecture of the root system of crops is a guarantee of plant resistance to adverse stress factors, improvement of nutrition, moisture supply and their high yield [9, 26]. This especially applies to alfalfa, which accumulates a large amount of root residues in the soil, improving its meliorational state, humus-forming processes and is a good precursor for the following crops.

The development of the root system depends on many factors, but the main one is the degree of provision of the soil with nutrients. Important factors affecting the development of the root system are moisture availability and nutrient composition of the soil. Low availability of nutrients or moisture reduces or stops cell division and elongation, which leads to the arrest of primary root growth [16, 25].

Plant roots live in close contact with a large number of species of bacteria and fungi in the rhizosphere [2]. Some species, producing substances (ethylene, auxins and cytokinins) can influence the growth and development of roots [3, 23]. Auxin and ethylene regulate the processes that change the architecture of the root system - the elongation of the primary root [1, 28] and the formation of additional root hairs [22].

Bacterial preparations affect the formation of the root structure, stimulating the formation of root hairs and strengthening the branching of lateral roots [21], which increases the surface area [6] and is usually associated with the increased ability of plants to respond to complex environmental conditions [17, 31]. In addition, root structures such as cluster roots [12], nitrogen-fixing nodules [5, 19] and mycorrhizae [2, 27] contribute to the improvement of moisture supply, the transfer of unavailable forms of nutrients into available ones and their absorption by the plant root system. Stimulation of root growth is one of the main markers used to measure the positive effect of bacteria that promote plant growth [11].

The content of organic substances, macro- and microelements, water, oxygen, as well as pH, temperature, and the presence of pathogenic microorganisms in the soil [4, 18] significantly affect the number, physiological and metabolic state of microorganisms. Mineral fertilizers are one of the factors inhibiting the effectiveness of soil microorganisms [8, 24, 35].

Therefore, studying the effectiveness of the inoculation of seeds with bacterial fertilizers to increase the volume of the root mass, activate symbiotic processes, increase the resistance of plants to environmental stress factors is a very important condition for increasing the seed productivity of alfalfa. Bacterial preparations that improve the growth and development of plants, stimulate an increase in yield, accumulation of organic matter (in the form of root residues) and symbiotic nitrogen, while reducing the application of mineral fertilizers for subsequent crops without polluting the environment is very important.

Study of the effect of bacterial preparations on seed productivity, nitrogen-fixing capacity, accumulation of root mass in the second year of alfalfa life and give an economic assessment of the effectiveness of their use.

MATERIALS AND METHODS

Research was conducted at the experimental field of the Institute of Irrigated Agriculture of the NAAS, located in the steppe zone of the Ingulets irrigated massif, during 2018–2020.

The method of establishing a field experiment is split plots. The main areas (factor A) are alfalfa varieties (Unitro and Zoryana); sub-plots (factor B) – treatment of seeds with bacterial preparations at the rate of 1% of the weight of seeds without dilution with water on the day of sowing: 1 – control (no treatment); 2 – Rhizobophyte (on a specific highly effective strain of nodule bacteria 404b); 3 - Complex of biological preparations (CBP) - includes symbiotic nitrogen-fixing, phosphate-mobilizing and bioprotective microorganisms with the functional properties of biological preparations: Rhizobophyte, Phosphoenterin and Biopolicid (1:1:1), which are characterized by a complex effect on leguminous crops; 4 – Cyanobacterial consortium (CBC) homogenate based on growth-stimulating cyanobacteria strain 144 and nodule bacteria strain 404b with primary and secondary metabolites; 5 – Cyanobacterial drug (CBP) drug based on growth-stimulating cyanobacteria strain 144 and nodule bacteria strain 404^b with primary metabolites. Sowing period is early spring. Wide-row sowing with 70 cm row spacing. The area of the sowing area is 60 m^2, the area of the accounting area is 40 m^2, repetition 3 times.

Correlation analysis was performed using Microsoft ® Excel 2013/XLSTAT © -Pro (v. 2015.6.01.23953, 2015, Addinsoft, Inc., Brooklyn, New York, USA). AgroSTAT, Statistica (v. 13), carried out statistical processing of experimental data.

RESULTS AND DISCUSSIONS

The obtained experimental data indicate a different reaction of alfalfa varieties to biological preparations. Seed yield when monoinoculated with nodule bacteria (Rhizobophyte) was 16.0–20.0% higher compared to the control and amounted to 271.8 kg/ha in the Zoryana variety and 361.9 kg/ha in the Unitro variety. However, the effect of the monoculture (Rhizobophyte) on seed productivity differed significantly and was lower than the three-component associations (CBP) based on Rhizobophyte, Phosphoenterin and Biopolycide with a seed yield of 303.6 kg/ha (Zoryana variety) and 398.8 kg/ha (Unitro variety) (Table 1).

The data of some authors indicate the stimulation of plant growth and development under the influence of artificial consortia of cyanobacteria and various species of *Rhizobium*, which helps to increase their yield [10, 11, 15, 20].

The analysis of the obtained results shows that the use of cyanorhizobial consortia contributes to a sharp increase in seed productivity compared to both control and monoinoculation.

Table 1. Economic assessment of growing alfalfa seeds in the second year of life depending on the variety and the use of bacterial preparations (2018–2020)

Variety (factor A)	Application of bacterial preparations (factor B)	Seed yield, kg/ha	The cost of the obtained products, €/ha	Costs per 1 ha, €	Cost of 1 kg, €	Conditionally net profit, €/ha	Profitability level, %
Unitro	Control 1 (no inoculation)	307.5	1,230.00	243.10	0.79	986.90	406
	Rhizobophyte	369.1	1,476.40	247.47	0.67	1,228.93	497
	CBP	398.8	1,595.20	249.60	0.63	1,345.60	539
	CBC	424.6	1,698.40	251.47	0.59	1,446.93	575
	CBP	456.4	1,825.60	253.67	0.56	1,571.93	620
	average	**391.3**	**1,565.12**	**249.06**	**0.65**	**1,316.06**	**527**
Zoryana	Control 1 (no inoculation)	234.1	936.40	243.10	1.04	693.30	285
	Rhizobophyte	271.8	1,087.20	247.47	0.91	839.73	339
	CBP	303.6	1,214.40	249.60	0.82	964.80	387
	CBC	337.3	1,349.20	251.47	0.75	1,097.73	437
	CBP	361.1	1,444.40	253.67	0.70	1,190.73	469
	average	**301.6**	**1,206.32**	**249.06**	**0.84**	**957.26**	**383**

Assessment of the significance of partial differences

LSD_{05}	A	23.76
LSD_{05}	B	18.61

Evaluation of the significance of the main effects

LSD_{05}	A	10.63
LSD_{05}	B	13.16

Note: The cost of 1 kg of seeds is €4.00/kg
Source: Own results.

It should be noted that a strongly pronounced stimulatory effect was noted in associations with cyanobacteria CBC and CBP. A high effect was shown by the cyanorhizobial consortium (CBC) (337.3; 424.6 kg/ha), but the maximum result was obtained in the variant with the use of CBP 361.1 and 456.4 kg/ha in Zoryana and Unitro varieties, respectively.

During the years of research, the cost price of 1 kg of seeds in the second year of life of Unitro and Zoryana alfalfa plants when grown in conditions of natural moisture significantly depended on the weather conditions of the year, and above all, the amount of atmospheric precipitation that fell during the growing season, and amounted to 0.56−0.79 €/kg and 0.70−1.04 €/kg, respectively.

The use of bacterial preparations helped to increase the productivity of the culture and reduce its cost. Thus, when treating seeds with Rhizobophyte, CBP and CBC, the cost price in the Unitro variety was 0.67, 0.63 and 0.59 €/kg and 0.91, 0.82 and 0.75 €/kg in the Zoryana variety, while in the control version it was 0.79 and 1.04 €/kg, respectively. The maximum yield and the lowest cost were obtained for the inoculation of CBP seeds - 0.56 €/kg in the Unitro variety and 0.70 €/kg in the Zoryana variety.

Conditionally net profit according to the field experiment options depended on the amount of production costs for growing the seeds of the crop and the amount of the obtained harvest. In the control version, the conditional net profit of the Unitro variety was €986.90 and the Zoryana variety was €693.30/ha. Inoculation of seeds with bacterial preparations contributed to obtaining a higher conditional net profit - 1,228.93–1,571.93 €/ha in the Unitro variety and 839.73–1,190.73 €/ha in the Zoryana variety.

Our studies have shown that together with the increase in seed yield, there are also changes in the parameters of accumulation of air-dry root mass and nitrogen fixation. The accumulation of dry mass of the roots according to the experimental variants also has significant fluctuations depending on the use of bacterial preparations. The highest mass was observed in Zoryana and Unitro varieties when using the cyanobacterial preparation (CBP) 5.76 and 5.80 t/ha, respectively, while it was 4.52 and 4.50 t/ha in the control variants (Table 2).

An increase in the activity of nitrogen fixation processes was noted when treated with the same preparations of CBC and CBP, but the highest nitrogen fixation was noted when using a cyanobacterial preparation (CBP), which amounted to 222 and 228 kg/ha in the varieties Unitro and Zoryana, respectively, with low indicators in the control variant of 162 kg /ha (Unitro) and 168 kg/ha (Zoryana).

But we not only determined the mass of the root system and the accumulation of symbiotic nitrogen in the soil by alfalfa plants after two years of use, but also tried to translate this nitrogen into monetary units, that is, what can be saved in the form of organic and mineral fertilizers for the next crop. The cost of symbiotic nitrogen was calculated based on the weighted average market price of ammonium nitrate. Using the humification coefficient for the root mass of alfalfa (18%), the amount of humus input after two years of alfalfa use was calculated [7]. The calculations did not take into account root secretions, which make up to 10% of the root mass, as well as annually dead root hairs up to 20% of the root mass [14]. Losses of nitrogen from fertilizers that were not absorbed by the plants of the next crop were also not taken into account, because symbiotic nitrogen is absorbed almost completely. The cost of humus was calculated based on the weighted average market price of manure (50% of dry matter) in terms of humus with a humification factor of 25%.

The amount of future savings depended on the amount of accumulated root mass and symbiotic nitrogen by alfalfa plants. In the variants of the experiment, the amount was the greater, the more the alfalfa plants accumulated root mass and symbiotic nitrogen in the soil. The minimum value of symbiotic nitrogen (133.43 €/ha in the Unitro variety and 138.67 €/ha in the Zoryana variety) and humified root mass of 108.00 and 108.47 €/ha, respectively, was obtained on the control variant without inoculation. In total, it was also the smallest in this variant and amounted to 241.43 €/ha for the Unitro variety and 247.13 €/ha for Zoryana.

The use of bacterial preparations increased the accumulation of root mass and symbiotic nitrogen, and accordingly, the amount of money saved in the future was greater. Thus, the increase in the value of symbiotic nitrogen when using bacterial preparations compared to the control was 25.67–49.84 €/ha in the Unitro variety and 21.03–48.80 €/ha in Zoryana, while the value of the humified root mass was 2.40–31.20 €/ha and 4.80–29.76 €/ha, respectively.

Table 2. The cost of symbiotic nitrogen and humified root mass depending on the variety and application of bacterial preparations (average for 2018-2020)

Variety (factor A)	Application of bacterial preparations (factor B)	Accumulation of air-dry root mass, t/ha	Atmospheric nitrogen fixation, kg/ha	Root mass humification, t/ha	Cost of symbiotic nitrogen, €/ha	Cost of humified root mass, €/ha	Σ, €/ha
Unitro	Control 1 (no inoculation)	4.50	162	0.81	133.43	108.00	241.43
	Rhizobophyte	4.60	193	0.83	159.10	110.40	269.50
	CBP	5.00	205	0.90	168.87	120.00	288.87
	CBC	5.62	215	1.01	177.30	134.87	312.17
	CBP	5.80	222	1.04	183.27	139.20	322.47
	average	**5.10**	**200**	**0.92**	**164.39**	**122.49**	**286.89**
Zoryana	Control 1 (no inoculation)	4.52	168	0.81	138.67	108.47	247.13
	Rhizobophyte	4.72	194	0.85	159.70	113.27	272.97
	CBP	5.08	213	0.91	175.53	121.93	297.47
	CBC	5.62	220	1.01	181.43	134.87	316.30
	CBP	5.76	228	1.04	187.47	138.23	325.70
	average	**5.14**	**205**	**0.93**	**168.56**	**123.35**	**291.91**

Assessment of the significance of partial differences

LSD_{05}	A	0.228	4.40
LSD_{05}	B	0.209	10.35

Evaluation of the significance of the main effects

LSD_{05}	A	0.114	1.97
LSD_{05}	B	0.148	7.32

Note: The cost of 1 ton of ammonium nitrate (34.4% nitrogen) is €283.33/t and the cost of 1 ton of cattle manure (50% dry matter) is €33.33/t
Source: Own results.

The maximum fixation of symbiotic nitrogen and the accumulation of root mass was obtained in the variant with the use of a cyanobacterial preparation. The price of symbiotic nitrogen was 183.27 €/ha in the Unitro variety and 187.47 €/ha in the Zoryana variety, and the humified root mass was 139.20 and 138.23 €/ha, respectively

When growing the Unitro variety, the amount of money saved for the following crops in the crop rotation (humicized root mass and symbiotic nitrogen) amounted to 286.89 €/ha, with the costs of cultivation - 249.06 €/ha, and with the addition of the cost of the obtained seeds, the total benefit from the cultivation of alfalfa was 1565.12 €/ha for seeds in crop rotation was 1602.95 €/ha with a profitability of 642%. In the Zoryana variety, the amount of funds saved for the following crops in the crop rotation was greater by 5.02 €/ha, with the same costs, but the cost of the obtained seeds was lower by 358.80 €/ha, and therefore the profit from growing alfalfa for seeds in the crop rotation was less by 353.78 €/ha with a profitability of 500% (Table 3).

The lowest profit from growing alfalfa for seeds in crop rotation was obtained in the control variant in the Unitro variety 1,228.33 €/ha with a profitability of 505%, while in the Zoryana variety 940.43 €/ha and 387%.

Seed inoculation with Rhizobophyte, a complex of biological preparations (KBP) and a cyanobacterial consortium (CBC) increased the profit from growing alfalfa for seeds in crop rotation in the Unitro variety by 270.10 €/ha, 406.14 and 530.77 €/ha, respectively, and in the Zoryana variety by 172.27 €/ha ha, 321.84 and 473.60 €/ha, respectively.

The maximum benefit of 1,894.40 €/ha from growing alfalfa for seeds in crop rotation was obtained in the Unitro variety with CBP inoculations with a profitability of 747%.

Table 3. Economic efficiency of growing alfalfa for seeds of the second year of life in crop rotation

Variety (factor A)	Application of bacterial preparations (factor B)	Cost of seeds, €/ha	Amount of aved funds s for the following crops, €/ha	Costs per 1 ha, €	Benefit received from growing alfalfa for seeds in crop rotation, €/ha	Profitability level of growing alfalfa for seeds in crop rotation, %
Unitro	Control 1 (no inoculation)	1,230.00	241.43	243.10	1,228.33	505
	Rhizobophyte	1,476.40	269.50	247.47	1,498.43	606
	CBP	1,595.20	288.87	249.60	1,634.47	655
	CBC	1,698.40	312.17	251.47	1,759.10	700
	CBP	1,825.60	322.47	253.67	1,894.40	747
	average	**1,565.12**	**286.89**	**249.06**	**1,602.95**	**642**
Zoryana	Control 1 (no inoculation)	936.40	247.13	243.10	940.43	387
	Rhizobophyte	1,087.20	272.97	247.47	1,112.70	450
	CBP	1,214.40	297.47	249.60	1,262.27	506
	CBC	1,349.20	316.30	251.47	1,414.03	562
	CBP	1,444.40	325.70	253.67	1,516.43	598
	average	**1,206.32**	**291.91**	**249.06**	**1,249.17**	**500**

Source: Own results.

CONCLUSIONS

The use of a cyanobacterial preparation made it possible to obtain the highest seed yield of 456.4 kg/ha in the Unitro variety at a cost of 0.56 €/kg and conditional net profit of 1571.93 €/ha and 1190.73 €/ha. The largest root weight of 5.80 t/ha was accumulated by the Unitro variety when using the cyanobacterial preparation, and the highest nitrogen fixation of 228 kg/ha was noted in the Zoryana variety. In conversion, the value of symbiotic nitrogen was 187.47 €/ha in the Zoryana variety and the value of the humified root mass was 139.20 €/ha in the Unitro variety. The greatest profit from growing alfalfa for seeds in crop rotation was obtained by inoculation with a cyanobacterial preparation in the Unitro variety 1,894.40 €/ha and in the Zoryana variety 1,516.43 €/ha.

REFERENCES

[1]Alonso, J. M., Stepanova, A. N., Solano, R., Wisman, E., Ferrari, S., Ausubel, F. M., Ecker, J. R., 2003, Five components of the ethylene-response pathway identified in a screen for weak ethylene-insensitive mutants in Arabidopsis. Proc. Natl. Acad. Sci., U.S.A. 100:2992-2997/

[2]Bonfante, P., Requena, N., 2011, Dating in the dark: how roots respond to fungal signals to establish arbuscular mycorrhizal symbiosis. Curr Opin Plant Biol., 14(4):451-457. doi:10.1016/j.pbi.2011.03.014

[3]Bowen, G.D., Rovira, A.D., 1999, The rhizosphere and its management to improve plant growth. Adv. Agron., 66:1-102

[4]Ceccanti, B., Marinari, S., Masciandaro, G., Grego, S., 2000, Influence of organic and mineral fertilisers on soil biological and physical properties. Bioresource Technology, 72(1):9-17. https://doi.org/10.1016/S0960-8524(99)00094-2

[5]Crespi, M., Frugier, F., 2008, De novo organ formation from differentiated cells: root nodule organogenesis. Sci Signal., 1(49):re11. doi:10.1126/scisignal.149re11

[6]Eissenstat, D.M., 1992, Costs and benefits of constructing roots of small diameter. J. Plant Nutr., 15:763–782. doi.org/10.1080/01904169209364361

[7]Grishina, L.A., Koptsik, L.A., Makarov, M.I., 1990, Transformation of soil organic matter. M.: MSU, 88.

[8]Hufnagel, B., de Sousa, S.M., Assis, L., Guimaraes, C.T., Leiser, W., Azevedo, G.C., Negri, B., Larson, B.G., Shaff, J.E., Pastina, M.M., 2014, Duplicate and conquer: Multiple homologs of phosphorus-starvation tolerance enhance phosphorus acquisition and sorghum performance on low-phosphorus soils. Plant Physiol.,166:659–677. doi: 10.1104/pp.114.243949

[9]Kell, D.B., 2011, Breeding crop plants with deep roots: their role in sustainable carbon, nutrient and water sequestration. Ann. Bot.-London, 108:407–418.doi: 10.1093/aob/mcr175.

[10]Kots, S.Ya., Vorobey, N.A., Kiriziy, D.A., Karaushu, E.V., 2016, The production process of alfalfa inoculated with the binary composition Sinorhizobium Meliloti – Nostos. Physiology of plants and genetics. 48(2):120-129.

[11]Kots, S. Ya., Vorobey, N.A., Kyrychenko, O.V., Melnikova, N.M., Mikhalkiv, L.M., Pukhtaevich, P.P., 2016, Microbiological preparations for agriculture. Kyiv.: LOGOS Publishing House, 48.

[12]Lambers, H., Shane, M.W., Cramer, M.D., Pearse, S.J., Veneklaas, E.J., 2006, Root structure and functioning for efficient acquisition of phosphorus: Matching morphological and physiological traits. Annals of botany, 98(4):693-713. doi:10.1093/aob/mcl114

[13]Latrach, L. Farissi, M., Mouradi, M., Makoudi, B., Bouizgaren, A., Ghoulam, C., 2014, Growth and nodulation of alfalfa-rhizobia symbiosis under salinity: electrolyte leakage, stomata conductance, and chlorophyll fluorescence. Turkish Journal of Agriculture and Forestry, 38:320–326. doi:10.3906/tar-1305-52.

[14]Lebedev, S.I., 1988, Physiology of plants. Moscow: Agropromizdat, 305-317

[15]Liu, L., Zhang, H., Ju, C., Xiong, Y., Bian, J., Zhao, B., Yang, J., 2014, Changes in Grain Yield and Root Morphology and Physiology of Mid-Season Rice in the Yangtze River Basin of China During the Last 60 Years. Journal of Agricultural Science, 6(7). doi:10.5539/jas.v6n7p1.

[16]López-Bucio, J., Hernández-Abreu, E., Sánchez-Calderón, L., Nieto-Jacobo, M.F., Simpson, J., Herrera-Estrella, L., 2002, Phosphate availability alters architecture and causes changes in hormone sensitivity in the Arabidopsis root system. Plant Physiol. 129:244-256

[17]Lynch, J.P., Ho, M.D., 2005, Rhizoeconomics: Carbon costs of phosphorus acquisition. Plant Soil., 269:45-56

[18]Mackenzie, F.T., Ver, L.M., Lerman, A., 2002, Century-scale nitrogen and phosphorus controls of the carbon cycle. Chem. Geol. 190:13–32. doi: 10.1016/S0009-2541(02)00108-0

[19]Oldroyd, G.E., Downie, J.A., 2008, Coordinating nodule morphogenesis with rhizobial infection in legumes. Annu Rev Plant Biol., 59:519-546. doi:10.1146/annurev.arplant.59.032607.092839

[20]Omar, S.A., Abd El-Naby, Z.M., Abd El-Rahman, S.S., 2016, Screening For Alfalfa Root Traits In Relation To Yield And Crown Rot Disease Resistance. International Journal of Applied and Pure Science and Agriculture (IJAPSA),02(05):184-191.

[21]Persello-Cartieaux, F., Nussaume, L., Robaglia, C., 2003, Tales from the underground: Molecular plant-rhizobacteria interactions. Plant Cell Environ, 26:189-199

[22]Rahman, A., Hosokawa, S., Oono, Y., Amakawa, T., Goto, N., Tsurumi, S., 2002, Auxin and ethylene response interactions during Arabidopsis root hair development dissected by auxin influx modulators. Plant Physiol., 130:1908-1917

[23]Ryu, C.M., Farag, M.A., Hu, C.H., Reddy, M.S., Wei, H.X., Pare, P.W., Kloepper, J.W., 2003, Bacterial volatiles promote growth in Arabidopsis. Proc. Natl. Acad. Sci. U.S.A., 100:4927-4932

[24]Saikia, P., Bhattacharya, S.S., Baruah, K.K., 2015, Organic substitution in fertilizer schedule: Impacts on soil health, photosynthetic efficiency, yield and assimilation in wheat grown in alluvial soil. Agric. Ecosyst. Environ., 203:102–109. doi: 10.1016/j.agee.2015.02.003

[25]Sánchez-Calderón, L., López-Bucio, J., Chacón-López, A., Cruz-Ramírez, A., Nieto-Jacobo M. F., Dubrovsky, J.G., Herrera-Estrella, L., 2005, Phosphate starvation induces a determinate developmental program in the roots of Arabidopsis thaliana. Plant Cell Physiol. 46:174-184.

[26]Smith, S., De Smet, I., 2012, Root system architecture: insights from Arabidopsis and cereal crops Introduction. Philos. T R Soc. B., 367:1441–1452.

[27]Smith, S., Jakobsen, I., Grønlund, M., Smith, F., 2011, Roles of Arbuscular Mycorrhizas in Plant Phosphorus Nutrition: Interactions between Pathways of Phosphorus Uptake in Arbuscular Mycorrhizal Roots Have Important Implications for Understanding and Manipulating Plant Phosphorus Acquisition. Plant physiology, 156:1050-7. doi:10.1104/pp.111.174581

[28]Swarup, R., Parry, G., Graham, N., Allen, T., Bennett, M., 2002, Auxin cross-talk: Integration of signaling pathways to control plant development. Plant Mol. Biol., 49:411-426

[29]Tyshchenko, O., Tyshchenko, A., Piliarska, O., Biliaeva, I., Kuts, H., Lykhovyd, P., Halchenko, N., 2020, Seed productivity of alfalfa varieties depending on the conditions of humidification and growth regulators in the Southern Steppe of Ukraine. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 20(4):551-562.

[30]Tyshchenko, O., Tyshchenko, A., Piliarska, O., Kuts, H., Lykhovyd, P., 2020, Evaluation of drought tolerance in alfalfa (*Medicago sativa*) genotypes in the conditions of osmotic stress. AgroLife Scientific Journal, 9(2):353-358.

[31]Vozhehova, R., Lavrynenko, Yu., Marchenko, T., Piliarska, O., Sharii, V., Tyshchenko, A., Drobit, O., Mishchenko, S., Grabovskyi, M., 2022, Water consumption and efficiency of irrigation of maize hybrids of different FAO groups in the Southern Steppe of Ukraine. Scientific Papers. Series A. Agronomy, LXV(1):603–612.

[32]Vozhehova, R., Marchenko, T., Lavrynenko, Yu., Piliarska, O., Zabara, P., Zaiets, S., Tyshchenko, A., Mishchenko, S., Kormosh, S., 2022, Productivity of lines – parental components of maize hybrids depending on plant density and application of biopreparations under drip irrigation. Scientific Papers

Series Management, Economic Engineering in Agriculture and Rural Development, 22(1):695-704.

[33]Vozhehova, R., Tyshchenko, A., Tyshchenko, O., Dymov, O., Piliarska, O., Lykhovyd, P., 2021, Evaluation of breeding indices for drought tolerance in alfalfa (Medicago) genotypes. Scientific Papers. Series A. Agronomy, LXIV(2):435-444.

[34]Vozhehova, R., Tyshchenko, A., Tyshchenko, O., Piliarska, O., Konovalova, V., Sharii, V., Fundirat, K., 2022, Economic feasibility of application of bacterial and fungal drugs on seed-used alfalfa. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(4):827-834.

[35]Walana, P., Davidssona, S., Johansson, Sh., Hööka, M., 2014, Phosphate rock production and depletion: Regional disaggregated modelling and global implications. Published in Resources Conservation and Recycling, 93:178–187 http://dx.doi.org/10.1016/j.resconrec.2014.10.011.

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THE ROLE OF PUBLIC AGRICULTURAL SPENDING AS A PANACEA FOR AGRICULTURAL SUBSECTOR PRODUCTION: EMPIRICAL EVIDENCE FROM CAMEROON

Udeme Henrietta UKPE[1], Raoul Fani DJOMO CHOUMBOU[2], Rayner TABETANDO[2], Emmanuel Nkwi GAMA[3]

[1]Federal University Wukari, Department of Agricultural Economics and Extension, PMB 1020, Wukari, Taraba State, Nigeria; Email: ukpe@fuwukari.edu.ng
[2]University of Buea, Department of Agricultural Economics and Agribusiness, P.O. Box 63, South West Region, Cameroon; Emails: djomo.choumbou@ubuea.cm, raynertabetando@gmail.com
[3]Federal University Dutse, Department of Agricultural Economics and Extension, Jigawa State, Nigeria; Email:gamaemmanuel@gmail.com

Corresponding author: djomo.choumbou@ubuea.cm

Abstract

The purpose of the paper was to analyse the role of public agricultural spending as a panacea for agricultural subsector production in Cameroon. The data were taken from World Bank development database and processed using growth model, and error correction model. Despite the agricultural sector's significant contributions to the country's economy throughout the years, the country has made little headway in reducing it. Recent interest in the relationship between government spending and economic output has not focused on the central question of whether government spending, particularly agricultural spending increases agricultural subsector output or otherwise. With instantaneous and compound growth rates of 6.7 percent and 6.93 percent, 3.03 percent and 3.08 percent, 13.66 percent and 14.64 percent, respectively, the results demonstrated stagnation in agricultural and livestock subsector production and labor. In contrast, public agriculture spending increased at a faster rate, with instantaneous and compound growth rates of 6.09 percent and 6.27 percent, respectively. In the short run, agricultural land, labor, and public agricultural spending all have a substantial impact on animal productivity. Cutting public agricultural spending by 25% is the most cost-effective way to maintain crop and livestock production in the short term. Incentives such as tax reductions and infrastructure development should be established to attract more private investors, knowledge transfer, and significant capital inflows to ensure the agricultural sub-long-term sector's viability. In the short term, privatization of the government's agricultural development projects will be critical for efficient use of public resources.

Key words: *public agricultural spending, livestock, crop, error correction model*

INTRODUCTION

Several studies have been carried out on the nexus between public expenditures and agricultural growth around the world [6, 17, 25, 13, 3, 16, 20, 26]. They focused on aggregate economic output and public spending with little or no emphasis on disaggregated economic production and governmental spending. As a result, a study is needed to experimentally address the information gap and record the extent to which public agricultural investment, particularly in the crop and animal subsectors, might be sustainable over years particularly in the instance of Cameroon. The direction and growth rates of crop subsector production, animal subsector production, public agriculture spending and labor are all explicitly determined in this study. It also looks at the impact of government agricultural spending on crop and livestock production, as well as the impact of changes in government agricultural spending on crop and livestock production. The findings of this study will serve as a foundation for policy development and advocacy in Cameroon, helping to sustain the crop and animal sectors.

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Agriculture is the backbone of society in most developing countries, providing food for people, jobs for workers, and trade for economies at the local, national, and worldwide levels. However, as we approach closer to the Sustainable Development Goals (SDGs), agriculture's chances of being at the vanguard of reducing hunger, ending poverty, and ensuring sustainable development may be jeopardized. Hunger levels were slowly rising prior to the COVID-19 epidemic and its social and economic consequences, and this was especially true in Sub-Saharan Africa (SSA) [12, 22]. In 2019, 690 million people were predicted to be malnourished, with 235 million of them living in Sub-Saharan Africa. This suggests that significant more resources will be necessary to attain Zero Hunger, and that these resources will need to be intelligently deployed. Increasing agricultural investment is one strategy to attain Zero Hunger. This is stressed in the Sustainable Development Goals, particularly Target 2 of sustainable goal development (SDG) which asks for increased investment and regional pledges to boost agricultural productivity by 2030 [22].

Cameroon is losing steam after a long era of shock resistance with one of the most resilient and diverse economies in the Economic and Monetary Community of Central African States (CEMAC). Despite difficult worldwide economic conditions, the Cameroonian economy has maintained a consistent Gross Domestic Product (GDP) growth rate since the 2008 financial crisis, increasing from 3.3 percent in 2010 to 4.6 percent in 2012, and then to 5.8 percent on average from 2013 to 2015. Apart from oil production, the primary sector (particularly subsistence farming) and several sections of the tertiary sector were the main drivers of economic growth (notably transport and telecommunications), The GDP growth rate remained strong, but slowed from 5.9% in 2015 to 4.5 percent in 2016 [2]. However, the fiscal policy of supporting significant backbone projects, particularly in the agriculture sector, in the context of diminishing oil revenues has resulted in an increase in budget deficits, although being somewhat expansionist. The budget deficit increased from 2% of GDP in 2015 to 6.5 percent of GDP in 2016, reflecting a 1.6 percent increase in governmental expenditures and a 1.9 percent drop in revenue (of which 0.9 percent was in oil revenue) [2].

Despite the agricultural sector's significant contributions to Cameroon's economy over the years, recent performance has been poor. Before the discovery of oil in 1978, the agricultural industry in Cameroon contributed as much as 30% of the country's GDP. Unfortunately, roughly a decade later, agriculture's contribution of GDP dropped to 24%, with a minor rebound to 27% in 1990. [15, 4, 14, 9, 10]. On the other hand, it fell to 19.8 percent in 2010 [31, 14, 9]. According to national accounts data, value-added growth in the primary sector averaged 4% between 2003 and 2012, outpacing GDP growth (which averaged 3.3%), but was relatively high only in 2007 (5.9%) and 2008 (5.2%), and could not maintain this level despite increased public sector investment [30, 31].

Between 1960 and the late 1980s, the Cameroon government established agricultural development programs defined by the promotion of export and industrial crops as a source of foreign cash and as a means of improving living circumstances in rural areas. Small-scale farmers were viewed as tools in the policy to ensure mass production. The government, on the other hand, guaranteed prices and tightly regulated the procurement and selling of agricultural goods like cocoa and coffee (price stabilization mechanisms). Other policy instruments included the formation of massive development projects and the establishment of development firms, which allowed the government to be present among farmers, provides technical guidance, and develops the infrastructure needed to better their lives. The policy's outcomes have been described as "mixed." Despite efforts to boost agricultural research and producer technical oversight, yields remained poor [8, 1]. However, the government amended its intervention strategy by establishing a development organization in each agricultural zone with financial and administrative autonomy, with the goal of establishing a "new type" of relationship between the government and farmers. When determining agricultural prices, factors such as producer income (rather than only the interests of urban customers) were taken into account. Intensive training for rural extension workers and production and processing management (by state agencies) were also pushed [1].

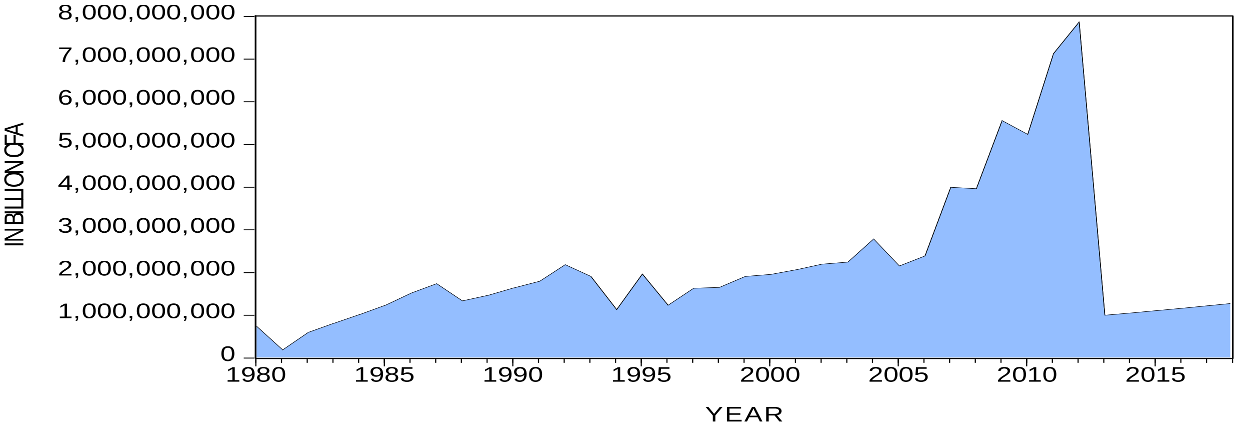


Fig. 1. Trend of Public Agricultural Spending in Cameroon
Source: Eviews data analysis output, 2022.

The government of Cameroon announced a New Agricultural Policy (NAP) in 1990, in line with the first SAP, to gradually commercialize development operations, empower farmers, and diversify agriculture. The NAP was funded by the Breton Woods Institutions and other key donors. After 1990, the NAP was reoriented to focus on the following goals, which are also included in the current NAP, which was enacted in 1999 and considers agriculture to be the driving force behind Cameroon's social and economic development, increase food security by increasing output and revenue [21], and encourage professional and inter-professional organization of diverse investors who are also partners in agricultural development. Cameroon's government prepared a rural sector development strategy paper as part of the highly indebted poor countries program. As a result, current agricultural policies are organized around seven strategic pillars: sustainable agricultural product production and supply; sustainable natural resource management; promotion of local and community development; development of appropriate funding mechanisms; and development of employment and vocational training in agribusiness [1].

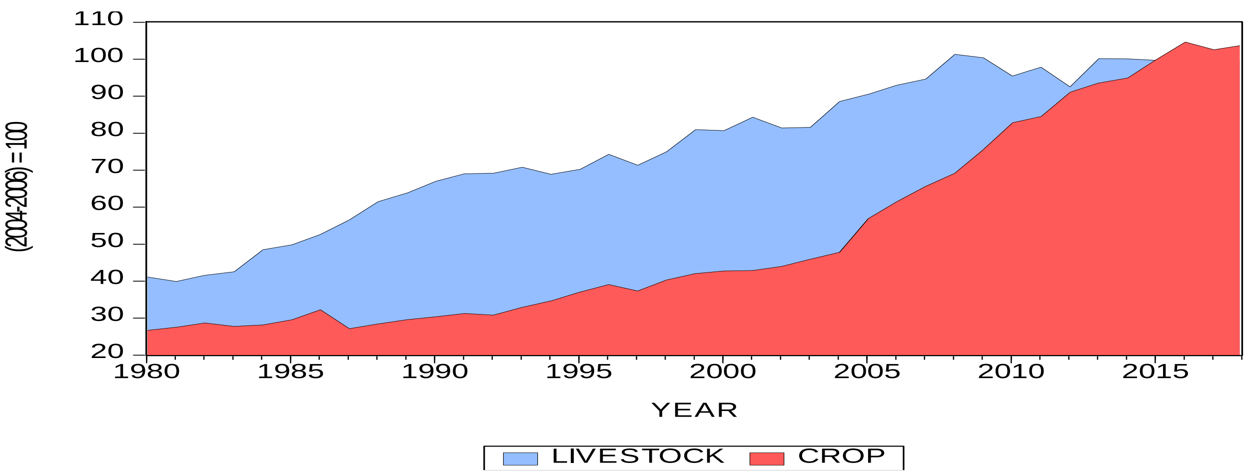


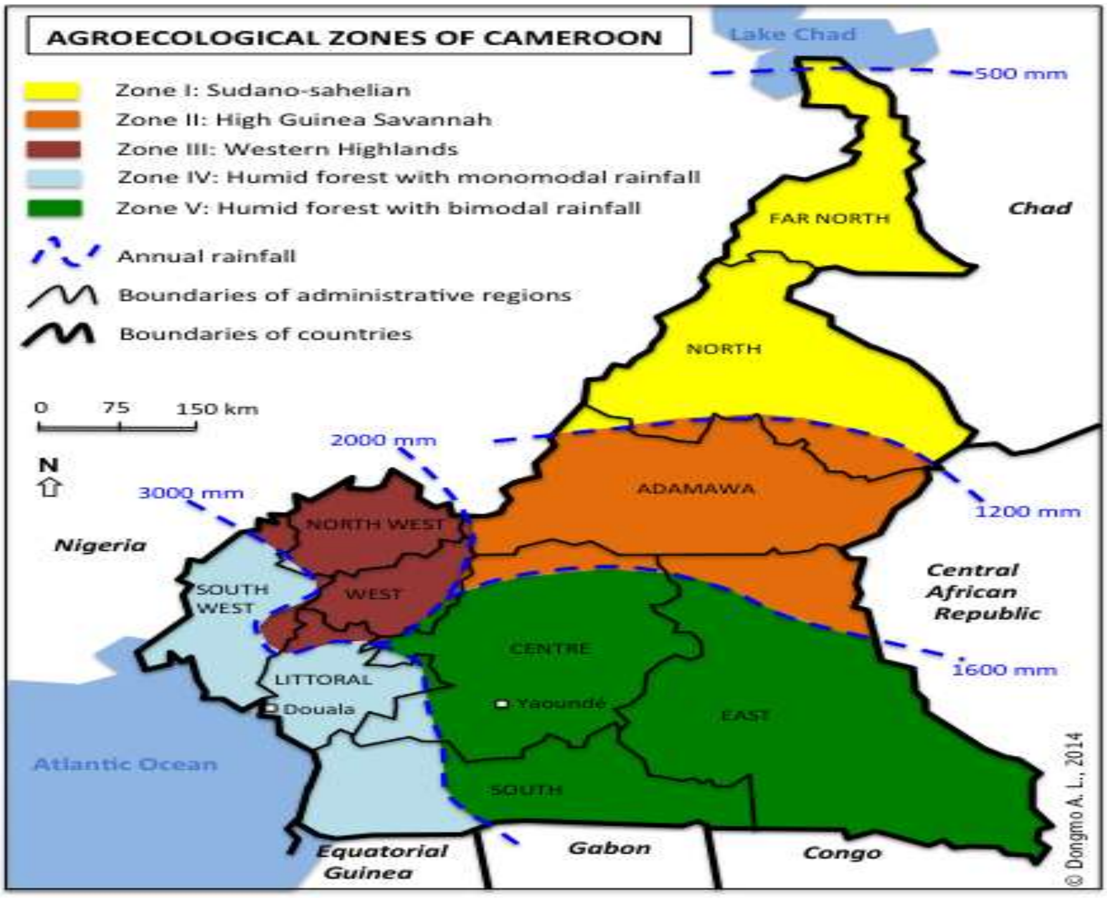
Fig. 2. Crop and Livestock Subsectors Production in Cameroon
Source: Eviews data analysis output, 2022.

This study found that cutting public agricultural spending by 25% is the most cost-effective way to maintain crop and livestock production in the short term. Incentives such as tax reductions and infrastructure development should be established to attract more private investors, knowledge transfer, and significant capital inflows to ensure the agricultural sub-long-term sector's viability. In the short term, privatization of the government's agricultural development projects will be critical for efficient use of public resources.

MATERIALS AND METHODS

The Research Area

The research was place in Cameroon, which is divided into 10 regions: Centre, Littoral, Adamawa, Far-North, North, South, East, West, North-West, and South-West. The country has a total land area of 475,442 square kilometers and is located in Africa's Central region between latitudes 2 and 13 degrees north and longitudes 9 and 16 degrees east of the equator [28]. The most widely grown crops in Cameroon include groundnuts, vegetables, cassava, and beans. Meanwhile, poultry, goats, sheep, cattle, and pigs bring in the most money in the livestock industry. From a household viewpoint, farming and agriculture in Cameroon is small-scale, informal, and subsistence, taking place on tiny plots of land and reliant on limited infrastructure, limited access to capital, and low-value chain linkages for final goods or markets.



Map 1. Map of Cameroon showing the different regions and agro-ecological zones
Source: www.maponline.com [32].

Method of Data Collection

The study was conducted using annual time series data spanning 39 years (1980-2018). The World Bank Development database indicators were used to collect data for agriculture and livestock subsector production. Cameroon's Ministry of Economic and Planning provided data on public agricultural spending. The Food and Agriculture Organization (FAO) provided labor data, while the World Fact Fish database provided data on malnutrition.

Data Analysis Techniques

The growth model was utilized to determine the direction and rates of variable growth. The influence of public agricultural spending on agricultural subsectors production, and the consequences for malnutrition were investigated using the Vector Error Correction Model. The impact of changes in public agricultural spending (two (2) scenarios at 25%) on agricultural subsectors production was studied using Monte Carlo Simulation.

Model Specifications/Variables selection

The following is the growth model that was used to determine the direction and growth rates of the variables of interest:

$\ln Y_t = \alpha + \beta_{crop} t + \mu_t$ …………………… (1)
$\ln Y_t = \alpha + \beta_{pagr} t + \mu_t$ …………………....(2)
$\ln Y_t = \alpha + \beta_{liv} t + \mu_t$ ……………………...(3)
$\ln Y_t = \alpha + \beta_{lab} t + \mu_t$ ……………………. (4)

where:
α = intercept;
β = vector of the trend variable and μ is the econometric error term.
β_{crop}, β_{pagr}, β_{liv},β_{fdi}, β_{lab} =coefficients of the trend variable for crop subsector production, public agricultural spending, livestock subsector, and labour respectively.

Because the study looked at both absolute and relative change in the parameters of interest, a semi-log growth rate model was devised instead of a linear trend model. The slope coefficient, which quantifies the constant proportional/relative change in Y for a given absolute change in the value of the regressor t, is the most important parameter in equations (1-4).

To begin, multiply b by 100 to obtain the instantaneous growth rate (IGR) at a given point in time.

IGR= β X 100 ……………………….. (5)

where:
IGR = Instantaneous growth rate and
β = is the least-square estimate of the slope coefficient

Second, the compound growth rate (CGR) over time is calculated by taking the antilog of β, subtracting 1 from it, and then multiplying the difference by 100. In each of the five scenarios, the compound growth rate (CGR) in % can be calculated using equations 7-10 as follows:

CGR = $(e^{\beta i} - 1)*100$ ……………………… (6)

Finally, if is positive and statistically significant, growth accelerates; if is negative and statistically significant, growth decelerates; and if is not statistically significant, growth stagnates.

The Vector Error Correction Model is used to investigate the impact of government agricultural spending on the agricultural sector.

The theory of production with the Cobb Douglas (CD) functional form serves as the theoretical underpinning for the interaction between public agricultural spending and the agricultural subsector. All factors of production, according to [24], are subject to the law of diminishing returns. As seen in equation 7, the classical theory of production posits that output is a function of capital and labor input.

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \quad (7)$$
$$0 < \alpha < 1$$

where:
Y_t is the output
K_t is the capital input
L_t is the labour input.

A_t is often referred to by macroeconomists as a measure of technological development, although it is ultimately just a measure of productive efficiency because an increase in A t boosts the productivity of other components. A_t is also known as total factor productivity (TFP) in common empirical jargon [11]. The CD functional form is used to analyze the production process, not because it is a basic instrument that can be handled quickly or as a crude estimation tool, but because of the benefits it offers. These benefits are due to its generalized form's ability to handle many inputs. It does not introduce distortions of its own, even in the face of market defects. The ability to manage diverse scales of manufacturing is further enhanced by the unconstrained CD production functional form. Various econometric estimating difficulties, such as serial correlation and heteroscedasticity, can be effectively and efficiently handled. It is suggested that the majority of its criticism is focused on its inflexibility, and that all other assumptions may be loosened except for one evident assumption. It is also claimed that it facilitates computations and has explicit uniformity, parsimony, and flexibility features. Simultaneity is also a challenge that can be overcome. It is also a good representation of aggregation technology [7].

Given that capital (public agricultural spending), land, and labor are the essential factors for agricultural output, variables including agricultural land, labor, and public agricultural spending were used in this study. As a result, our CD-production function could be described as follows:

$Y_t = A_t AGL_t^{\alpha} PAS_t^{\gamma} LB_t^{\delta}$ …………………....(8)

where:

$$\alpha + \gamma + \delta = 1$$

Y_t is crop or livestock production
AGL is agricultural land
PAS is public agricultural spending
LB is labour.

The inputs (AGL, PAS, LB) and outputs (crop or livestock production Y) have a nonlinear connection and the three inputs interact. The nonlinear CD must be linearized in order to estimate the parameters, β, γ, δ, A, Taking both sides of the natural log of $Y_t = A_t AGL_t^{\alpha} PAS_t^{\gamma} LB_t^{\delta}$, we obtain the following equation for estimation:

$lnY_t = lnA_t + \alpha lnAGL_t + \gamma PAS_t + \delta LB_t$…………………………………............. .... (9)

α, γ and δ are estimated parameters representing elasticity. Therefore, following Djomo et al. (2017), the model can be specified as:

$\ln Y_t = \ln\beta_0 + \beta_1 \ln X_{1t} + \beta_2 \ln X_{2t} + \beta_3 \ln X_{3t} + ECT_{t-1} + \varepsilon_t$...(10)

where:
Y_{it}^* is Crop or Livestock subsector output (Tons)
X_{1it} is Agricultural land (hectares)
X_{2it} is Labour (employed persons in the agricultural sector)
X_{3t} is Public Agricultural Spending (FCFA)
ECT_{t-1} is error correction term.

The impact of changes in public agriculture spending on agricultural subsectors production is modelled as follow:

$lnY_{it}^* = \alpha_{0i} + \alpha_1 lnX_{1it} + \alpha_2 lnX_{2it} + \alpha_3 * (lnX_{3it} + \vartheta_{3,it}) + ECT_{t-1} + \zeta_{it}$ ………... (11)

where:
Y_{it}^* is Crop or Livestock subsector output (Tons)
X_{1it} is Agricultural land (hectares)
X_{2it} is Labour (employed persons in the agricultural sector)
X_{3t} is Public Agricultural Spending (FCFA)
ECT_{t-1} is error correction term
ϑ_{3it}= uncertainties in the measurement ofX_{3it}
ζ_{it}= exogenous white noise disturbance on the model.

The behavior of crop and livestock subsectors output under various scenarios was explored due to the stochastic nature of this model. The simulated scenarios include a 25% increase in public agriculture spending and a 25% drop in public agricultural spending.

RESULTS AND DISCUSSIONS

Table 1 shows the outcome of the direction and growth rates. With instantaneous and compound growth rates of 6.7 percent and 6.93 percent, respectively, there was standstill in agricultural subsector production. In the livestock subsector, there was also stagnation, with instantaneous and compound growth rates of 3.03 percent and 3.08 percent, respectively.

Table 1. Direction and growth rates

	Crop Production	Livestock Production	Public Agricultural Spending	Labour
@TREND	0.06*** (8.41)	0.03*** (8.27)	0.06*** (3.29)	0.005 (0.31)
@TREND^2	-0.0002 (-0.48)	2.08E-05 (0.09)	0.003 *** (3.01)	0.001 (1.57)
C	4.28 (155.86)	4.44 (351.13)	24.06 (377.74)	15.75 (248.93)
R-squared	0.984	0.986	0.975	0.78
Adjusted R-squared	0.982	0.984	0.972	0.75
S.E. of regression	0.04	0.01	0.09	0.09
Sum squared resid	0.02	0.005	0.13	0.13
Log likelihood	31.30	44.48	17	17.11
F-statistic	456.77	506.26	283.64	25.69
Prob(F-statistic)	0.000	0.000	0.000	0.000
Mean dependent var	4.79	4.68	24.84	15.95
S.D. dependent var	0.32	0.15	0.59	0.19
Akaike info criterion	-3.33	-4.88	-1.64	-1.66
Schwarz criterion	-3.18	-4.73	-1.50	-1.51
Hannan-Quinn criter.	-3.31	-4.86	-1.63	-1.64
Durbin-Watson stat	1.12	1.77	1.11	0.74
Instantaneous growth rate (%)	6.7	3.03	6.09	0.58
Compound growth rate (%)	6.93	3.08	6.27	0.58
Direction of growth	Stagnation	Stagnation	Acceleration	Stagnation

*** is significant at 1% N.B. Values in parentheses are t statistics
Source: Eviews data analysis output, 2022.

This could be explained by program duplication within subsectors, which could imperil growth rates due to policy reversals. This contrasts with the findings of [20], who showed a negative growth rate of -0.87% for the total agricultural industry in Cameroon from 1970 to 2014. In addition, labor stagnated, with instantaneous and compound growth rates of 0.58 percent and 0.58 percent, respectively. This could be attributed to professional structures' insufficient capacity to train young and nimble human resources to contribute to the agriculture sector's long-term viability. When compared to [27]'s findings, which indicated instantaneous and compound growth rates of 2.58 percent and 2.61 percent, respectively, these figures show a decline in labor growth rates in Cameroon. In contrast, public agriculture spending increased at a faster rate, with instantaneous and compound growth rates of 6.09 percent and 6.27 percent, respectively. This could be attributable to the completion point of highly indebted developing country programs, which made funding available to enhance the agriculture sector in Cameroon.

Table 2 summarizes the results of unit root tests performed under the ADF at the level and first difference. The findings show that all of the variables under investigation were not stationary at the level, but were stationary at the first difference at the 1%, 5%, and 10% level of significance.

Table 2. Augmented Dickey Fuller (ADF) test

Variables	**ADF Results**				
	At level		At First difference		Decision
	t-statistic	probability	t-statistic	probability	
Crop	-1.51	0.80	-7.15	0.000***	I(1)
Livestock	-1.20	0.89	-3.75	0.031**	I(1)
Agricultural land	-0.36	0.98	-4.51	0.004***	I(1)
Public agricultural spending	-2.57	0.29	-7.01	0.000***	I(1)
Labour	0.67	0.99	-3.22	0.09*	I(1)

***, **and * indicate stationary at 1%, 5% and 10% level of significance
Source: Eviews data analysis output, 2022.

As a result of examining Table 2, it is clear that all of the variables are stationary at first difference and are thus classified as an I(1) process. The trace statistics at a 5% level of significance are used in the unconstrained cointegration test.

Table 3 reveals that the trace statistic value exceeds the critical value, meaning one (1) co-integrating equation at a 5% level of significance, indicating a long-term link between variables. However, crucial values are bigger than trace statistics in the subsequent cointegration equation, meaning that the null hypothesis of cointegration is rejected.

Table 3. Cointegration Rank Test based on Trace Statistics

Hypothesized		**Trace**	**0.05**	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.64	71.03	69.81	0.03
At most 1	0.32	32.97	47.85	0.55
At most 2	0.26	18.53	29.79	0.52
At most 3	0.12	7.17	15.49	0.55
At most 4	0.05	2.04	3.84	0.15

Trace test indicates 1 cointegratingeqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values
Source: Eviews data analysis output, 2022.

Table 4 shows the impact of public agricultural spending on the output of agricultural subsectors. The results demonstrate that agricultural land, labor, and public agricultural spending account for 49 percent and 66 percent of the variation in crop and animal subsector production, respectively. Furthermore, the findings demonstrate that labor has a considerable impact on crop yield in theshort term. In the short run, agricultural land, labor, and public agricultural spending have a substantial impact on cattle output.

The coefficient of labor, in particular, was negative and significant at the 5% level. This means that 1% increase in labor will decrease crop production by 0.04%. The labor coefficient, on the other hand, is positive and significant at the 5% level. This means that a 0.02 percent increase in labor will enhance animal production. The negative association between labor and crop output may be due to smallholder farmers' use of manual tools, which may have a major impact on their productivity and, as a result, reduce aggregate crop production. Also, the adoption of any farm management practice may not have any significant role in increasing farm output. This result is contrary to the findings of [23]. It's possible that the positive association between labor and livestock productivity is due to the fact that livestock production requires less labor than crop production. Agricultural land has a negative coefficient that is substantial at the 1% level.

Table 4. Effect of public agricultural spending on agricultural subsector output

Variables	Crop production		Livestock production	
	coefficient	t-statistics	coefficient	t-statistics
ln Agricultural land	-0.0003	-0.91	-0.0004***	-2.94
ln Labour	-0.0004**	-2.14	0.0002**	2.56
ln Public agricultural spending	-0.12	-0.88	0.15**	2.33
Error correction term (ECT)	-1.08***	-3.89	-0.29***	3.61
R-squared	0.49		0.66	
Adj. R-squared	0.39		0.49	
Sum sq. resids	491.65		174.66	
S.E. equation	4.11		2.75	
F-statistic	4.80		4.07	
Log likelihood	-98.13		-77.79	
Akaike AIC	5.84		5.13	
Schwarz SC	6.14		5.66	
Mean dependent	0.29		0.25	
S.D. dependent	5.29		3.89	
Determinant resid covariance (dof adj.)	6.50E-10		3.97E-10	
Determinant resid covariance	2.21E-10		4.87E-11	
Log likelihood	144.81		167.23	
Akaike information criterion	-5.76		-5.78	
Schwarz criterion	-3.96		-2.85	

*** and ** are significant at 1% and 5% respectively
Source: Eviews data analysis output, 2022

This means that 1% increase in agricultural land reduces livestock and crop production by 0.04% and 0.03% respectively. This result could be explained by market failures [5], and the heterogeneity in productivity by farm size within the country [29].

The public agricultural spending coefficient is positive and significant at 5%, meaning that a 1% increase in public agriculture spending improved cattle subsector production by 15%. This could be owing to the government of Cameroon establishing numerous agricultural targeted programs after the completion of highly indebted poor nation projects. This finding is consistent with [19] findings, which revealed that disaggregated government expenditures resulted in positive externalities on Pakistan's economic production. As for the relationship between public agricultural spending and crop production, the result implies that 1% increase in public agricultural spending will reduce crop production by 12%.

This result suggests that there could be redundancy and inefficient use of resources in the various subsidy programmes [18].

Table 5 and Figures 5 and 6 show the impact of a 25% reduction in public agriculture spending on agricultural subsectors. The result demonstrates that baseline crop subsector production, which ranges from 55.80 tons to 218.42 tons with a mean of 105.26 tons, is lower than scenario 1, which has a mean of 125.88 tons and ranges from 56.88 tons to 256.86 tons. The crop subsector production increased by 17.84 percent as a result of this result.

The cattle subsector production baseline, which ranges between 49.94 tons and 722.76 tons with a mean of 233.24 tons, was lower than scenario 1, which ranges between 50.77 tons and 951.68 tons with a mean of 288.22 tons.

Table 5. Effect of a 25% decrease in public agricultural spending on agricultural subsectors

	Crop Subsector Production			Livestock Subsector Production		
	Baseline	Scenario 1	% Change	Baseline	Scenario 1	% Change
Mean	105.26	125.88	17.84	233.24	288.22	21.08
Median	86.73	107.55		159.96	184.73	
Maximum	218.42	256.86		722.76	951.68	
Minimum	55.80	56.88		49.94	50.77	
Std. Dev.	49.30	59.57		190.06	252.70	
Skewness	0.86	0.72		1.09	1.16	
Kurtosis	2.44	2.27		3.13	3.28	
Jarque-Bera	4.98	3.97		7.05	8	
Probability	0.08	0.13		0.02	0.01	
Sum	3789.61	4532.02		8163.52	10087.88	
Sum Sq. Dev.	85097.92	124225.1		1228233	2171280	

Source: Eviews data analysis output, 2022.

The cattle subsector's production increased by 21.08 percent as a result of this result. This means that cutting government agriculture investment and focusing on recurring spending will help the agricultural crop and livestock subsector grows faster. This conclusion is consistent with the findings of [16], who found that reducing government spending enhanced agricultural growth in Cameroon from 1985 to 2016.

Table 6 and Figures 7 and 8 show the impact of a 25% increase in public agriculture spending on agricultural subsectors. According to the findings, baseline crop output ranged from 55.80 to 218.42 tons, with a mean of 105.26 tons.

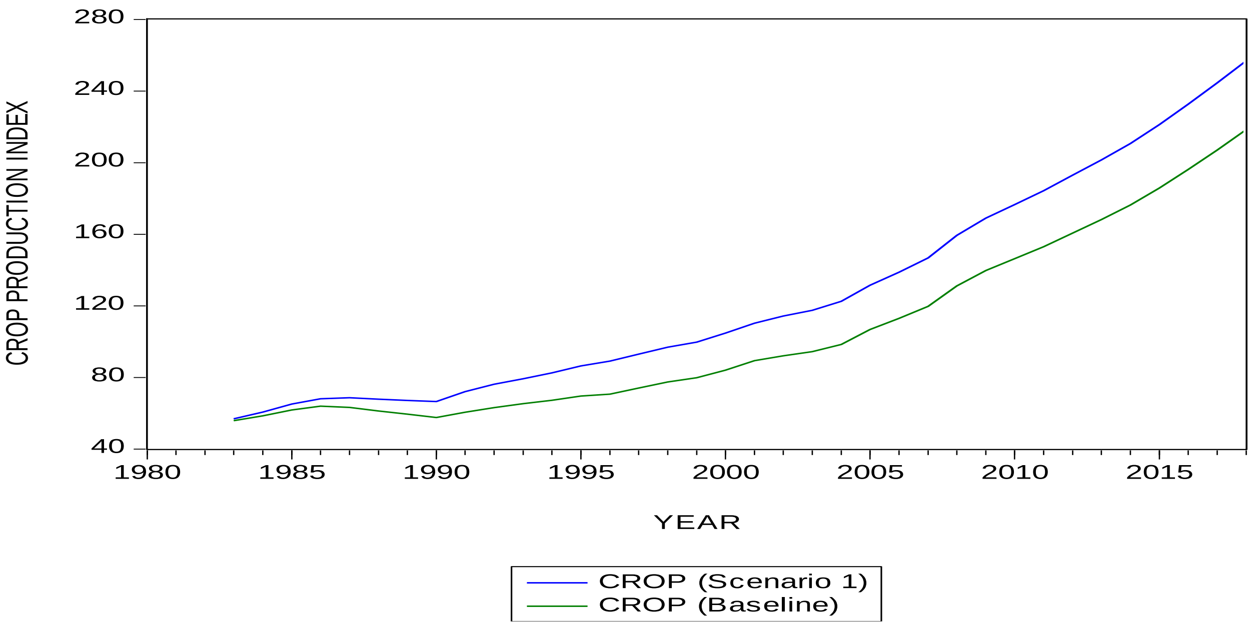


Fig 4. Effect of a 25% decrease in public agricultural spending on crop production
Source: Eviews data analysis output, 2022.

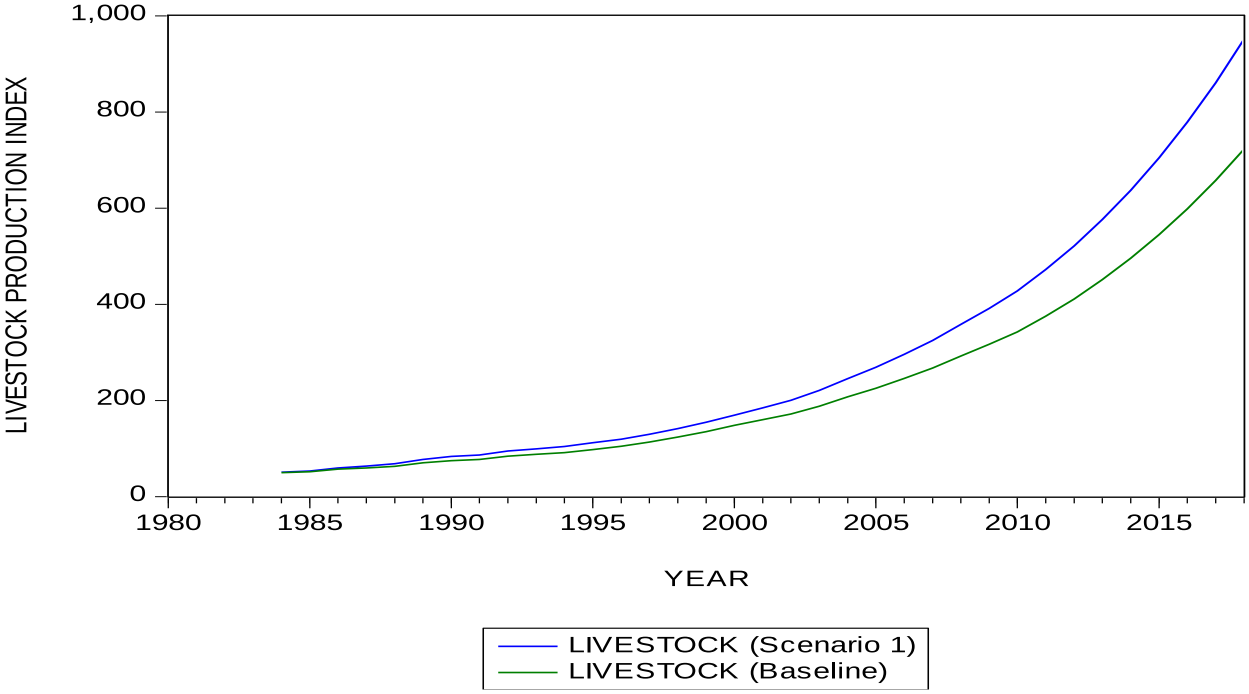


Fig 5. Effect of a 25% decrease in public agricultural spending on livestock production
Source: Eviews data analysis output, 2022.

Table 6. Effect of a 25% increase in public agricultural spending on agricultural subsectors

	Crop Subsector Production			Livestock Subsector Production		
	Baseline	Scenario 2	% Change	Baseline	Scenario 2	% Change
Mean	105.26	84.64	-21.71	233.24	178.26	-26.72
Median	86.73	65.92		159.96	135.20	
Maximum	218.42	179.97		722.76	493.84	
Minimum	55.80	48.55		49.94	49.11	
Std. Dev.	49.30	39.46		190.06	127.65	
Skewness	0.86	1.02		1.09	0.96	
Kurtosis	2.44	2.72		3.13	2.84	
Jarque-Bera	4.98	6.39		7.05	5.48	
Probability	0.08	0.04		0.02	0.06	
Sum	3789.61	3047.21		8163.52	6239.16	
Sum Sq. Dev.	85097.92	54508.23		1228233	554015.9	

Source: Eviews data analysis output, 2022.

This was higher than scenario 2, which had a range of 48.55 to 179.97 tons with an average of 84.64 tons. Further findings show a -21.71 percent increase in crop subsector production. When compared to scenario 2, which ranges between 49.11 tons and 493.84 tons with a mean of 178.26 tons for the cattle subsector, baseline ranges between 49.94 tons and 722.76 tons with a mean of 233.24 tons. This result reveals a decrease in livestock subsector production of -26.72 percent, showing that a rise in government agricultural spending severely slows the advancement of agricultural crop and livestock subsector output. This outcome could be attributed to capital expenditures, which may or may not boost agricultural production in the short term. This study backs up the findings of [10], who found that increasing government spending slowed agricultural growth in Cameroon from 1985 to 2016.

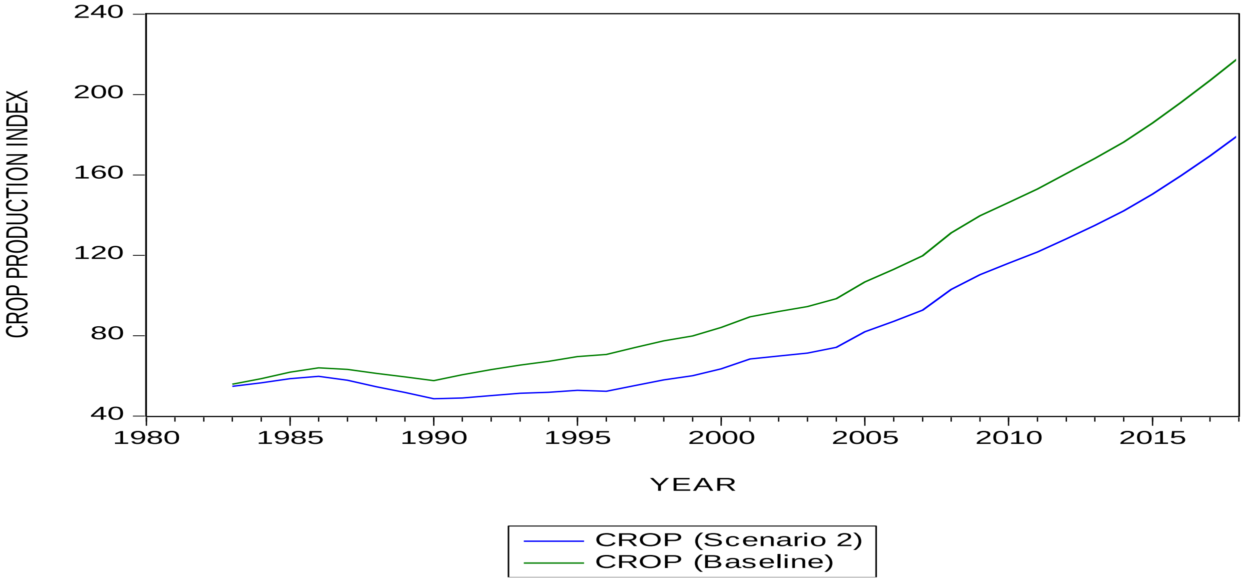


Fig. 6. Effect of a 25% increase in public agricultural spending on crop production
Source: Eviews data analysis output, 2022.

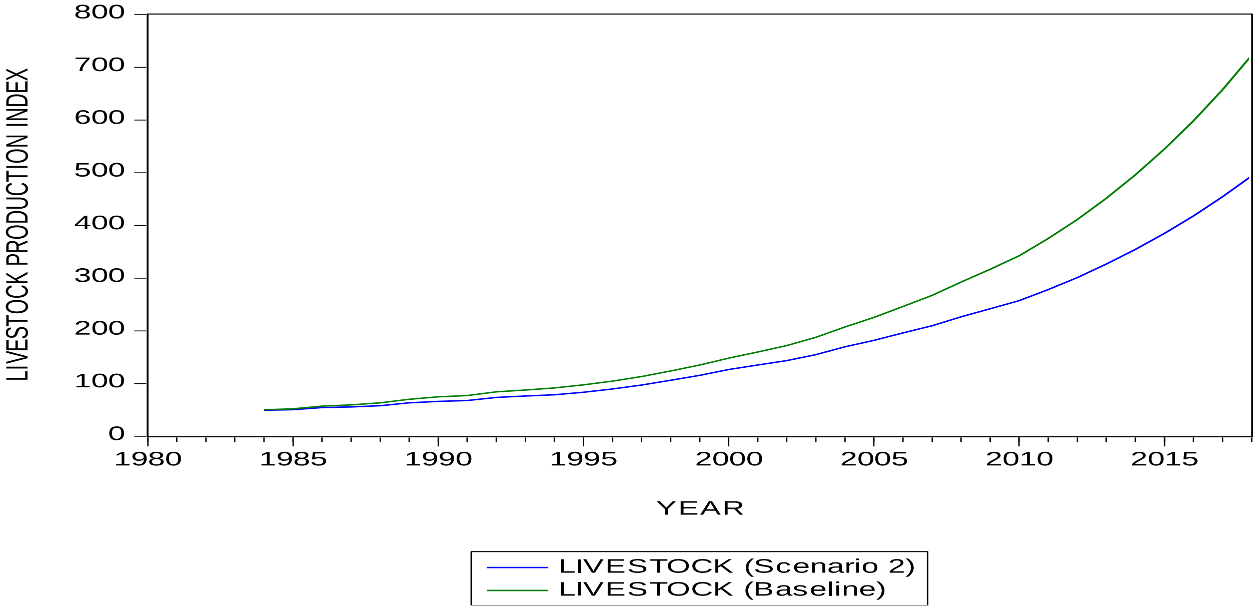


Fig. 7. Effect of a 25% increase in public agricultural spending on livestock production
Source: Eviews data analysis output, 2022.

CONCLUSIONS

Despite the vast amount of fertile land available for the agricultural industry in Cameroon, the country is wedged between west and central African countries, making it a vital location. With this geographic advantage, the country can become a big agricultural exporter if this sector of the economy is properly funded and managed. Unfortunately, due to ineffective agricultural policy, agriculture in Cameroon remains subsistence. Labor, agriculture, and livestock subsector production were all determined to be stagnant in this study. Agriculture received a lot of government funding throughout the time period under consideration. In the short run, labor had a major impact on crop subsector output. In the short run, agricultural land, labor, and public agricultural investment all have a substantial impact on livestock subsector output. Furthermore, the analysis found that a 25% reduction in public agricultural investment in the short term is the

most effective tool for sustaining crop and livestock output The following are suggested:
-In the medium term, privatization of the government's agricultural development projects will be critical for efficient use of public funds.
-Incentives such as tax reductions and infrastructure development should be set up to attract foreign direct investors (FDI), given that FDI provides direct and indirect employment, technology transfer, and a large capital inflow for the sustainability of agricultural development programs.
-Incentives like as fertilizer distribution, improved varieties, extension delivery services, and low-interest financing facilities for farmers should be encouraged in order to increase farm production and thereby minimize hunger

REFERENCES

[1]Achancho, V., 2013, Review and analysis of national investment strategies and agricultural policies in central Africa: The Case of Cameroun, In: Rebuilding West Africa's Food Potential. A. Elbehri (ed.), FAO/IFAD.
[2]African Development Bank (AFDB)., 2017, Competitiveness and Economic Growth Support Programme (PACCE). Appraisal Report for Cameroon.
[3]Balaj, D., Lani, L., 2017, The Impact of Public Expenditures on Economic Growth of Kosovo. Oeconomica, 13(5): 401-412.
[4]Bamou, E., Masters, W. A., 2007, Distortions to Agricultural Incentives in Cameroon. Agricultural Distortion Working Paper 4, World Bank Development Research Group. p.6.
[5]Barett, C. B., 1996, Market analysis methods: Are our Enriched Toolkits Well-Suited to Enlivened markets? American Journal of Agricultural Economics, 78(3):825-829.
[6]Benin, S., Mogues, T., Cudjoe, G., Randriamamonjy, J., 2009, Public expenditures and agricultural productivity growth in Ghana. Contributed Paper. IAAE, 1-32.
[7]Bhanumurthy, K. V., 2002, Arguing a case for the Cobb-Douglas production. Review of commerce studies, Delhi, India.
[8]Bokagne, F., 2006, Évolution et situation actuelle de l'agriculture et de l'élevage. Rapport de synthèse. MINADER – OCDE - Projet « Appui à l'Agriculture Africaine» P3A.
[9]Djomo, C. R. F., 2015, Analysis of Technical Efficiency and Profitability in Small Scale Rice Production in the West Region of Cameroon. M.Sc. Thesis submitted to the Department of Agricultural Economics. University of Agriculture, Makurdi-Benue State, Nigeria. Pp1.
[10]Djomo, C. R. F., Aye, G. C., Ukpe, U. H., Ngo, V. N., Gbadebo, O., Oben, N, E., 2020, Maximizing Agricultural Growth Policy Space Through Public Expenditures and Foreign Direct Investment in Cameroon (1985–2016), G. Odularu (ed.), Nutrition, Sustainable Agriculture and Climate Change in Africa, Issues and Innovative Strategies, https://doi.org/10.1007/978-3-030-47875-9_10 ©Palgrave Macmillan under exclusive license to Springer Nature Switzerland AG, Gewerbestrasse 11, 6330 Cham, Switzerland. Chapter 10: pp 133-155. https://www.palgrave.com/gp/book/9783030478742#, Accessed on 23/12/2022.
[11]Djoumessi, E. C. K., 2009, Financial Development and Economic Growth: A Comparative Study between Cameroon and South Africa. M.Sc. thesis submitted to the Department of Economics, University of South Africa. 192pp.
[12]Food and Agriculture Organization of the United Nations (FAO)., International Fund for Agricultural Development (IFAD)., United Nations Children's Fund (UNICEF)., World Food Programme (WFP)., and World Health Organization (WHO)., 2020, The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets. Rome, FAO.
[13]Gajate-Garrido G., 2013, Excluding the Rural Population: The Impact of Public Expenditure on Child Malnutrition in Peru. Policy Research Working Paper No 6666. World Bank, Washington D.C. https://openknowledge.worldbank.org/handle/10986/16880, Accessed on 27/11/2022.
[14]Gama E., 2013, Analysis of productivity and economic efficiency of cocoa farmers in the South-West Region of Cameroon. PhD thesis submitted at the Department of Agricultural Economics and Rural Sociology, Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria. 2013. 1pp.
[15]Gbetnkom, D., Khan, S. A., 2002, Determinants of Agricultural Exports: The Case of Cameroon being an emerging country. An African Economic Research Consortium Research Paper 120, Nairobi, Kenya.
[16]Gui-Diby S L., 2016, Essays on the Impact of Foreign Direct Investments in Africa. Economies and finances. Université d'Auvergne - Clermont-Ferrand I, English. CLF10489>.<tel-01282942>
[17]Husnain, M. I., Khan, M., Padda, I. H., Akram, N., Haider, A., 2011, Public Spending, Foreign Direct Investment and Economic Growth: A Time Series Analysis for Pakistan (1975-2008). International Research Journal of Finance and Economics, 61: 20-28.
[18]Lencucha, R., Pal, N. E., Appau, A., Thow, A.M., Drope, J., 2020, Government policy and agricultural policy: A scoping review to inform research and policy on healthy agricultural commodities. Globalization and health, 16 (11): 1-15.
[19]Muhammad, I. J. A., Attiya Y J., 2013, Inflation, Economic Growth and Government Expenditure of

Pakistan: 1980-2010. Procedia Economics and Finance, 25: 58 – 67.

[20]Nde T AA., 2016, Analysis of the Nexus Betweeen Agricultural Commodity Trade and Agricultural growth in Cameroon: 1970 - 2014. An unpublished Master of Science (M.Sc.) thesis submitted to the Department of Agricultural Economics, University of Agriculture Makurdi, Nigeria. p. 61.

[21]New Partnership for African Development (NEPAD)., 2012, African Gender, climate change and agriculture support program (GCCASP). Cameroon National Desk Review Report.

[22]Pernechele V., Fontes F., Baborska R., Nana J C N., Pan X., TuyishimeC., 2021, Public expenditure on food and agriculture in sub-Saharan Africa: trends, challenges and priorities. http://www.fao.org/3/cb4492en/cb4492en.pdf, Accessed on 13/11/2022.

[23]Ravallion, M., Datt, G., 1999, When is growth pro-poor? Evidence from the diverse experiences of India's states. Policy research working paper 2263, World Bank, Washington, DC.

[24]Solow, R.M., 1956, A contribution of the theory of economic growth. Quarterly Journal of Economics, 70: 65-94.

[25]Uboh, E., Oduh, M., Ujah, O., 2012, Drivers and Sustainability of Agricultural Growth in Nigeria. African Institute for Applied Economics, Enugu, Nigeria. Research paper 8: 1-51.

[26]Ukpe, U. H., Djomo, C. R. F., Onuigbo, I., Nwalem, P. M., 2018, Macroeconomic Determinants and Forecast of Agricultural Growth in Nigeria. International Journal of Academic Research in Economics and Management Sciences. 7(1):37-52

[27]Ukpe, U, H., 2018, The Role of Public External Debt and Private Investment as drivers for Agricultural Growth in Nigeria: 1980-2016. Ph.D Thesis submitted to the Department of Agricultural Economics. University of Agriculture, Makurdi-Benue State, Nigeria. 131pp.

[28] United Nations in Cameroon (UN), 2016, Annual Report. p.11.

[29]Vollrath, D., 2007, Land distribution and international agricultural productivity. American Journal of Agricultural Economics, 89(1):202-2016.

[30]World Bank., 2013, Basic agricultural public expenditure diagnostic review (2003–12) Republic of Cameroon. Strengthening National Comprehensive agricultural public expenditure in Sub-Saharan Africa. Pp.1-131.

[31]World factsbook., 2010, Cameroon economy. www.cia.gov/cia/publication/factsbook/goes/htm, Accessed on 10/03/2023.

[32]www.maponline.com.Camerun. Accessed on 15/10/2022

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BIOCOMPOST VALORIZATION IN THE CONTEXT OF THE CIRCULAR ECONOMY; CASE STUDY IN ORNAMENTAL PLANTS

Cristina URGHE[1], Florin SALA[1,2]

[1]University of Life Sciences "King Michael I" from Timisoara, Timișoara, 300645, Romania, E-mail: ur_cris@yahoo.com; florin_sala@usvt.ro
[2]Agricultural Research and Development Station Lovrin, Lovrin, 307250, Timis County, Romania, E-mail: florin_sala@usvt.ro

Corresponding author: florin_sala@usvt.ro

Abstract

The study analyzed the possibility of capitalizing compost resulting from fermentable organic waste, for the purpose of growing plants. To prepare the growth substrates, compost (Comp) was used in a single variant (V2), as well as in a mixture with peat (Pea) and vermiculite (Ver). Depending on the weight in the mixture (% in volume), the experimental variants resulted: variant V3 – Comp:Pea:Ver, 20:70:10; variant V4 – Comp:Pea:Ver, 30:60:10; variant V5 – Comp:Pea:Ver, 40:50:10. For comparison, a control variant (V1) based on garden soil (GS) was used. The biological material was represented by the species Tagetes patula Durango® Tangerine. The experiment was done on pots. Vegetative parameters, tagetes shoots diameter (TsD), tagetes shoots number (TsN), tagetes plant height (TpH), tagetes plants diameter (TpD) were determined and the ratio TpH/TpD was calculated; floral quality indices, tagetes inflorescence number (TiN), tagetes inflorescence diameter (TiD). The determinations were made during the vegetation period, at six different times, T1 to T6, between March and October. Correlations were identified between the considered parameters and indices. Based on the PCA, the common orientation of the vegetative parameter TpD with the index of floral quality TiD, respectively of the parameter TpH with TiN was found. PC1 explained 45.648% of variance, and PC2 explained 22.774% of variance. Scaling dendrogram resulted for variant classification. Mathematical models resulted through regression analysis, which described the variation of floral quality indices (TiN and TiD) in relation to vegetative parameters, with 3D graphic representation and in the form of isoquants.

Key words: *circular economy, compost, growth substrate, models, Tagetes*

INTRODUCTION

The circular economy is considered as an effective tool in the context of sustainable development [1]. The circular economy appeared as a potential solution, starting from a concept based on technology to generate economic gains and through the balanced exploitation of resources [27].
Some researchers [4] found how the circular economy has become a popular paradigm in the political and business sphere, and highlighted positive aspects but also some potential shortcomings (reduced impact by focusing on incremental innovations, generating some negative effects).
Morone and Imbert (2020) [14] considered that the circular bioeconomy must rely as much as possible on waste and residual raw materials in order to be socially accepted, and in this way it would reduce dependence and pressure on crops.
In the context of the circular economy, certain categories of waste (e.g. food waste) represent an important residual raw material, which can be converted into biofuels, bioplastics [14]. The fermentable waste that comes from human activities (anthropic ecosystems) represents a residual raw material that can be converted into different types of products such as biofuels, bioplastics, biocompost, etc. [14, 21].
Organic waste represents a source with high potential of renewable energy, with processing under controlled conditions (anaerobic digestion), a fact that facilitates energy recovery and reducing the impact on the environment [9]. An alternative to anaerobic digestion is the composting of some categories of fermentable waste, in relation to

the properties of organic waste and the quantification of energy consumption, in balance with the beneficial ecological, economic and social effects.

In addition to reducing food waste, attracting food waste as residual raw materials and valorizing it through different processing methods in the circular economy is of great interest [16, 19, 22].

The bioconversion of waste is seen as a sustainable means of valorizing resources from the perspectives of population growth and the growing need for energy [3]. In the management of organic waste, composting has been recognized as a dual technology [21]. As the circular economy is based on innovative technologies, waste composting is a technology that practically integrates into the valorization of residual raw materials, thus changing the paradigm "from waste to resources" [21].

Depending on the type and properties of fermentable organic waste, considered for composting, the major components present in the organic matter (C, N, P, K) were studied, different procedures for improving the final product, respectively compost, by adding some ingredients in the process composting (e.g. organo-mineral components, or minerals) [2, 18, 21]. Fermentation installations and methods were also tested, as well as analytical installations to monitor the process [7, 26]. Different physical, chemical, biological or microbiological testing methods were used to evaluate the quality of the final product (compost), but "in situ" testing with test plant species showed high interest [18]. An integrated approach and "multi-stakeholder" cooperation have proven to be beneficial in the success of the valorization of fermentable organic waste through composting [13].

Plant crops systems have the ability to utilize, in the form of compost, different categories of organic or mineral waste, originating from other sectors of the economy [5, 15].

In urban ecosystems, green spaces require different types of substrate, in relation to the quality of the soil, of the developed land, but also the ecophysiological conquests of ornamental plant species [8, 24]. Compost can represent a dominant component for making substrates, to which other organic, mineral or organo-mineral components can be added.

The circular economy takes into account the valorization of waste and the integration of the resulting products in a balanced way in the "ecological - economic - social" triad.

In this context, the present study tested the compost resulting from the recycling of some fermentable organic waste, together with other components, as substrates for plant growth, and described through mathematical and statistical methods the variation of some vegetative parameters and indices of floral quality in the biological material.

MATERIALS AND METHODS

The study analyzed the possibility of using a compost product in the cultivation of ornamental plants, in the context of the circular economy.

The compost was obtained from the fermentation of fermentable organic waste (FOW) currently collected at the urban locality level (e.g. Oradea Municipality). The organic waste was fermented in a controlled manner through a composting process (CP), within our ecological platform (Municipality of Oradea).

The compost (Comp) was used in different variants (alone – V2), or mixed with other components for growth substrates, such as peat (Pea), and vermiculite (Ver). Depending on the weight in the mixture (components in the mixture, in %), the experimental variants resulted: Comp:Pea:Ver (20:70:10), variant V3; Comp:Pea:Ver (30:60:10), variant V4; Comp:Pea:Ver (40:50:10), variant V5. For comparison, a control variant was used, with the substrate based on garden soil (V1), figure 1. The experiment was organized in pots, Salonta Locality, Bihor County.

The biological material was represented by the species *Tagetes patula* Durango® Tangerine. A species was chosen that lends itself to being cultivated on different growth substrates, in conditions of open spaces, but also in protected spaces. At the same time, *Tagetes* is a species with multiple valences of

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use for ornamental, pharmaceutical and medicinal purposes (based on the active principles), cosmetics, as well as for food purposes [6, 17].

To evaluate the growth and development of plants in relation to the growth substrate, a series of vegetative (physiological) plant parameters were evaluated: Tagetes shoots diameter (TsD), tagetes shoots number (TsN), tagetes plant height (TpH), tagetes plants diameter (TpD) and the TpH/TpD ratio was calculated.

Floral quality indices were used to evaluate the inflorescences: tagetes inflorescence number (TiN), tagetes inflorescence diameter (TiD). The determination of the considered parameters and indexes was done monthly, at six different times (T1 to T6), evolving during the vegetation period, in the interval April - October.

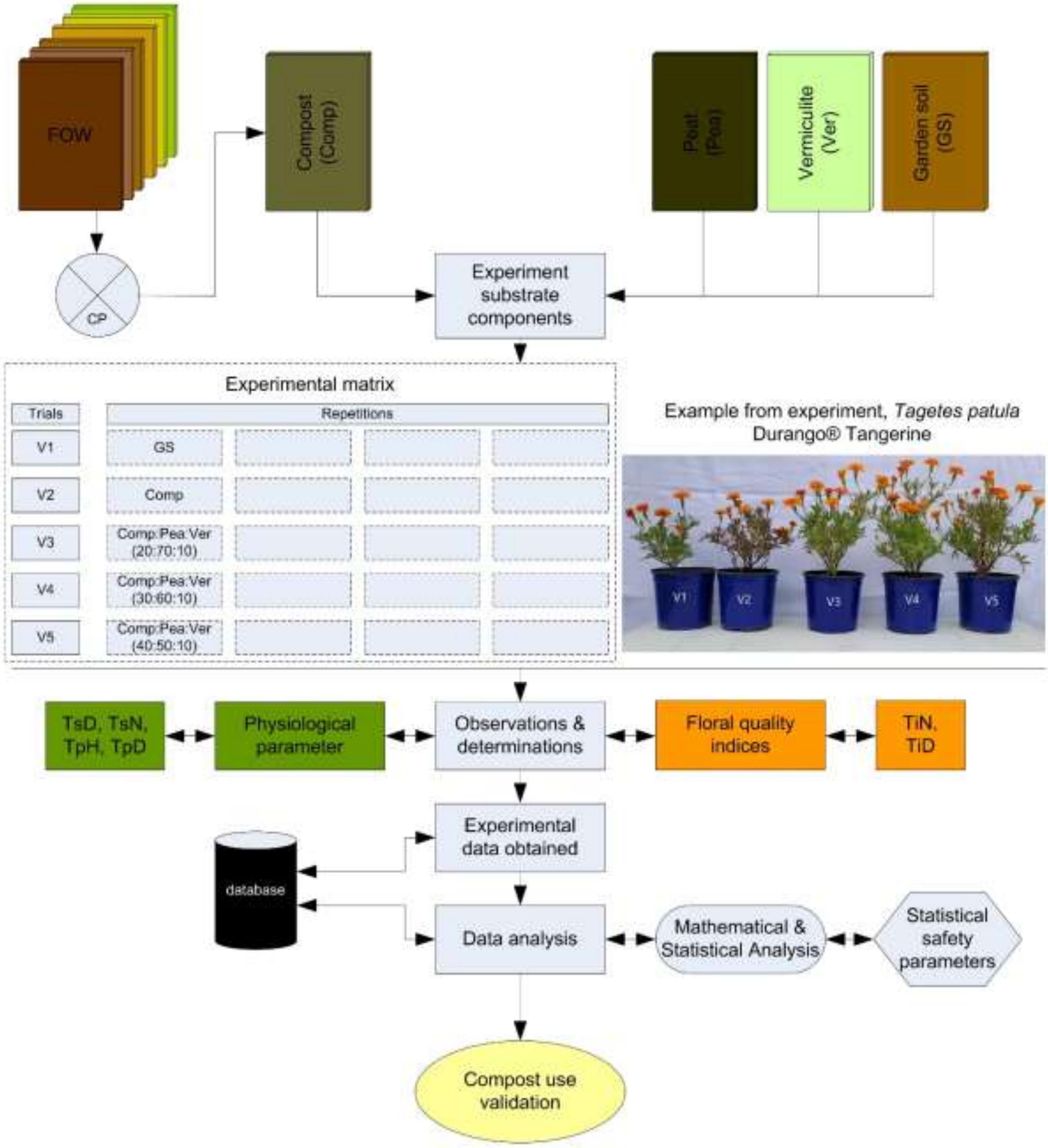

Fig. 1. Experimental flow chart
Source: Original figure.

The recorded experimental data were analyzed for statistical reliability, the presence of variance, the time variation of the studied parameters and indices, the distribution of the variants in relation to the recorded indices, the variation of floral quality indices in relation to vegetative parameters, in the study conditions. Appropriate mathematical and statistical analysis tools were used [10, 12, 28]. A flow chart designed by the authors, shown in Figure 1, was used to conduct the study.

RESULTS AND DISCUSSIONS

Physiological parameters (TsD, TsN, TpH, TpD) and floral quality indices (TiN, TiD) in *Tagetes patula* were determined at six different times, between April 22 and October 22, and the recorded values are presented in Table 1.

The test Anova confirmed the statistical reliability of the data and statistical reliability in the set of recorded experimental data ($p<0.001$, $F > Fcrit$; $Alpha=0.001$), Table 2.

Table 1. Values of the parameters of *Tagetes patula* Durango® Tangerine in the experimental conditions

Trial	TsD	TsN	TpH	TpD	TpH/TpD	TiN	TiD
	(mm)	(no.)	(cm)	(cm)		(no.)	(cm)
V1-T1	3.50	9.25	20.38	13.13	1.55	1.00	3.81
V2-T1	6.50	26.75	26.38	24.88	1.06	3.75	5.82
V3-T1	6.75	22.50	29.13	25.75	1.13	3.25	5.86
V4-T1	7.00	22.50	29.00	25.25	1.15	3.75	5.92
V5-T1	7.13	22.25	28.38	25.50	1.11	3.75	6.03
V1-T2	4.20	21.50	25.38	20.95	1.21	2.75	4.62
V2-T2	6.90	40.25	28.00	27.00	1.04	2.50	4.75
V3-T2	7.38	38.00	34.38	26.38	1.30	5.25	5.34
V4-T2	7.88	42.00	35.38	28.88	1.23	4.25	4.96
V5-T2	7.75	45.00	30.63	27.25	1.12	3.75	5.21
V1-T3	4.50	28.50	26.00	22.38	1.16	1.75	4.24
V2-T3	8.00	27.00	19.50	17.50	1.11	1.00	4.10
V3-T3	7.75	58.00	32.50	28.50	1.14	4.00	4.64
V4-T3	8.13	60.50	34.13	29.00	1.18	4.50	4.18
V5-T3	8.00	60.25	30.50	28.50	1.07	6.25	4.52
V1-T4	4.63	15.50	22.00	14.78	1.49	1.00	3.70
V2-T4	7.50	25.00	22.75	22.00	1.03	2.00	4.05
V3-T4	7.38	25.25	29.00	21.75	1.33	5.25	3.68
V4-T4	8.00	24.00	29.00	26.00	1.12	1.00	3.20
V5-T4	8.25	22.50	22.00	22.50	0.98	0.50	4.10
V1-T5	4.67	30.33	23.67	22.83	1.04	5.00	4.32
V2-T5	7.50	32.00	22.00	31.00	0.71	4.50	7.23
V3-T5	7.00	29.00	33.00	26.50	1.25	5.00	4.08
V4-T5	10.00	29.00	32.00	34.00	0.94	6.00	5.13
V5-T5	8.50	31.00	28.00	33.00	0.85	5.00	4.13
V1-T6	4.83	34.67	23.17	25.83	0.90	5.33	4.36
V2-T6	7.75	34.00	23.25	7.75	3.00	7.50	4.77
V3-T6	7.75	26.50	31.50	7.75	4.06	3.50	4.23
V4-T6	9.50	33.00	28.00	9.50	2.95	4.00	5.07
V5-T6	8.50	29.00	27.50	8.50	3.24	6.00	4.20
SE	±0.29	±2.20	±0.80	±1.34	±0.14	±0.33	±0.16

Source: Original data from the experiment.

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Table 2. Anova test values

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	28950.91	6	4825.152	149.4423	1.18E-71	3.917582
Within Groups	6554.408	203	32.28772			
Total	35505.32	209				

Source: Original data, calculation results.

The correlation analysis led to the values presented in table 3, under statistical safety conditions (p<0.05; p<0.01). A strong, negative correlation was recorded between TpD and the TpH/TpD ratio (r=-0.838***), weak correlation between Tsn and TpH (r=0.555**). Correlations of low intensity were recorded between other determined parameters, under conditions of statistical safety.

Table 3. Correlation table

Variable		TsD	TsN	TpH	TpD	TpH/TpD	TiN	TiD
TsD	Pearson's r	—						
	p-value	—						
TsN	Pearson's r	0.390*	—					
	p-value	0.033	—					
TpH	Pearson's r	0.447*	0.555**	—				
	p-value	0.013	0.001	—				
TpD	Pearson's r	0.149	0.387*	0.390*	—			
	p-value	0.432	0.034	0.033	—			
TpH/TpD	Pearson's r	0.202	-0.096	0.062	-0.838***	—		
	p-value	0.283	0.614	0.744	< .001	—		
TiN	Pearson's r	0.342	0.466**	0.424*	0.118	0.216	—	
	p-value	0.064	0.009	0.019	0.536	0.251	—	
TiD	Pearson's r	0.151	0.090	0.117	0.304	-0.157	0.285	—
	p-value	0.425	0.638	0.539	0.102	0.407	0.126	—
* p < .05, ** p < .01, *** p < .001								

Source: Original data.

According to the PCA, the diagram in Figure 2 resulted, in which the variants were distributed in relation to the contribution to the achievement of the vegetative parameters and the evaluated physiological indices (I will plot in the PCA diagram).

It was found, first of all, the common orientation of the vegetative parameter TpD with the index of floral quality TiD, respectively of the parameter TpH with TiN. The experimental variants were distributed differently in relation to the considered parameters and indexes. PC1 explained 45.648% of variance, and PC2 explained 22.774% of variance).

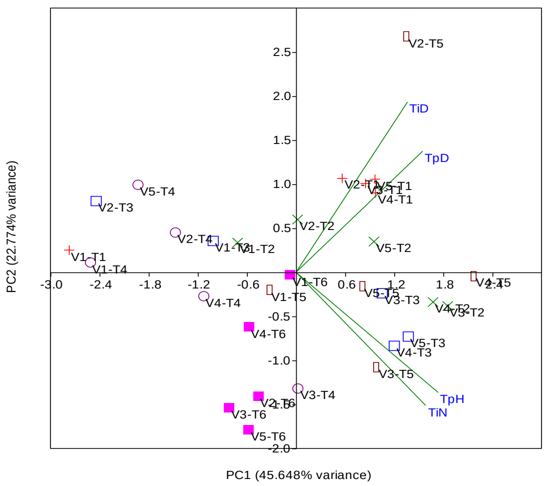


Fig. 2. PCA diagram regarding the experimental variants of *Tagetes patula* in relation to the considered parameters and indices
Source: Original figure.

The experimental variants were ranked, based on Ranking-Scaling, in relation to vegetative parameters (TpD, TpH) and floral quality indices (TiN, TiD) considering the values recorded during the vegetation period, and the six moments of determination, Figure 3.

The variation in the number of inflorescences, as floral quality index (TiN), was evaluated by regression analysis and the result was equation (1) as a general model of variation (Multiple R=0.507). The graphic distribution of TiN variation in relation to TsD (x-axis) and TpH (y-axes) is presented in figure 4.

$$TiN = a\,x^2 + b\,y^2 + c\,x + d\,y + ex\,y + f \quad (1)$$

where:
TiN – Tagetes inflorescence number (no.); x – TsD – Tagetes shoot diameter (mm); y – TpH – Tagetes plant height (cm); a, b, c, d, e, f – coefficients of the equation (1); a= -0.12229550; b= -0.01996708;
c= -0.47033993; d= 0.52756729;
e= 0.09256904; f= -3.82428478.

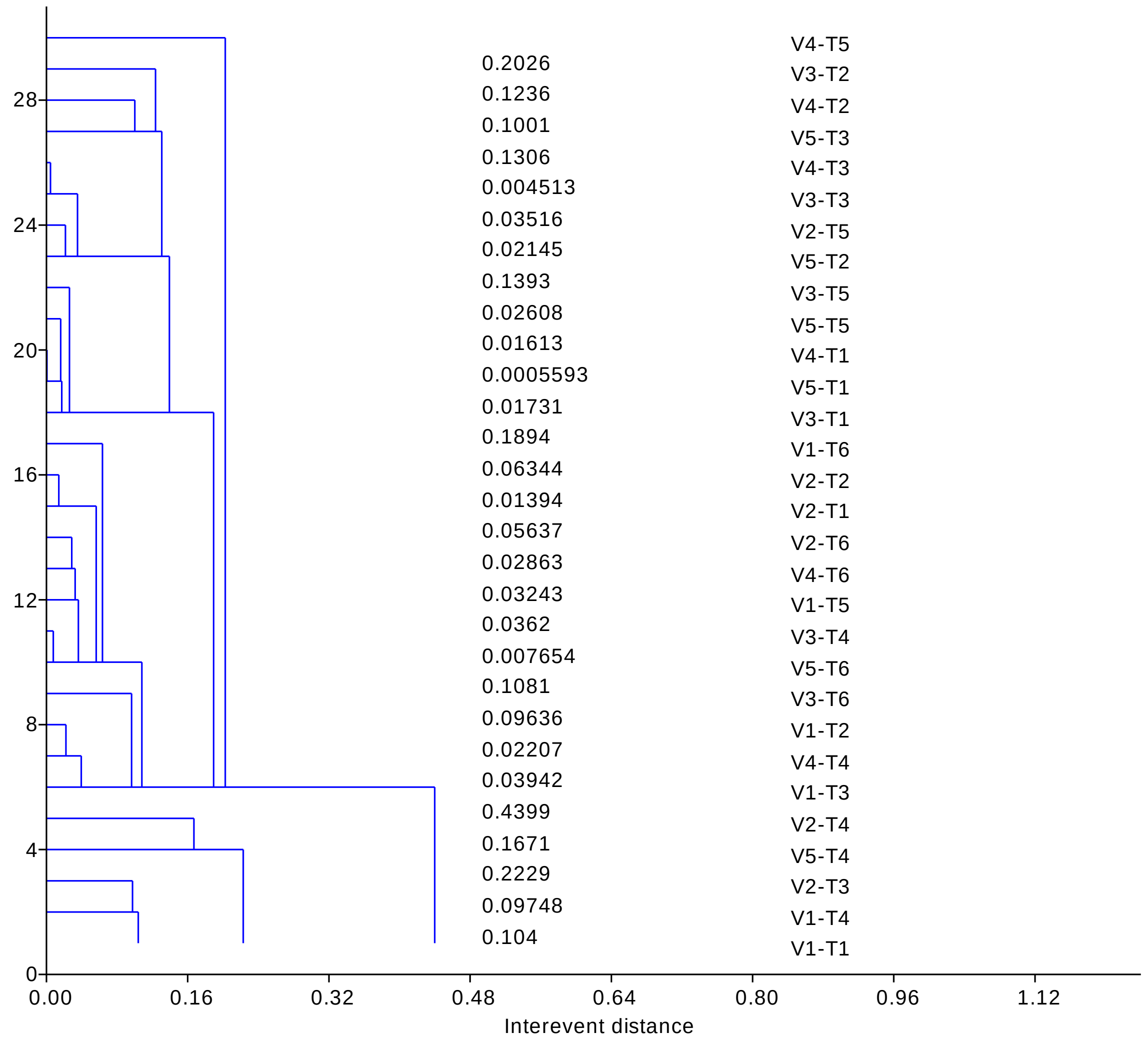
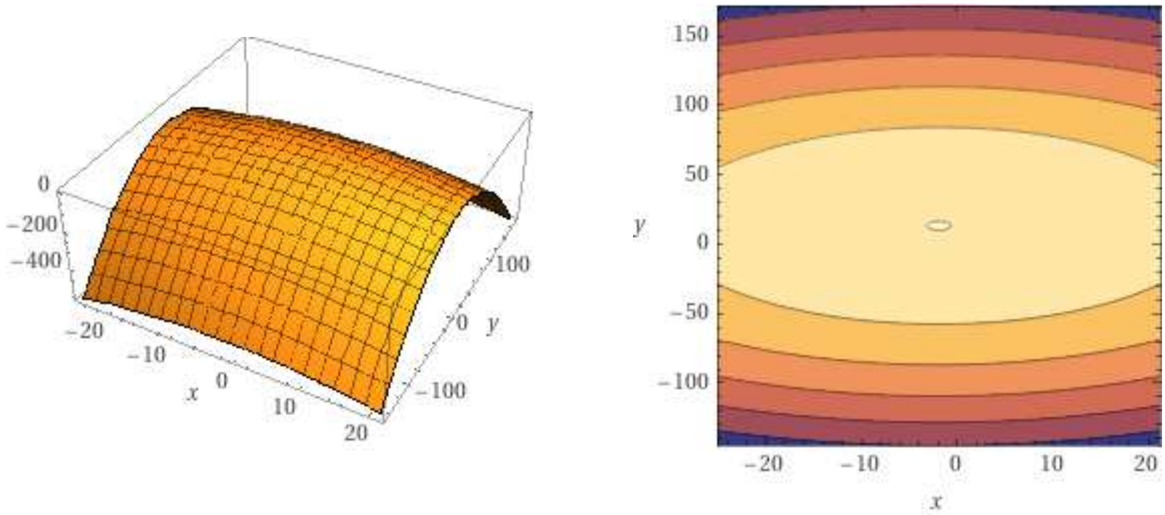


Fig 3. Scaling dendrogram for the experimental variants
Source: Original figure.



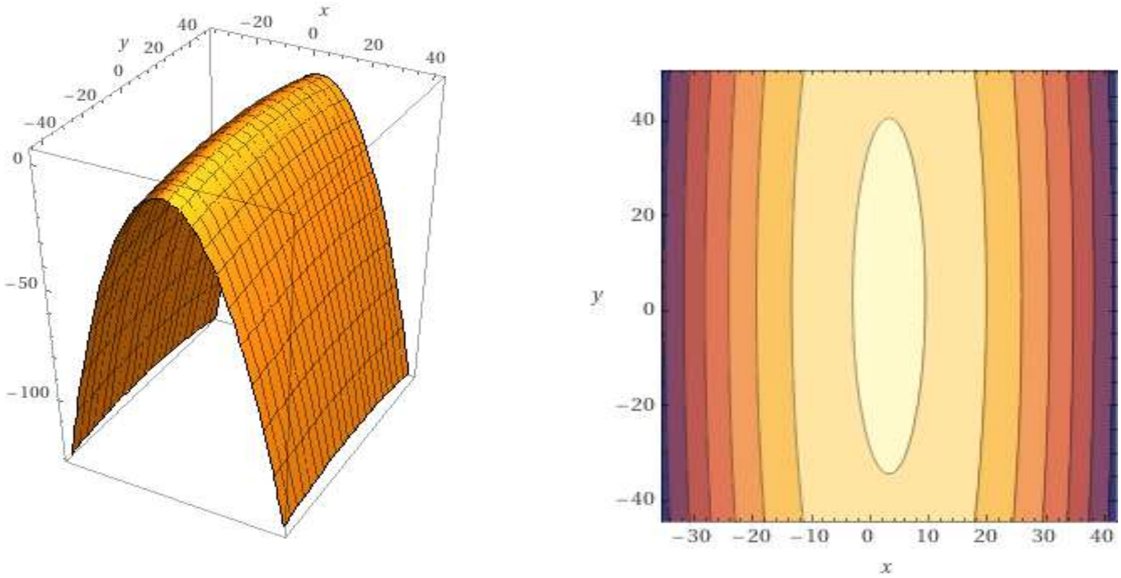
(a) (b)

Fig. 4. Spatial distribution of the TiN index in relation to TsD (x-axis) and TpH (y-axes)
Source: Original figure.

Inflorescence diameter variation, as floral quality index (TiD), was described by equation (2) as a general model of variation, in conditions of Multiple R=0.377 in relation to TsD and TsN, respectively in conditions of Multiple R=0.451 in relationship with TpH and TpD. The graphic distribution of the variation of TiD in relation to TsD (x-axis) and TsN (y-axes) is presented in Figure 5, and the variation of TiD in relation to TpH and TpD is presented in Figure 6.

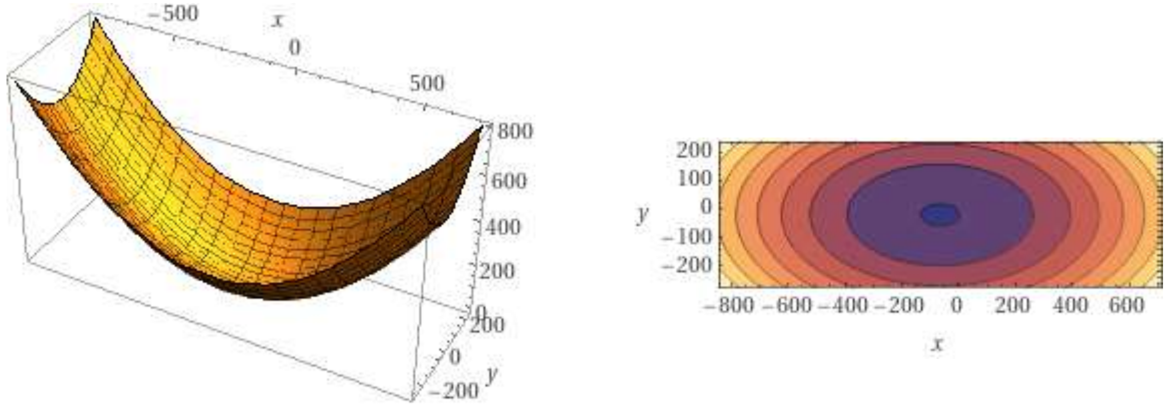
$$TiD = a\,x^2 + b\,y^2 + c\,x + d\,y + ex\,y + f \quad (2)$$

where:
TiD – Tagetes inflorescence diameter (cm); *x* – TsD – Tagetes shoot diameter (mm); *x* – TpH – Tagetes plant height (cm); *y* – TsN – Tagetes shoot number (cm); *y* – TpD – Tagetes plant Diameter (cm); a, b, c, d, e, f – coefficients of the equation (2); values in relation to TsD and TsN: a= -0.12229550; b= -0.01996708; c=-0.47033993; d= 0.52756729; e=0.09256904;f=-3.82428478; values in relation to TpH and TpD: a= 0.00098191; b= 0.00334110; c= 0.12681571; d= 0.14228610; e= -0.00856014;f= 0.74208576.



(a) (b)

Fig. 5. TiD variation in relation to TsD (x-axis) and TsN (y-axes)
Source: Original figure.



(a) (b)

Fig. 6. TiD variation in relation to TpH (x-axis) and TpD (y-axis)
Source: Original figure.

The differences generated by variants V2 to V5 compared to variant V1 (control) were calculated. The calculations resulted in different values of the growth rate (Δ) generated by the growth substrate, depending on the analyzed parameters. In the case of ΔTsD, positive values were recorded for all variants and for the entire study period (March - October) in relation to V1, values between 2.33 - 5.33 mm. In the case of ΔTsN, positive values were recorded (in the first part of the vegetation period T1 to T4), but also negative values, especially in the last months of the vegetation period (T5 - T6). In the case of ΔTpH, positive increases were recorded with the exception of the V2T3 and V2T5 variants. In the case of ΔTpD, positive increases were recorded in the case of the first five determination moments (T1 to T5, except V2T3) and negative values at the T6 determination moment. In the case of ΔTiN, positive increases were recorded in most variants, with some exceptions (V2T2, V2T3, V5T4, V2T5, V3T6 and V4T6). In the case of ΔTiD, positive increases were also recorded, with some exceptions for certain variants and determining moments (V2T3, V4T3, V3T4, V4T4, V3T5, V5T5V3T6 and V5T6). The graphic distribution of the increase calculated for all cases is presented in Figure 7.

Fermentable organic residues represent a rich source of nutrients and organic matter, so necessary for the soil, by composting their nutritional value increases for the soil and plants and can be used as an organic fertilizer or as a component for different growth substrates [20]. The use in agriculture (horticulture, forestry) of composts resulting from municipal solid organic waste has also been studied from ecological and environmental protection perspectives, in the sense of improving the composting process and reducing the impact [25].

Sayara et al. (2020) [23] considered composting to be a technology that can be implemented at any scale, both in large, industrial plants and at family level, of course with some differences regarding the categories of waste components, work facilities, performance and composting yield to. Imran et al. (2022) [11] reported an increase in chlorophyll content (≈35%), biomass (≈25%) and yield (75%) in vegetable species through the use of compost.

Associated with better nutrition, the authors of the study recorded an increase in the content of mineral elements in the samples of the studied vegetable species (hot peppers, tomatoes).

Composting technology, composting parameters and optimal composting conditions, evaluation criteria, conversion processes of organic matter and some mineral elements (e.g. P) were studied to optimize, reduce the impact on the environment and increase the efficiency of compost as a product [29].

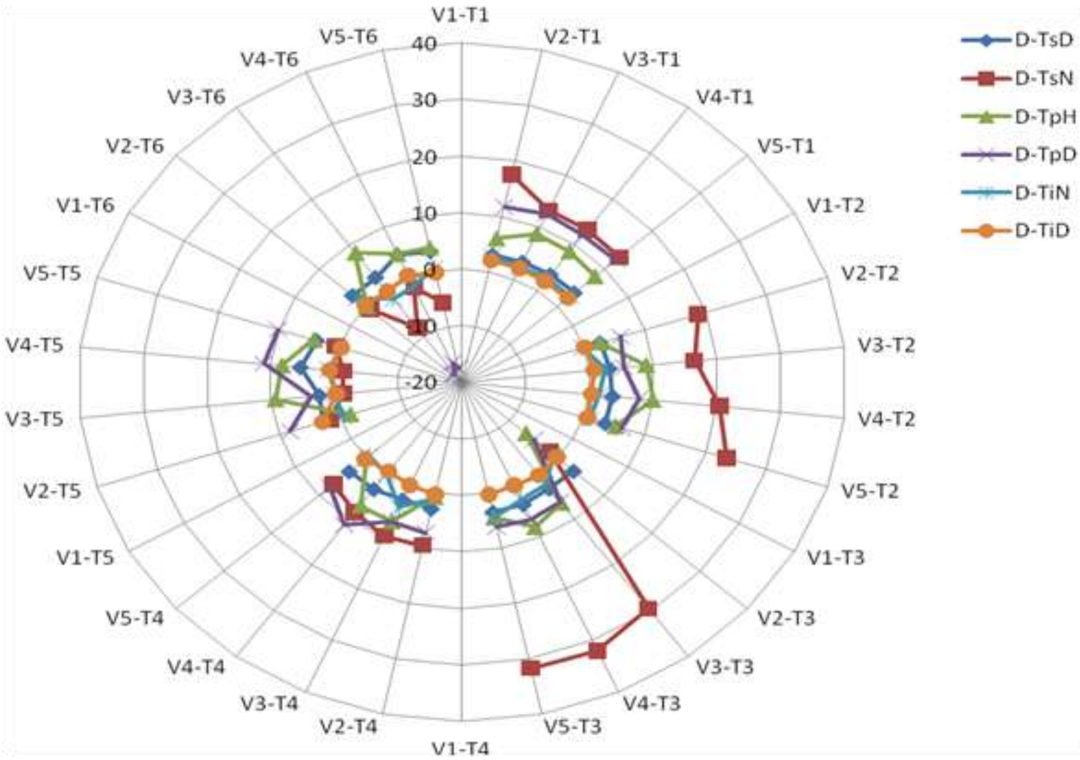


Fig. 7. Graphic representation of the calculated Δ values
Source: Original figure.

The present study was also included in this context, to evaluate the effect of a compost resulting from the fermentation of fermentable urban waste, in the culture of ornamental plants, and the results provided show the potential of the compost as well as some shortcomings in the study conditions. The results recorded, analyzed and properly interpreted can provide an information base for other similar studies, with theoretical, scientific and practical applicability.

CONCLUSIONS

The compost resulting from the fermentation of organic waste, used alone and in combination with peat and vermiculite ensured the obtaining of favorable substrates for the growth of ornamental plants, *Tagetes patula* Durango® Tangerine.

Physiological parameters (TsD, TsN, TpH, TpD) and floral quality indices (TiN, TiD) showed variable dynamics during the study period, in relation to the specifics of each parameter and the experimental variants.

Correlations varying in intensity between the studied parameters were recorded. According to PCA, the common orientation of the vegetative parameter TpD with the index of floral quality TiD, respectively of the parameter TpH with TiN was found. The experimental variants were distributed differently in relation to the considered parameters and indexes. PC1 explained 45.648% of variance, and PC2 explained 22.774% of variance).

The ranking of the variants was obtained, of the Ranking-Scaling type, in relation to vegetative parameters (TpD, TpH) and floral quality indices (TiN, TiD).

Equation-type models, and 3D and isoquant graphic models resulted from the regression analysis, and described the variation of floral quality indices (TiN, TiD) in relation to vegetative parameters, under the study conditions under the influence of growth sub-treatments.

REFERENCES

[1]Arruda, E.H., Melatto, R.A.P.B., Lewy, W., Conti, D.M., 2021, Circular economy: A brief literature

review (2015–2020), Sustain. Operations Comput., 2:79-86.

[2]Barthod, J., Rumpel, C., Dignac, MF., 2018, Composting with additives to improve organic amendments. A review, Agron. Sustain. Dev., 38:17.

[3]Bibra, M., Samanta, D., Sharma, N.K., Singh, G., Johnson, G.R., Sani, R.K., 2023, Food waste to bioethanol: Opportunities and challenges, Fermentation, 9:8.

[4]Bocken, N.M.P., Niessen, L., Short, S.W., 2022, The sufficiency-based circular economy - An analysis of 150 companies, Front. Sustain., 3:899289.

[5]Chen, T., Zhang, S., Yuan, Z., 2020, Adoption of solid organic waste composting products: A critical review, J. Clean. Prod. 272:122712.

[6]Chkhikvishvili, I., Sanikidze, T., Gogia, N., Enukidze, M., Machavariani, M., Kipiani, N., Vinokur, Y., Rodov, V., 2016, Constituents of French marigold (*Tagetes patula* L.) flowers protect jurkat T-cells against oxidative stress, Oxid. Med. Cell. Longev., 2016:4216285.

[7]Esercizio, N., Lanzilli, M., Vastano, M., Landi, S., Xu, Z., Gallo, C., Nuzzo, G., Manzo, E., Fontana, A., d'Ippolito, G., 2021, Fermentation of biodegradable organic waste by the family thermotogaceae, Resources, 10:34.

[8]Francini, A., Romano, D., Toscano, S., Ferrante, A., 2022, The contribution of ornamental plants to urban ecosystem services, Earth, 3:1258-1274.

[9]Grosser, A., Neczaj, E., 2022, Anaerobic digestion, In: Book Editor(s): Kacprzak, M., Attard, E., Lyng, K.-A., Raclavska, H., Singh, B.R., Tesfamariam, E., Vandenbulcke, F., Biodegradable waste management in the circular economy: Challenges and opportunities, https://doi.org/10.1002/9781119679523.ch8

[10]Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001, PAST: Paleontological Statistics software package for education and data analysis, Palaeontol. Electron., 4(1):1-9.

[11]Imran, A., Sardar, F., Khaliq, Z., Nawaz, M.S., Shehzad, A., Ahmad, M., Yasmin, S., Hakim, S., Mirza, B.S., Mubeen, F., Mirza, M.S., 2022, Tailored bioactive compost from agri-waste improves the growth and yield of chili pepper and tomato, Front. Bioeng. Biotechnol., 9:787764.

[12]JASP Team, 2022, JASP (Version 0.16.2)[Computer software].

[13]Mihai, F.-C., Plana, R., Arizmendiarrieta, J.S., Irigoyen, I., 2023, Chapter 13 - Business models of composting for a circular economy, Current Developments in Biotechnology and Bioengineering Advances in Composting and Vermicomposting Technology, ISBN: 9780323919029, pp. 319-345.

[14]Morone, P., Imbert, E., 2020, Food waste and social acceptance of a circular bioeconomy: the role of stakeholders, Curr. Opin. Green Sustain. Chem., 23:55-60.

[15]Moschou, C.E., Papadimitriou, D.M., Galliou, F., Markakis, N., Papastefanakis, N., Daskalakis, G., Sabathianakis, M., Stathopoulou, E., Bouki, C., Daliakopoulos, I.N., Manios, T., 2022, Grocery waste compost as an alternative hydroponic growing medium, Agronomy, 12:789.

[16]Ortiz-Sanchez, M., Inocencio-García, P.-J., Alzate-Ramírez, A.F., Alzate, C.A.C., 2023, Potential and restrictions of food-waste valorization through fermentation processes, Fermentation, 9:274.

[17]Riaz, M., Ahmad, R., Rahman, N.U., Khan, Z., Dou, D., Sechel, G., Manea, R., 2020, Traditional uses, Phyto-chemistry and pharmacological activities of *Tagetes Patula* L., J. Ethnopharmacol., 255:112718.

[18]Rizzo, P.F., Salinas, M.C., Della Torre, V., Diez, J.P., Sallesses, L.F., Riera, N.I., Pathauer, P.S., Komilis, D., Sánchez, A., 2022, Effect of poultry manure-derived compost on the growth of *Eucalypts* spp. hybrid clones, Processes, 10:2182.

[19]Roy, P., Mohanty, A.K., Dick, P., Misra, M., 2023, A review on the challenges and choices for food waste valorization: Environmental and economic impacts, ACS Environ. Au., 3(2):58-75.

[20]Sala, F., 2011, Agrochemistry (Agrochimie), Eurobit Publishing House, Timisoara, pp. 534.

[21]Sánchez, A., 2023, Special Issue on "Composting in the Framework of a Circular Economy", Processes, 11(5): 1573.

[22]Sánchez, M., Laca, A., Laca, A., Díaz M., 2023, Towards food circular economy: hydrothermal treatment of mixed vegetable and fruit wastes to obtain fermentable sugars and bioactive compounds, Environ. Sci. Pollut. Res., 30:3901-3917.

[23]Sayara, T., Basheer-Salimia, R., Hawamde, F., Sánchez, A., 2020, Recycling of organic wastes through composting: Process performance and compost application in agriculture, Agronomy, 10(11):1838.

[24]Seitz, B., Buchholz, S., Kowarik, I., Herrmann J., Neuerburg L., Wendler J., Winker L., Egerer M., 2022, Land sharing between cultivated and wild plants: urban gardens as hotspots for plant diversity in cities, Urban Ecosyst., 25:927-939.

[25]Srivastava, V., de Araujo, A.S.F., Vaish, B., Bartelt-Hunt S., Singh P., Dingh R.P., 2016, Biological response of using municipal solid waste compost in agriculture as fertilizer supplement, Rev. Environ. Sci. Biotechnol., 15:677-696.

[26]Thygesen, A., Tsapekos, P., Alvarado-Morales, M., Angelidaki I., 2021, Valorization of municipal organic waste into purified lactic acid, Bioresour. Technol., 342:125933.

[27]Velenturf, A.P.M., Purnell, P., 2021, Principles for a sustainable circular economy, Sustain. Prod. Consum., 27:1437-1457.

[28]Wolfram, Research, Inc., Mathematica, Version 12.1, Champaign, IL (2020).

[29]Xie, S., Tran, H.-T., Pu, M., Zhang, T., 2023, Transformation characteristics of organic matter and phosphorus in composting processes of agricultural organic waste: Research trends, Mat. Sci. Energy Technol., 6:331-342.

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SLOVAK FOOD INDUSTRY AND ITS POSITION ON THE DOMESTIC AND FOREIGN MARKETS

Maroš VALACH

Slovak University of Agricultural, Faculty of European Studies and Regional Development, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, Phone: +421 37 641 5654, E-mail: maros.valach@uniag.sk

Corresponding author: maros.valach@uniag.sk

Abstract

The subject of this article's analysis is the position of the Slovak food industry on the domestic and foreign markets. The period under review was 2015-2019. The identification of the share of Slovak products in the retail network was carried out on the basis of two methodological approaches, which are based on statistically available data, one in financial and the other in kind terms. Research results show that the food industry in the Slovak Republic is thriving, with revenues exceeding costs in the long term. Labour productivity from added value, which is an important economic indicator of the industry's competitiveness, grows over time, which is caused by a decrease in the workforce. On the domestic market, it is a priority to resist the pressure of foreign imports and to increase the share of Slovak products in domestic retail network. The low competitiveness of Slovak food products is reflected in the massive import of substitutable food products that can be produced domestically.

Key words: *food industry, competitiveness, domestic market, self-sufficiency, agro-food commodities*

INTRODUCTION

The food industry follows on from agricultural primary production, in addition to food production, it provides jobs with a significant impact on the development of regions. [8] stated that "agri-food refers to primary products derived from plants, forestry, animal husbandry, and fishery, that is, plants, animals, microorganisms, and their products obtained in agricultural activities). Agri-food is the necessity of human survival, which is related to the fate of the human community".

According to [1] and [11] in developing food policies governments are to an increasing extent substituting and supplementing traditional top-down methods of public regulation with more interactive forms of collaborative governance. [5] noted that „in this constellation governments deliberate with relevant stakeholders from the market as well as civil society with the aim of jointly agreeing on a set of measures through having each of the parties commit to taking distinct measures that serve public goals. These new hybrid forms of food governance result in a wide range of voluntary agreements, covenants, pledges, pacts, public–private partnerships or 'deals' in which policy goals, ambitions and measures are spelled out".

According to [4] food industry is a strategic industry, which within the agri-food complex has the potential to ensure a high level of food security in Slovakia while simultaneously respecting the requirements of environmental protection and preserving the principles of sustainable development. Despite the fact that the high quality of Slovak food is guaranteed by strict national legislation, strong competition on the EU market, the policy of trade chains, unbalanced support within agriculture and food industry, insufficient investments in innovation and modernization of the food industry have weakened its competitiveness on the domestic and foreign markets [9].

[3] noted that the food processing industry plays a critical role in generating demand for agricultural raw materials and is an important factor affecting the competitiveness of domestic agricultural production. According to [10] the efficiency of food processing determines the position of domestic production on food markets, both domestic and foreign. The high share of imported

products on the consumer food market and the negative trade balance indicate low competitiveness of the domestic processing industry. Overcapacity and technological backwardness contribute to its low efficiency.

"An important finding about the food industry competitiveness is that the monetary autonomy and the possibility to depreciate national currency is a significant factor that can increase competitiveness and the balance of trade in the times of economic crisis"[2].

According to [7] the decreasing trend of the share of added value in the food industry is to a certain extent caused by the changing share of its level in other sectors of the national economy, but mainly by the decline in production of decisive branches of the food industry and significant imports of finished food products with added value realized outside the Slovak Republic also from primary agricultural raw materials exported from Slovakia.

The potential of the food industry as a generator of added value in the national economy was pointed out by [6], who came to the conclusion that the economic possibilities of this sector compared to other processing industries lie primarily in its innovation capacity as well as the speed of capital turnover. These support the efficiency of intermediate consumption and high labour productivity.

MATERIALS AND METHODS

The chosen methodological procedure corresponds to the material focus of the paper, which is oriented towards selected aspects of food sector competitiveness in the period 2015-2019. The fulfilment of the goal was ensured by analysis, synthesis and comparison of data, which were processed into tabular, graphic and textual form, and expert estimates.

The information platform for the analysis in question was data from the Statistical Office of the Slovak Republic, departmental statistics of the Ministry of Agriculture and Rural Development of the Slovak Republic and from the National Agricultural and Food Centre Branch: Research Institute of Agriculture and Food Economics.

The self-sufficiency rate of agri-food commodities in the Slovak Republic was calculated in accordance with Eurostat's methodological procedure, whereby:

$$Self-sufficiency = \frac{\text{production}}{\text{consumption}} * 100$$
....(1)

The calculation is based on the balance production and consumption of specific commodities, which are published in the relevant situational and outlook reports of the Ministry of Agriculture and Rural Development of the Slovak Republic and from the National Agricultural and Food Centre Branch: Research Institute of Agriculture and Food Economics. In the Food Industry Development Concept for 2014-2020 [4], it is stated that the level of self-sufficiency of strategic raw materials should not be lower than 80%.

To determine the share of Slovak food on the domestic market, two methodological approaches were used, which are based on statistically available data according to selected branches of the food industry, namely:

1) based on sales and financial volume of foreign trade:

- $\text{Share of foreign goods} = \frac{\text{import}}{(\text{sales} - \text{export} + \text{import})} * 100$
....(2)
- $\text{Share of domestic goods} = 100 - \text{share of foreign goods}$
....(3)

2) based on the natural volume of production and foreign trade

- $\text{Share of foreign goods} = \frac{\text{import}}{(\text{production} - \text{export} + \text{import})} * 100$
....(4)
- $\text{Share of domestic goods} = 100 - \text{share of foreign goods}$
....(5)

Both calculations are indicative and must be interpreted with caution due to the potential possibility of certain discrepancies in the database of customs statistics, where the data are not abstracted from re-exports.

In addition, for the financial expression, the choice of respondents in the different food industries may partly vary, mainly due to changes in ownership of existing food businesses, and for the in-kind expression, a limiting factor is the choice of commodities or commodity groups within a given industry, which should correspond to the codes of customs statistics.

Due to the high re-exports, an expert estimate of the monitored indicator was made for the fat and confectionery industries, and only for the first methodological approach.

RESULTS AND DISCUSSIONS

Economic aspects of competitiveness

The food industry as a whole is thriving, with revenues exceeding costs over the long term, which is adequately reflected in profitability indicators. The most favourable cost profitability values in 2019 were recorded in the wine, brewing and malting, canning and confectionery industries (Table 2). A significant part of the cost of one created product consists of material, energy and labour costs.The share of intermediate inputs in production costs in the food industry in 2015-2019 was around 62% (Table 1). In the observed 5-year period, the financial volume of production (revenues from the sale of products and services, activation and changes in inventory levels) of the food industry decreased by 6.5%. Adequately, the volume of sales for own products and services decreased by 6.6% and for the sale of goods by 1.2%.The increase in total added value by 9.8% is positive (Fig. 1).

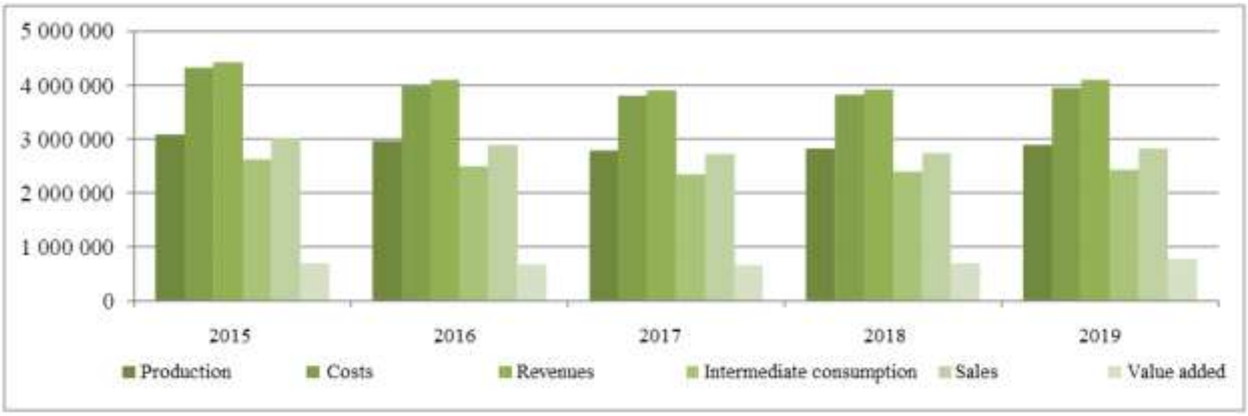

Fig. 1. Development of selected economic indicators of the food industry (thousands EUR)
Source: Ministry of Agriculture and Rural Development of the Slovak Republic; National Agricultural and Food Centre Branch: Research Institute of Agriculture and Food Economics.

Table 1. Analytical indicators of the food industry

Indicator	**2015**	**2016**	**2017**	**2018**	**2019**	**Difference 2019-2015 (%)**
Share of intermediate consumption on costs (%)	60.7	62.9	61.6	62.5	61.6	0.9
Costs effectiveness (%)	2.3	3.2	2.6	2.4	3.5	1.2
Profitability of total assets (%)	3.3	4.6	3.7	3.2	4.4	1.1
The share of sales on revenues (%)	68.0	70.2	69.5	70.0	68.8	0.7
Debt of total asset (%)	51.5	50.9	51.1	52.0	51.8	0.4
Shabbiness of long-term tangible and intangible asset (%)	51.4	54.0	54.6	54.9	55.8	4.4
The share of foreign capital on fixed asset (%)	59.2	51.7	50.3	48.7	63.2	3.9
The share of own funds to finance investments (%)	73.4	82.6	73.4	69.5	67.6	-5.8
The share of technologies on purchased investments (%)[11]	61.8	62.0	63.1	55.7	57.3	-4.4
Labour productivity from value added (th. EUR)	23.4	22.7	22.9	23.3	24.4	104.0

Source: Ministry of Agriculture and Rural Development of the Slovak Republic; National Agricultural and Food Centre Branch: Research Institute of Agriculture and Food Economics.

The most important indicators of growth in the competitiveness of a company or an industry include labour productivity from added value, which in the monitored period in the food sector increased by only 4.0% and in 2016 reached 24.4 thousand EUR. The highest value of labour productivity from added value in 2019 was achieved by the starch, brewing-malt and confectionery industries (Table 2).

Table 2. Selected economic indicators in the food industry branches in 2019

Indicator	Costs effectiveness (%)	Debt of total assets (%)	Shabbiness of long-term tangible and intangible asset (%)	The share of foreign capital on fixed assets (%)	The share of own funds to finance investments (%)	Labour productivity from value added (th. €)
Food industrybranches:	3.5	51.8	55.8	63.2	67.6	24.4
-milk	1.3	54.4	52.0	77.4	63.8	23.5
-meat	0.3	63.4	56.7	75.5	70.8	14.6
- poultry	-1.7	59.5	57.7	64.9	89.4	19.3
- milling	1.3	68.1	44.5	0.0	9.8	23.9
- bakery	0.5	63.3	59.5	56.2	69.3	14.8
- brewery-malt	10.4	57.5	62.8	79.4	96.2	53.3
- starch	6.7	18.7	60.7	100.0	99.2	111.9
- distillery	2.7	34.4	47.8	10.7	75.4	26.5
- fat	0.1	62.9	52.6	0.5	46.0	21.4
- wine	10.5	43.0	46.3	5.9	62.4	29.0
- canning	8.0	56.6	53.1	61.4	66.3	28.6
-freezing	0.0	78.9	60.4	0.0	24.7	15.5
- fishing	-0.6	71.3	38.1	0.0	5.7	13.4
- sugar	2.9	35.1	62.8	97.2	87.2	56.0
- confectionery	9.4	40.1	50.1	0.0	100.0	32.2
- beverages	7.7	50.5	68.3	82.8	32.1	30.9

Source: Ministry of Agriculture and Rural Development of the Slovak Republic; National Agricultural and Food Centre Branch: Research Institute of Agriculture and Food Economics.

In contrast to the previous period, growth in the number of employees (+5.6%) contributed to the slowdown in the growth rate of value-added labour productivity. In 2019, there were 31.6 thousand employees. The bakery and confectionery, meat and dairy industries employed the largest number of employees in 2019 (Table 3).

Table 3. Selected economic indicators in the food industry branches in 2019

ML	MT	PO	MI	BA	B-M	ST	DI	FT	W	CA	FR	FI	SU	CO	BE
14.7	16.3	6.3	2.5	21.0	5.7	1.1	2.4	1.2	3.7	7.3	1.4	2.3	1.1	8.3	4.7

Notes: food industry branches: ML - milk, MT - meat, PO - poultry, MI - milling, BA - bakery, B-M - brewery-malt, ST starch, DI - distillery, FT - fat, W - wine, CA - canning, FR - freezing, FI - fishing, SU – sugar, CO - confectionery, NE - beverages

Source: Ministry of Agriculture and Rural Development of the Slovak Republic; National Agricultural and Food Centre Branch: Research Institute of Agriculture and Food Economics.

Foreign capital accounted for 63.2% of the share capital of food companies in 2019, while some companies are part of multinational corporations with a strong capital background enabling them to invest in modern technologies, product innovations and

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marketing. On the other hand, marketing strategies are partially absent in many small and medium-sized enterprises due to a lack of resources. The highest share of foreign capital in the fixed capital is currently recorded in the starch (100%), confectionery (97.2%) and beverage (82.8%) industries. Financial capital is absent in the milling, freezing and fishing industries.

In spite of the above, the food industry is generally dominated by a limited volume of financial resources for the permanent modernisation of processing capacities, which is also caused by the insufficient generation of own capital resources, dependence on financing of investments from foreign sources and limited volumes of procured investments. This is related to insufficient spending on research and development (a brake on the dynamic development of the industry and a weakening of competitiveness), reserves in product innovation and insufficiently developed links between the processing and departmental research spheres.

On the negative side, there is a relatively high wear and tear of long-term tangible and intangible assets in the food industry (around 55%). In 2019, 45.5% more funds were reinvested in the monitored industry than in 2018, while the procured investments were directed mainly to technologies (57.3%). In the observed 5-year period, the volume of procured investments in technologies increased by 35.0%. The financing of investments was to a decisive extent (67.6%) provided from own resources (from depreciation and, in the case of profitable companies, also from profit), which means that it was directly dependent on the achieved profitability.

The confectionery industry had the highest share of own resources in financing investments (100%) and the fishing industry the lowest (2.7%). Depreciation and profit were not a sufficient source of financing for the acquisition of new technologies and the renovation of buildings.

For this reason, the renovation was also financed from domestic loans (15.4%), from subsidies from the Ministry of Agriculture and Rural Development of the Slovak Republic (1.4%), from support for investments in agriculture and the food industry (3.6%), from other sources (11 .4%) and also from foreign capital (0.6%). Total asset indebtedness in the food industry has been around 51.5% over the long term, with the freezing industry (78.9%) the most indebted and the starch industry (18.7%) the least indebted in 2019.

Self-sufficiency in agri-food commodities

Agricultural and food commodities are the basic inputs to individual branches of the food industry. In Slovakia, more and more emphasis is being placed on the offer of foods of domestic origin, which are carriers of quality, regional and regional specificity and also traceability with regard to food safety from the point of view of hygiene and other quality standards. For these reasons, we should strive to process as many inputs as possible of Slovak origin in the food industry and limit their import from abroad. On the other hand, we should increase the efficiency of the food industry and try to process agrarian commodities domestically and not massively export them abroad.

Indicators of competitiveness include the rate of self-sufficiency in agri-food commodities or in basic raw materials for the food industry, which is determined by the ability to cover the needs of the monitored country with its own production potential. The production of plant commodities in Slovakia developed differently in the period 2015-2019, which is not only related to the development of cultivated areas, but also to the development of weather conditions affecting the parameters of production intensity, which in 2019 were favourable for the cultivation of cereals, oilseeds, vegetables, potatoes, sugar beet and legumes, which is evidenced by the fact that compared to the average of the previous 4 years, their production has increased, most significantly in the case of legumes. On the other hand, fruit production fell by half due to the frosty weather in the spring months, which significantly damaged the harvest of fruit trees and strawberries. In 2019, compared to the average of 2015-2018, the consumption of cereals, fruit, potatoes and sugar showed slightly decreasing tendencies, in contrast to oilseeds and especially pulses, where the opposite trend prevailed (Fig. 2).

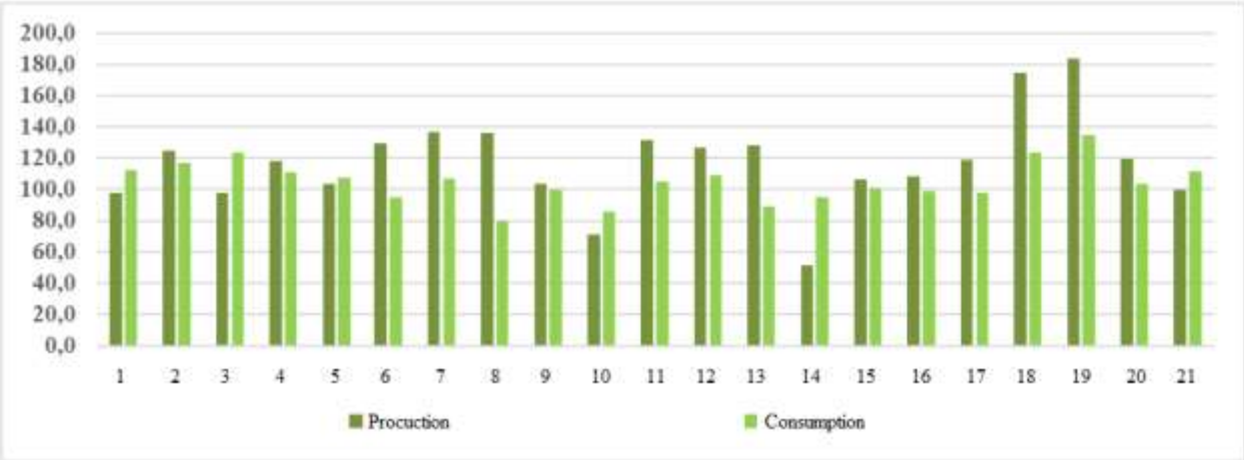

Fig. 2. Development of production and consumption in 2019 (average of 2015-2018=100 %)
Notes: 1-milk, 2-beef meat, 3-pig meat, 4-poultry meat, 5- eggs, 6-grains, 7-wheat, 8-maize, 9-barley, 10-rye, 11-oilseeds, 12-rape seeds, 13-sunflower, 14-fruits, 15-vegetables, 16-potatoes, 17-sugar, 18-legumes, 19-peas, 20-beans, 21-lentil
Source: National Agricultural and Food Centre Branch: Research Institute of Agriculture and Food Economics.

The data on the self-sufficiency rate in Table 4 testify to how the production of commodities of plant origin participated in their total consumption. In 2019, we covered the total domestic consumption of cereals with production at 189.7%, oilseeds at 262.8%, legumes at 150.7% and sugar at 127.8%, which created space for their export abroad. The dominant legume is peas, the production of which exceeds domestic consumption by approximately two times, in contrast to the other species, which show a minimal rate of self-sufficiency. If we consider the level self-sufficiency rate at 80% as the threshold of food security, then we have reached an acceptable level for vegetables as well (86.8%). In addition to lentils (14.7%) and beans (4.9%), the critical situation was with fruits (33.7%) and potatoes (61.7%), where we have to massively cover domestic consumption with imports, while these are traditional replaceable commodities that were grown in our territory in the past in a volume that satisfactorily satisfied domestic demand.

In 2019, compared to the average of 2015-2018, the domestic consumption of all commodities of animal origin increased quite significantly (Fig. 2), which, among other things, contributed to the decrease in consumer prices of meat and dairy products and, consequently, the growth of their consumption per capita. This happened in an environment of increasing performance of the meat and poultry industry (measured by production and sales for own products and services). As a result of the reduction in the number of dairy cows and pigs, the production of milk and pork decreased slightly. A positive development in production was recorded mainly in beef and poultry meat, and more moderate in eggs.

Specific data on the self-sufficiency rate of agri-food commodities of animal origin (Table 4) show that in 2019 we were able to cover domestic demand with commodities of Slovak provenance for beef and poultry meat. In addition, in the case of beef, we produced surpluses that exceeded domestic consumption by 17.8%, which created the conditions for their export abroad. In 2018, we were absolutely self-sufficient in milk and eggs. In the following years, we already had to supplement the domestic demand for these commodities with imports. However, we are reaching the food security threshold, which we exceeded by 1.9% for milk and 11.6% for eggs in 2019. The situation is alarming for pork, where we cover only 45.1% of consumption, i.e. we have to import more than half of our domestic consumption from abroad, and the indicator has deteriorated significantly in the last two years.

Table 4. Self-sufficiency rate of selected agrarian commodities in Slovakia (%)

Indicator	2015	2016	2017	2018	2019	Difference 2019-2015 (%)
Animal commodities						
Milk from sales	101.8	95.7	89.1	92.9	81.9	-19.9
Beef meat	116.5	105.2	108.3	113.2	117.8	1.2
Pork meat	55.3	56.6	68.3	48.2	45.1	-10.1
Poultry meat	91.8	77.3	96.7	113.3	100.0	8.1
Eggs	100.1	90.3	91.7	96.9	91.6	-8.4
Plant commodities						
Grains, out of which:	116.5	128.9	172.6	138.4	189.7	73.3
Wheat	122.9	154.5	178.5	167.9	201.1	78.1
Maize	115.8	109.9	203.4	124.6	233.1	117.4
Barley	102.4	101.4	133.6	103.5	114.6	12.2
Rye	117.1	197.5	109.2	94.5	107.3	-9.8
Oilseeds, out of which:	155.0	227.0	253.1	205.8	262.8	107.8
Rape seeds	102.3	182.2	210.7	148.0	187.1	84.8
Sunflower	1,314.8	1,957.4	2,007.0	1,742.9	2,465.0	1,150.1
Fruits	57.4	65.6	69.1	61.0	33.7	-23.6
Vegetables	84.2	86.7	79.9	79.6	86.8	2.6
Potatoes	58.6	55.8	59.0	51.4	61.7	3.1
Sugar	80.1	102.4	131.1	105.8	127.8	47.7
Legumes, out of which:	67.7	77.6	119.8	150.1	150.7	83.1
Peas	86.3	106.2	179.4	192.5	203.3	117.0
Beans	4.1	3.4	5.2	4.2	4.9	0.8
Lentil	22.0	15.9	3.4	21.6	14.7	-7.3

Source: Ministry of Agriculture and Rural Development of the Slovak Republic; National Agricultural and Food Centre Branch: Research Institute of Agriculture and Food Economics.

Foreign trade exchange with agro-food products

The competitiveness of Slovak agri-food products on the foreign market is mainly influenced by strong competitive pressure, which is manifested by massive imports of substitutable products to Slovakia at comparable or more competitive price ranges, especially from EU countries. The attractiveness of foreign, innovative products at prices comparable to domestic food, well-thought-out marketing and attractive advertising of retail chains are an attraction that partially dampens the patriotism of the dominant segment of Slovak consumers.

From the data presented in Table 5, it is evident that Slovakia has a long-term negative foreign trade balance with agri-food commodities, the volume of which is deepening over time. In order to be able to identify the causes of the negative development of agri-food foreign trade of the Slovak Republic, it is necessary to divide it into two basic components - trade in agricultural and food products. Since in our analysis we worked with aggregated data on foreign trade of the Slovak Republic at HS 04 level (four-digit code of customs tariff), the identification of agricultural and food products is only indicative. Moreover, the structure of the customs tariff does not respect such division even at the most detailed level of HS 08 (eight-digit code of customs tariff), so absolutely objective and exact division of agro-food products is not possible.

Table 5. Foreign trade of the Slovak Republic with agricultural and food products (thousands EUR)

Indicator	2015	2016	2017	2018	2019	2019/15
Agricultural products						
Import						
In total	914,594	832,742	801,450	822,308	876,371	95.8
out of which: replaceable	702,567	598,113	554,585	565,906	593,410	84.5
irreplaceable	212,027	234,629	246,865	256,402	282,961	133.5
Export						
In total	1,221,414	1,126,689	893,804	907,434	913,901	74.8
out of which: replaceable	1,150,096	1,038,443	822,180	829,813	831,100	72.3
irreplaceable	71,318	88,246	71,623	77,620	82,800	116.1
Trade balance						
In total	306,820	293,947	92,354	85,126	37,530	12.2
out of which: replaceable	447,529	440,330	267,596	263,908	237,690	53.1
irreplaceable	-140,709	-146,383	-175,242	-178,782	-200,160	142.3
Food products						
Import						
In total	3,049,290	3,065,282	2,988,178	3,022,841	3,227,974	105.9
out of which: replaceable	2,438,641	2,447,182	2,334,319	2,299,600	2,511,364	103.0
irreplaceable	610,649	618,100	653,859	723,240	716,610	117.4
Export						
In total	2,371,776	2,088,084	1,840,687	1,892,245	1,912,989	80.7
out of which: replaceable	2,075,491	1,838,785	1,595,853	1,591,772	1,599,750	77.1
irreplaceable	296,285	249,299	244,834	300,472	313,239	105.7
Trade balance						
In total	-677,514	-977,198	-1,147,491	-1,130,596	-1,314,985	194.1
out of which: replaceable	-363,150	-608,397	-738,466	-707,828	-911,614	251.0
irreplaceable	-314,364	-368,801	-409,025	-422,768	-403,371	128.3
Agri-food trade in total						
Import						
In total	3,963,884	3,898,024	3,789,628	3,845,149	4,104,344	103.5
out of which: replaceable	3,141,208	3,045,296	2,888,904	2,865,506	3,104,774	98.8
irreplaceable	822,676	852,729	900,724	979,642	999,570	121.5
Export						
In total	3,593,190	3,214,773	2,734,490	2,799,678	2,826,889	78.7
out of which: replaceable	3,225,588	2,877,229	2,418,033	2,421,586	2,430,850	75.4
irreplaceable	367,603	337,545	316,457	378,093	396,039	107.7
Trade balance						
In total	-370,694	-683,251	-1,055,137	-1,045,470	-1,277,455	344.6
out of which: replaceable	84,379	-168,067	-470,871	-443,920	-673,924	-798.7
irreplaceable	-455,073	-515,184	-584,267	-601,550	-603,531	132.6

Source: Statistical Office of the Slovak Republic; National Agricultural and Food Centre Branch: Research Institute of Agriculture and Food Economics.

We have a long-term positive trade balance with agricultural products, the financial volume of which decreased by 46.9% for substitutable commodities in the period under review. In 2019, we have imported agricultural products with a total value of 876.4 million EUR, which compared to the base year of 2015 is 4.2% less. Of this, the import of substitutable agricultural products accounted for 67.7% (in 2015, up to 76.8%). A significant part of the import of agricultural products is made up of non-substitutable commodities for us, which must be imported to ensure domestic consumption. In addition, in the off-season, a significant part of the import is made up of fresh fruit and vegetables, which, given the level of costs and the structure of our production, are cheaper to import from countries with a more favourable climate. In the same period, we exported the mentioned products for 913.9 million EUR. Compared to the base year of 2015, the export of agricultural products overall decreased by 25.2%.

The unfavourable situation in the Slovak Republic's foreign trade with food products continues, as in 2019 up to 102.9% (in 2018 108.1%, in 2017 108.8%, in 2016 up to 143.0% and in 2015 even 182.8%) of our total agro-food balance was generated by food products and semi-finished products. In 2019, we imported food products for a total of 3,228.0 million EUR (compared to the base year 2015 by 5.9% more), of which up to 77.8% (in 2015 even 80.0%) represented the import of substitutable food products. In the monitored five-year period, there was a significant slowdown in the export of food products. In 2019, we placed the mentioned products on foreign markets with a total value of 1,913.0 million EUR, while compared to the base year, this is a decrease of up to 19.3%. Of the stated value, the export of substitutable food products accounted for 83.6% (in the base year of 2015, even 87.5%).

The aforementioned development was reflected in the significantly passive trade balance of the food industry, which generated a deficit of 677.5 million EUR in 2015 (of which 53.6% accounted for substitutable commodities), in the last year of the analysis in question, it generated a record deficit of 1,315.0 million EUR (of which 69.3% accounted for substitutable products).

Share of Slovak products on the domestic market

It is very important for the Slovak agro-food sector that as many Slovak products as possible are sold through the network of retail chains. How competitive they are on the domestic market can be derived from the data on the share of Slovak food production on the domestic market. To determine it, we used two methodological approaches, which are described in detail in the methodological part of the paper.

Determining the share of Slovak products from sales and the financial volume of foreign trade

Taking into account the above facts, it is evident from the following figure that in 2019 (compared to 2015), the share of Slovak products on the domestic market decreased in more than half of the branches of the food industry.

As for the key branches that ensure the basic nutrition of the population, in the period 2015-2019, the share of products of the Slovak dairy and meat industry in the business network decreased. On the contrary, we note a significantly positive development in the poultry industry (+16.6%).

The mentioned industries process products of animal production, while the first two have to supplement their raw material base with imports from abroad due to the lack of self-sufficiency in the production of milk and pigs. The share of Slovak milling industry products in 2019 reached 47.2%, which in our opinion is not an optimal situation considering the high surplus of wheat on the Slovak market. Bakery products are characterized by a lower shelf life with the predominance of fresh bread and pastries, whose foreign trade exchange is not as intense as in other branches. Despite this, their share in the domestic market is decreasing (-6.8%). The mentioned development is influenced to a small extent by the growth in the offer of baked goods in retail stores from imported frozen semi-finished products.

Among the industries producing beverages, despite a slight decline, the brewing and malting industry maintains the best position with a 77.3% share of the Slovak market. The beverage industry covers 39.8% and the wine industry 56.9% of the domestic market, with growing demand for Slovak wine, the situation is opposite for non-alcoholic beverages of domestic origin. The specific development of the monitored indicator for individual branches of the food industry in the period 2015-2019 is presented in Table 6.

Table 6. Share of Slovak food products in the domestic market (%)

Industry	**2015**	**2016**	**2017**	**2018**	**2019**	**Difference 2019-2015 (%)**
Milk industry	66.2	62.8	62.3	61.0	59.1	-7.2
Meat industry	39.4	36.5	37.4	39.0	38.1	-1.3
Poultry industry	26.4	33.8	27.1	29.9	42.4	16.6
Milling industry	42.6	44.7	45.5	64.2	47.2	4.6
Bakery industry	38.8	34.6	34.2	22.7	32.0	-6.8
Brewery-malt industry	83.1	79.3	77.8	75.9	77.3	-5.8
Distillery industry	22.7	28.6	25.6	15.2	6.0	-16.7
Starch industry	58.7	57.3	52.6	55.3	48.0	-10.7
Fat industry	16.8	19.5	13.5	13.9	13.0	-3.8
Sugar industry	20.3	22.6	21.2	61.9	59.1	38.8
Confectionery industry	15.8	17.7	18.4	17.3	17.1	1.3
Beverages industry	59.2	59.6	53.1	49.0	39.8	-19.4
Wine industry	51.3	46.1	47.9	52.1	56.9	5.6
Canning industry	26.5	30.3	30.2	39.4	37.9	11.4
Freezing industry	18.6	6.3	4.1	11.3	10.0	-8.6
Fishing industry	23.9	15.5	12.0	21.2	24.4	0.5

Note: calculation from sales and financial volume of foreign trade; data on fat industry and confectionery industry are estimated by National Agricultural and Food Centre Branch: Research Institute of Agriculture and Food Economics because of high re-exports

Source: Statistical Office of the Slovak Republic; National Agricultural and Food Centre Branch: Research Institute of Agriculture and Food Economics.

Determining the share of Slovak products from the natural volume of production and foreign trade

The development of the shares of Slovak products on the domestic market, calculated from the natural volume of production and indicators of foreign trade, was different in the period 2015-2019.

The specific values are shown in Table 7, while it is evident that in some cases they differ considerably from the values calculated on the basis of the previous methodological procedure.

Considering the development of the monitored indicator in the monitored period, Figure 3 shows the trend of its development in two consecutive 3-year periods, with both variant calculations. The results show that, regardless of the methodological approach, in the second half of the monitored period (2017-2019), the share of Slovak dairy, bakery, brewing-malt, beverage and freezing industry products in the domestic market clearly decreased. On the contrary, the share of Slovak products of poultry and milling industry clearly shows increasing tendencies. The development in other branches is diametrically different in both methodological procedures with positive development in wine and canning industry when calculated from financial volumes and in meat industry when calculated from natural volumes of production and foreign trade.

Table 7.Share of Slovak food products in the domestic market (%)

Industry	2015	2016	2017	2018	2019	Difference 2019-2015 (%)
Milk industry	60.7	41.1	40.2	51.3	47.0	-13.7
Meat industry	44.8	42.6	49.5	51.7	46.5	1.8
Poultry industry	37.5	28.5	30.2	42.4	41.6	4.1
Milling industry	78.2	78.9	81.9	74.1	80.1	1.9
Bakery industry	14.1	11.8	11.2	14.9	14.6	0.5
Brewery-malt industry	73.0	67.6	67.6	62.7	65.2	-7.8
Beverages industry	64.7	66.2	64.1	61.8	62.8	-1.9
Wine industry	33.0	42.4	26.5	35.3	40.2	7.2
Canning industry	34.1	25.3	22.3	25.8	19.1	-14.9
Freezing industry	36.6	65.0	30.2	12.3	16.6	-19.9

Note: calculation from natural volumes of production and foreign trade
Source: Statistical Office of the Slovak Republic; Radela s.r.o.,Ministry of Agriculture and Rural Development of the Slovak Republic, National Agricultural and Food Centre Branch: Research Institute of Agriculture and Food Economics.

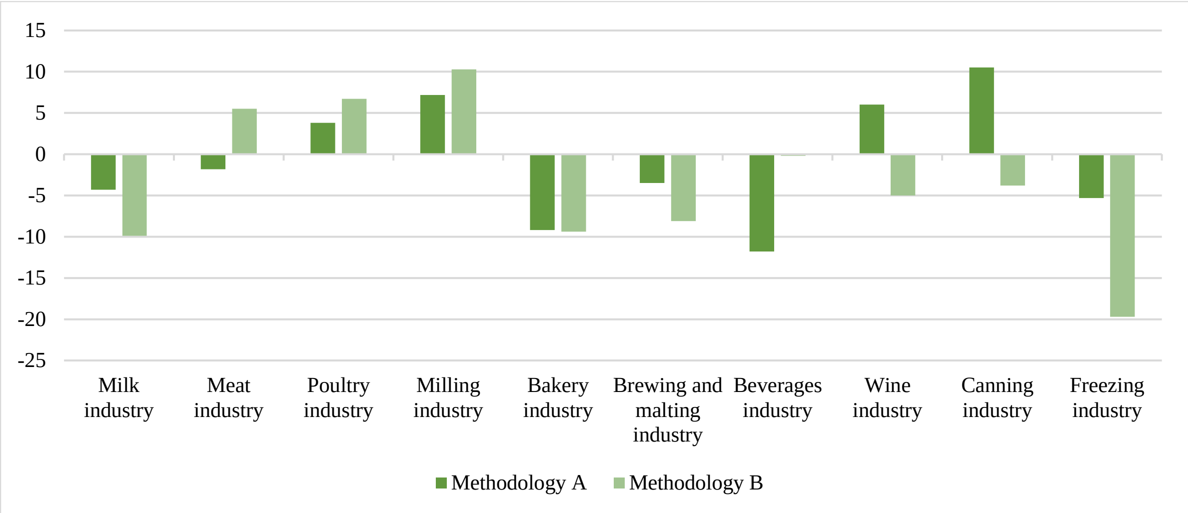

Fig. 3. Change in the share of Slovak products on the domestic market in the period 2014-2016 compared to the period 2011-2013 (%)
Note: Methodology A - calculation from sales and financial volume of trade; Methodology B - calculation from natural volumes of production and trade
Source: Statistical Office of the Slovak Republic; Radela s.r.o.,Ministry of Agriculture and Rural Development of the Slovak Republic, National Agricultural and Food Centre Branch: Research Institute of Agriculture and Food Economics.

Regarding the predictive power of the presented methodological approaches, in further solutions we recommend to apply the first methodological approach to more global aggregations of data (e.g. determination of the share of Slovak products on the domestic market by individual branches of the food industry). With regard to data availability, we recommend to preferably apply the second methodological approach to specific commodities.

CONCLUSIONS

The paper focuses on analyses of the position of the Slovak food industry on domestic and foreign markets. The object of interest were the economic indicators of the food industry, self-sufficiency of the Slovak Republic in selected agro-food commodities, foreign trade exchange and identification of the share of Slovak food products on the domestic market. The research results show that the food industry in the Slovak Republic is thriving, with revenues exceeding costs in the long term. Despite the above, as a result of high competition on the liberalized EU market and the pressure of retail chains on the price of raw materials, in the monitored period we have recorded a stagnation or a decline in its performance measured by the development of production and sales. What is important is the fact that labour productivity from added value, which is an important economic indicator of the industry's competitiveness, grows over time, which is caused by a decrease in the workforce. The food industry has a sufficient raw material base for the processing of beef and poultry, cereals, oilseeds, sugar and domestically produced peas. With the mentioned commodities, there are surpluses for export abroad. If we consider the level self-sufficiency rate at 80% as the threshold of food security, then we at least reach it for vegetables, milk and eggs. The unfavourable situation is with fruits, potatoes, lentils, beans and pork, where we reach the lowest self-sufficiency rates. On the domestic market, it is a priority to resist the pressure of foreign imports and to increase the share of Slovak products in the domestic retail network. The low competitiveness of Slovak food products is reflected in the massive import of substitutable food products that can be produced domestically.

The mentioned commodities accounted for up to 77.8% of total imports in 2019. Overall, the Slovak Republic has a high deficit with food products, which worsens over time. On the other hand, we export an excessive amount of agricultural raw materials from Slovakia, which are returned in the form of products of the foreign food industry. The identification of the share of Slovak products in the retail network of the Slovak Republic was carried out on the basis of two methodological approaches, which are based on statistically available data, one in financial and the other in kind terms. The results clearly showed that in the period 2017-2019, compared to the previous 3-year period, the share of Slovak products of the dairy, bakery, brewing-malt, beverage and freezing industries on the domestic market decreased. On the contrary, the share of Slovak products of the poultry and milling industry is growing.

REFERENCES

[1]Ansell, C., Gash, A., 2008, Collaborative Governance in Theory and Practice, Journal of Public Administration Research and Theory, Vol. 18(4), 543-571.

[2]Bandasz, K., 2013, Poland and Slovakia during the economic crisis 2008-2010, Society and Economy, Vol. 35(2), 141-165.

[3]Blaas, G., 2013,Poľnohospodárstvo a potravinárstvoSlovenska z hľadiskaprechodu k vyššiemuštádiurozvoja (Slovakia's agriculture and food industry from the point of view of the transition to a higher stage of development). Working papers 52. Bratislava: EÚ SAV, 2013, p. 46.

[4]Food Industry Development Concept 2014-2020. Bratislava: MPRV SR, 2014, p. 102.

[5]Gubová, M., Ambrózyová, M., 2005, Vývojovétendencieštrukturálnychzmien v poľnohospodárskejprvovýrobe (Development tendencies of structural changes in agricultural primary production). VUEPP: Bratislava, 2005, 123–138.

[6]Hutník, F.,1999, Národohospodárskedimenzieagropotravinárstva (National economic dimensions of agro-food industry), Agropotravinárskysektor v transformujúcejsaekonomike. Bratislava: VÚEPP, 1999, p. 167.

[7]Chrastinová, Z., 2018, Ekonomickéaspektypoľnohospodárstva a potravinárstvavrátanebezpečnostipotravínnaSlovensku (Economic aspects of agriculture and food, including food safety in Slovakia). Štúdia č. 200/2018, Bratislava: NPPC-VÚEPP, 2018, p. 209.

[8]Lelieveldt, H., 2023, Food industry influence in collaborative governance: The case of the Dutch prevention agreement on overweight,FoodPolicy,Vol. 114(1),78-89.

[9]Matošková, D., Gálik, J., Jamborová, M., 2018,Vybranéaspektykonkurencieschopnosti v dodávateľsko-odberateľskomreťazciagropotravinárskychkomodít (Selected aspects of competitiveness in the supply-customer chain of agri-food commodities), Bratislava: NPPC-VÚEPP, 2018, p. 168.

[10]Petrášová, V., Valach, M., 2012, Sociálnafunkciapôdohospodárstvaporoku 1990 v SR. Ekonomikapoľnohospodárstva (The social function of agriculture after 1990 in the Slovak Republic. Economics of agriculture), Vol. 7 (3), 67-79.

[11]Siddiki, S.N., Carboni, J.L., Koski, C., Sadiq, A.-A., 2015, How Policy Rules Shape the Structure and Performance of Collaborative Governance Arrangements, Public Administration Review, Vol. 75 (1), 536-547.

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EXPORT POTENTIAL OF AGRICULTURAL-INDUSTRIAL COMPLEX OF UKRAINE: LOGISTICS AND DEVELOPMENT PROSPECTS

Andriy VERZUN[1], Liliia VOINYCHA[1], Olga FEDYK[1], Olha SHULHA[2], Liubov LIPYCH[3*], Tetiana SHMATKOVSKA[4], Volodymyr HERYLO[3]**

[1]Lviv National Environmental University named after Prof. Ye. V. Khraplyvyi, Department of Management, 1 Volodymyra Velykogo street, 80381, Dubliany, Lviv region, Ukraine. Emails: andrijverzun@gmail.com, voinycha@gmail.com, olgafedyk@ukr.net
[2]Private Higher Education Establishment «European University», Department of Economics, Finance and Accounting, 16V, Vernadsky Boulevard, Kyiv, Ukraine. Email: olga.shulga@e-u.edu.ua
[3]Lutsk National Technical University, *Department of Entrepreneurship, Trade and Exchange Logistiks, **Department of Management, 75 Lvivska str., 43018, Lutsk, Ukraine. Emails: lipych_liubov@lutsk-ntu.com.ua, gerylo.v@gmail.com
[4]Lesya Ukrainka Volyn National University, Department of Accounting and Taxations, 28 Vynnychenko Street, 43025, Lutsk, Ukraine. E-mail: shmatkovska2016@gmail.com

Corresponding author: shmatkovska2016@gmail.com

Abstract

The article describes the current state, retrospective, and perspective of the development of the export potential of the agricultural sector of the Ukrainian economy. The share of agricultural exports in the structure of the total export of goods from Ukraine was analyzed. The geographical structure of the export of goods from Ukraine, in particular the agro-industrial complex, was studied. Special attention was paid to the issue of the change in the structure of the export of goods in 2022. The structure of the export of products from Ukraine, in particular agricultural products, was studied in terms of partner countries. Special attention was focused on considering changes in the structure of exports in 2022 in Ukraine. In 2022, the logistics of exporting agricultural products became significantly more complicated. Neighbouring European countries felt a significant burden during the restructuring of the logistics channels for the export of Ukrainian agricultural products before the opening of the «grain corridor». Customs crossings, railway infrastructure and the infrastructure of sea and river ports of the European Union countries were fully involved. In the article, we substantiated that in order to unblock the export of agricultural products from Ukraine through the domestic Black Sea seaports, the significant burden of building export logistics flows was taken on by European neighboring countries, which fully utilized all their logistics infrastructure. In 2022, there was a reduction in the export of agricultural products, and in 2023, its further decline is predicted. Using the example of grain crops, polynomial approximation was used to forecast their gross harvest, as well as calculate domestic consumption and export potential in 2023. The study indicates that in 2023, export revenue from the sale of grain crops should be expected to be more than twice as much as in 2021.

Key words*: *export potential, agricultural-industrial complex, logistics, agricultural enterprise

INTRODUCTION

Currently, Ukraine has a developed agricultural sector, which creates significant economic advantages for it, as it is largely export-oriented. At the same time, during the last decade, agriculture in Ukraine occupies the structure of gross added value from 8.4% in 2010 to 12.4% in 2021, when it was the third sector of the domestic economy in terms of the share of the formation of gross added value.

The main share of the gross added value in Ukraine is created by the industry, which accounts for 21% to 25% of the gross added value, the second is wholesale and retail trade with a share of more than 16% in the structure of the country`s gross added value.

Along with this, it is the agrarian sphere that is an important source of foreign exchange earnings. Export volumes of agrar products are constantly growing. According to analysts of the Ukrainian Agrarian Business Club, according to the results of 2021, agricultural products were exported for a total amount of 27.8 billion USD, which is 41% of all Ukrainian exports. Compared to 2020, this indicator increased by 25%. Crop products account for the largest share of Ukrainian exports of agricultural products. In 2021, it accounts for 15.6 billion USD or 56% of the total export of agricultural products. The smallest export revenue came from the livestock industry. Thus, in 2021, these products were exported in the amount of 1.4 billion USD, which is only 5% of the total export of agricultural products [30].

Many works of various scientists and practitioners are devoted to the study of the problems of the efficiency of the export of agricultural products.

It accounts for 56% of the total export of agricultural products, which made it possible to obtain $15.6 billion in export revenue. The livestock sector generated the lowest export revenue. In 2021, the export of this product amounted to $1 billion or 5% of the total volume of exports of products of the agro-industrial complex. [1]

Many scientists and practitioners devoted their research to the problems of the efficiency of export of agricultural products.

In this aspect, it is especially worth highlighting the works of such researchers as M. Dziamulych [1-10], I. Lazaryshyna [11], A. Marcuta [12], T. Nestorenko [14-15], A. Popescu [16-26], N. Serdiuk [27], T. Shmatkovska [28-29], S. Voloshyna [32], I. Voronenko [33], and many others.

MATERIALS AND METHODS

The study provides an assessment of the dynamics of the export of agricultural products in retrospect and its projected value in 2023. For this, it is necessary to evaluate and determine the role of performance indicators that affect the country`s export capabilities, in particular, the logistics capacity of the corresponding types of transport and other infrastructure, changes in the size of cultivated areas, and productivity agricultural crops.

Conducting research is based on the use of the following methods and methodological approaches: analysis and synthesis, structural analysis, historical method, and graphic and tabular methods – for visual display of research results. Data visualization was carried out using Microsoft Excel version 2016.

Statistical data contained in the databases of the State Statistics Service of Ukraine, as well as analytical materials of various agricultural information and analytical agencies, were used for calculations.

RESULTS AND DISCUSSIONS

Ukraine successfully exports tens of billions USD worth of goods and services every year, and it is the export of goods that occupies the lion's share of its overall structure (Fig. 1).

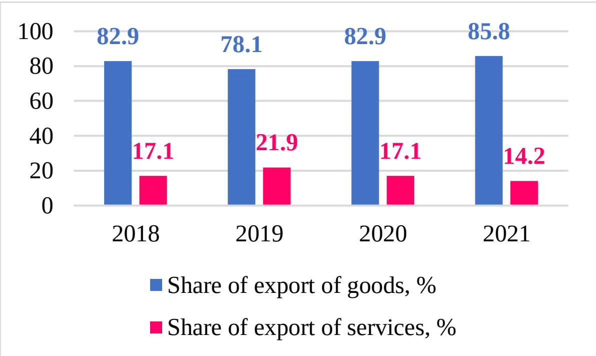

Fig. 1. The structure of exports of goods and services of Ukraine
Source: calculated by the authors based on [30].

In the structure of export of goods and services in 2018, the share of export of goods is about 83%. The total volume of exports of goods and services in 2018 amounted to 59.2 billion USD, of which 47.3 billion USD accounted for the export of goods. In 2019, the export of goods and services amounted to 64.1 billion USD, including the export of goods – 50.1 billion USD, i.e. 78.2% of the total export structure. 2019 is characterized by the lowest share of exports of goods during the period under review. In 2021, in the structure of Ukraine's exports, the share of exports of goods was the largest and amounted to 85.8%.

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Examining the volume of exports of goods from Ukraine, it is advisable to emphasize that a significant share, on average more than 41.5% over the last five years, is the export of agricultural products and the food industry (Table 1).

In 2018, exports of goods and services amounted to $59.2 billion, with a share of exports of goods of about 83%, i.e. $47.3 billion. In 2019, the total volume of exports increased to $64.1 billion, while exports of goods amounted to $50.1 billion, which accounted for 78.2% of the total export structure. The lowest specific weight of the export of goods for the analyzed period was recorded in 2019. In 2021, the specific weight of the export of goods in the export structure of Ukraine was the largest and amounted to 85.8%.

It should be noted that over the past five years, a significant share, on average over 41.5%, of the structure of exports of goods from Ukraine has been occupied by the export of products of the agro-industrial complex and the food industry (Table 1).

Analyzing the change in the domestic export of goods in 2018-2021, it is appropriate to note that the export of agricultural and food industry products and the export of mineral products show the most positive dynamics. In 2021, the business received more than USD 9.2 billion more from the export of agro-industrial complex and food industry products than in 2018, i.e., the increase was 49.7%. Analyzing the changes in the domestic export of goods from 2018-2021, it should be noted that the export of products of the agro-industrial complex and the food industry, as well as the export of mineral products, showed the most positive dynamics. In 2021, the increase in exports of agricultural and food industry products compared to 2018 amounted to more than $9.2 billion or 49.7%. In 2021, there is a significant increase in the export of products of the metallurgical complex – by more than 4.3 billion USD.

Table 1. Export of goods from Ukraine in 2018-2021, million USD

Indicator	2018	2019	2020	2021	Deviation, 2021 to 2018, +/ -
Products of agriculture and food industry	18,612.8	22,144.2	22,179.4	27,875.3	9,262.5
Production of the metallurgical complex	11,633.1	10,255.7	9,030.0	15,992.5	4,359.4
Mechanical engineering products	5,475.1	5,528.1	5,405.8	6,120.2	645.1
Mineral products	4,340.0	4,866.5	5,331.6	8,414.4	4,074.4
Products of the chemical industry	2,565.8	2,652.3	2,702.8	3,920.8	1,355
Wood and paper pulp	2,043.6	1,838.1	1,814.6	2,540.6	497
Various industrial goods	1,449.4	1,585.1	1,649.3	1,250.0	-199.4
Products of the light industry	1,220.3	1,184.7	1,078.4	1,975.5	755.2
Total export of goods	47,340.1	50,054.7	49,191.9	68,089.3	20,749.2

Source: calculated by the authors based on [30].

From the export of mineral products, the increase in foreign exchange earnings in 2021 compared to 2018 amounted to more than 4 billion USD.

At the same time, the increase in the export of mineral products in 2021 compared to 2018 was 93.9%, that is, it has almost doubled in four years.

Among the main partner countries that exported Ukrainian goods in 2018-2021, the following can be distinguished: the European Union, China, Turkey, India, the Russian Federation, Belarus, and the USA (Table 2).

Table 2. Structure of exports of goods from Ukraine by country in 2018-2021, %

Indicator	2018	2019	2020	2021	Deviation, 2021 to 2018, +, -
European Union	42.6	41.5	37.8	39.4	-3.2
China	4.6	7.2	14.4	11.8	7.2
Turkey	5.0	5.2	5.0	6.1	1.1
Russian federation	7.7	6.5	5.5	5.0	-2.7
India	4.6	4.0	4.0	3.7	-0.9
Egypt	3.3	4.5	3.3	2.9	-0.4
Belarus	2.8	3.1	2.7	2.2	-0.6
USA	2.3	2.0	2.0	2.4	0.1
Other countries of the world	27.1	26.0	25.3	26.5	-0.6

Source: calculated by the authors based on [30].

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The European Union and China are the largest trade partners for the export of goods from Ukraine. The dynamics we observe in Table 2 indicate that the share of the European Union in the export of Ukrainian goods is decreasing, while China has significantly strengthened its position as a partner country. Since 2018, the export of Ukrainian goods to China has increased by 7.2 points.

We believe that taking into account the full-scale invasion of the Russian Federation into the territory of Ukraine, the structure of the export of Ukrainian goods to partner countries will change significantly. Of course, the Russian Federation and Belarus will be excluded from these. The structure of product positions will also change significantly. The share of the metallurgical complex in the structure of domestic exports will obviously be significantly reduced due to logistical problems, as well as due to the concentration of metallurgical enterprises in the East of Ukraine, their destruction or reduction of production volumes. In particular, Ukraine lost such metallurgical enterprises as Azovstal, the Mariupol Metallurgical Plant named after Ilich, etc. It is also impossible to relocate this type of business to safer regions of Ukraine, even with the largest state support for this process.

The structure of the export of services by partner countries is somewhat different. The main consumer of services from Ukraine is the European Union. In general, the countries of the European Union export more than a third of services from Ukraine every year.

The situation regarding significant volumes of export of services to the Russian Federation is quite unclear. In general, for the period 2018-2021, the export of services to the Russian Federation amounted to 14,112.7 million USD. The significant volume of exports to the Russian Federation, the total amount of exports of goods and services during the study period was more than 27,120.2 million USD, poses significant economic and security risks for Ukraine. The situation regarding significant volumes of service exports to the Russian Federation remains unclear and leads to significant economic and security risks for Ukraine. During the period of 2018-2021, the total volume of exports of goods and services to the Russian Federation amounted to $14,112.7 million. In general, the amount of exports of goods and services to the Russian Federation for the period under review amounted to more than 27,20.2 million US dollars. 2022 is indicative of this statement. Ukraine's annual losses from the suspension of financial relations with the Russian Federation will be painful for the national economy. In general, during the study period, we observe a significant reduction in exports to the Russian Federation. In 2021, the share of exports of services to the Russian Federation was 15.2%, while in 2018 this indicator exceeded 28%. In 2021, the specific weight of the export of services to the Russian Federation decreased by almost two times compared to 2018 - to 15.2%.

Table 3. Structure of export of services from Ukraine by country in 2018-2021, %

Indicator	2018	2019	2020	2021	Deviation, 2021 to 2018, +, -
European Union	32.9	28.6	38.7	34.6	1.7
Russian federation	28.1	39.7	22.9	15.2	-12.9
USA	8.2	8.2	12.3	15.3	7.1
Switzerland	7.5	6.3	6.8	9.3	1.8
UAE	2.2	2.3	2.9	3.2	1
Israel	1.7	1.6	1.9	2.3	0.6
Turkey	1.5	1.3	1.3	1.4	-0.1
China	0.9	1.2	1.1	0.8	-0.1
Other countries of the world	27.1	26	25.3	17.9	-9.2

Source: calculated by the authors based on [30].

In the structure of export of services, the share of the USA is growing significantly. During the last five years, it has almost doubled. To a large extent, this is related to the change in the structure of the types of services that are exported from Ukraine. In 2018, the export of computer and information services from Ukraine amounted to 2,044.2 million USD, i.e. 17.2% in the structure of export of services. In 2021, the export of computer and information services brought USD 4,032.0 million in foreign exchange earnings and accounted for 31.5% of the structure of the export of services.

The sphere of providing transport services is the most effective in terms of the formation of export foreign exchange earnings. In 2019, 58.3% of export foreign currency earnings were generated due to the provision of transport services, i.e. 9,109.9 million USD. In 2021, the share of transport services in the export of services from Ukraine decreased and amounted to 36.4%, i.e. 4,657.5 million USD. In terms of value, export revenue from the provision of transport services in 2021 has almost halved compared to 2019.

Figure 2 shows the structure of the export of services from Ukraine in terms of types of activity on average during the study period. Transport services are an area that forms almost half of the export foreign exchange earnings.

In 2021, export revenue from the provision of transport services decreased to $4,657.5 million and accounted for 36.4% of the structure of exports of services from Ukraine. It is worth emphasizing that in 2021, compared to 2019, export revenues from the provision of transport services decreased by almost two times.

Characterizing the structure of export of services from Ukraine by type of activity, it is appropriate to emphasize that transport services are the sphere that provides about half of the foreign exchange earnings from exports. Over 21% of the structure of export of services is occupied by computer and information services. As we have already noted, their share is growing dynamically every year.

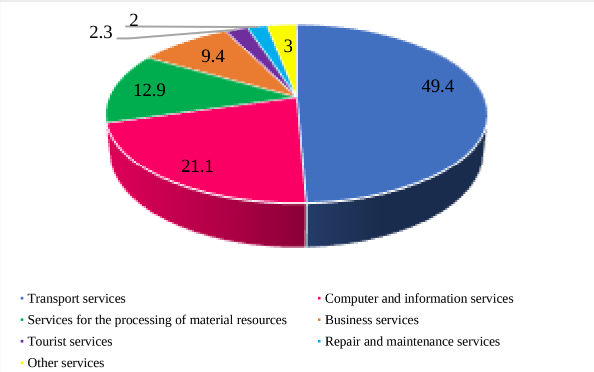

Fig. 2. The structure of export of services from Ukraine by type of activity, on average during the study period, %

Source: calculated by the authors based on [30].

12.9% and 9.4% in the structure of export of services are occupied by services for the processing of material resources and business services, respectively. Other types of services occupy an insignificant part in the structure of exports, within the range of 2.3% or less.

The agricultural sector in Ukraine has recently been called the locomotive of the national economy. In the structure of the export of goods from Ukraine, the share of agricultural products and the food industry is from 39.3% in 2018 to 53.0% in 2022.

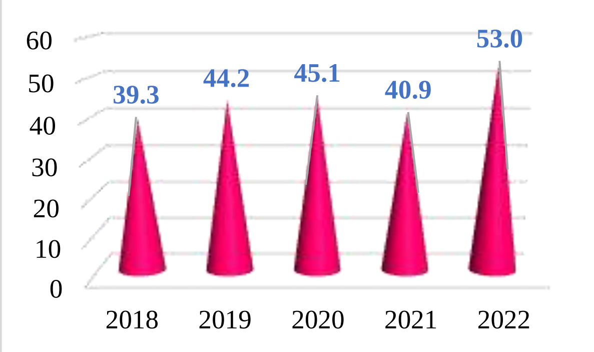

Fig. 3. The specific weight of agricultural products and the food industry in the structure of exports of goods from Ukraine in 2018-2022, %

Source: calculated by the authors based on [30].

The agricultural sector of Ukraine plays an active role in stabilizing the foreign exchange market, and reducing unemployment, as it provides orders, and therefore also the work of workers in related industries.

Analyzing the commodity structure of the export of agricultural and food industry products from Ukraine, we can note the following. In value terms, the volume of exports of live animals and products of animal origin in 2021 compared to 2018 increased by 0.1 billion USD, and the share of this group in the structure of exports of agricultural products decreased in 2021 by 1.8 percentage points (Fig. 4). In 2021, Ukraine received $1.3 billion from the export of live animals and products of animal origin, which is $0.1 billion more than in 2018. At the same time, the specific weight of this group in the structure of agricultural exports decreased in 2021 year by 1.8 percentage points (Fig. 4). In 2022, the volume of exports for this group increased by 0.2 billion USD compared to 2021, and the share increased by 1.7 percentage points.

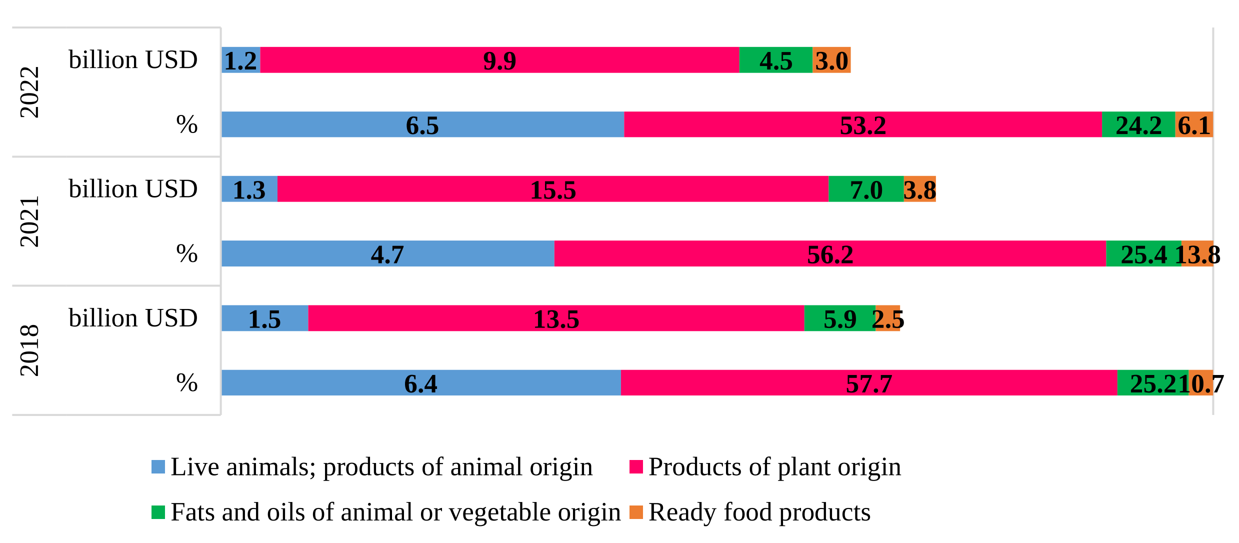

Fig. 4. Value structure of exports of agricultural products and food industry from Ukraine in 2018-2022
Source: calculated by the authors based on [30].

The number of export revenues from the sale of plant products in 2021 compared to 2018 increased by 5.6 billion USD, while their share in the structure and export of agricultural products increased by only 3.0 percentage points. In 2022, compared to 2021, the export of plant products decreased by 2.0 billion USD, but the share in the structure of the export of products of the agricultural sector increased by 1.5 percentage points. This indicates that in 2022, after the start of large-scale hostilities, the structure of agar exports underwent significant changes.

The amount of animal or vegetable fats and oils exported from Ukraine to the EU has increased significantly. In 2018, the export of this group of goods in value equivalent amounted to 4.5 billion USD, and in 2021 it increased to 7.0 billion USD, although it decreased in 2022 to 5.9 billion USD. In the structure of exports, the share of this group of goods has increased and fluctuated within 25%.

According to the accepted classification, the structure of exports of agricultural products and the food industry includes 4 groups of goods, each of which includes separate types of goods, of which there are 24 in total.

Characterizing the export of agricultural products and the food industry in Ukraine, four types of goods can be distinguished, which bring the lion`s share of export revenue in this direction (Table 4). Ukraine exports products of the agro-industrial complex and the food industry, four main types of goods can be distinguished, which provide a significant part of export revenues in this area of activity (Table 4).

The largest share in the structure of export of agricultural products is grain crops. During 2018-2022, grain exports are increasing. In 2018, the share of grain exports exceeded 22% in the structure of exports of agricultural products and the food industry, and in 2021, the share of grain exports increased to 25.5%. In general, grain exports in value equivalent increased in 2022 compared to 2018 by 1,871.9 million USD. A significant increase is observed in the export of fats and oils of animal and vegetable origin. In 2018, the share of this group of products in the structure of exports of agricultural products was 13.7% and increased to 14.6% in 2022, that is, it increased by 1,452.9 million USD over the period under study. Cereal crops constitute the largest specific weight in the structure of domestic export of agricultural products. In 2018, the specific weight of grain exports in the structure of exports of products of the agro-industrial complex amounted to more than 22%, and in 2021 it increased to 25.5%. Export revenue from the sale of grain crops increased in 2022 by $1,871.9 million compared to 2018.

Another group of agricultural products, namely fats and oils of animal and vegetable origin, also saw significant growth. The share of this group of products in the structure of exports of products of the agro-industrial complex was 13.7% in 2018 and reached 14.6% in 2022. Thus, cash receipts from the export of this group of goods increased by $1,452.9 million over the period under study.

Table 4. Structure of Ukrainian exports of agricultural products and food industry, 2018-2022

The code and name of goods according to the Ukrainian classification of goods of foreign economic activity	2018		2019		2020		2021		2022		Deviation, 2022 to 2018, +/ -	
	million USD	share, %	million USD	share, %	million USD	share, %	million USD	share, %	million USD	share, %	million USD	share, %
grain crops	7,240.6	22.1	9,633.3	24.4	9,410.7	24.4	12,343.8	25.5	9,112.5	22.3	1,871.9	0.2
fats and oils of animal or vegetable origin	4,496.5	13.7	4,732.2	12.0	5,746.9	14.9	7,037.2	14.5	5,949.4	14.6	1,452.9	0.9
seeds and fruits of oil plants	1,954.1	6.0	2,563.2	6.5	1,842.4	4.8	2,435.2	5.0	3,758.8	9.2	1,804.7	3.2
food industry residues and waste	1,224.8	3.7	1,486.2	3.8	1,576.5	4.1	1,733.1	3.6	1,082.0	2.6	-142.8	-1.1
meat and edible offal	646.0	2.0	711.9	1.8	652.1	1.7	845.6	1.7	923.9	2.3	277.9	0.3
milk and dairy products, poultry eggs; natural honey	480.9	1.5	453.9	1.1	426.5	1.1	378.5	0.8	452.5	1.1	-28.4	-0.4
edible fruits and nuts	228.6	0.7	260.1	0.7	238.4	0.6	368.2	0.8	313.1	0.8	84.5	0.1
vegetables	235.7	0.7	184.5	0.5	168.1	0.4	196.6	0.4	102.7	0.3	-133	-0.4
finished grain products	268.3	0.8	269.4	0.7	313.1	0.8	414.6	0.9	251.8	0.6	-16.5	-0.2
sugar and sugar confectionery	366.9	1.1	254.4	0.6	250.3	0.6	246.5	0.5	299.6	0.7	-67.3	-0.4
tobacco and industrial tobacco substitutes	398.7	1.2	437.6	1.1	441.3	1.1	453.0	0.9	138.7	0.3	-260	-0.9
other goods and products of the agriculture and food industry	15,186.0	46.5	18,569.4	46.9	17,545.5	45.4	21,928.3	45.3	18,460.1	45.2	3,274.1	-1.3
Total agro-industrial complex	32,727.1	100.0	39,556.1	100.0	38,611.8	100.0	48,380.6	100.0	40,845.1	100.0	8,118.0	-

Source: calculated by the authors based on [30].

A dynamic increase in the export of seeds and fruits of oil crops in 2022 compared to 2018. In 2022, the export of seeds and fruits of oil crops increased compared to 2018 by 1,804 million USD, i.e. by 3.2 percentage points.

2022 turned out to be very difficult for Ukraine and for the world as a whole.

The hostilities in the region blocked the main logistics flows of the export of products from Ukraine and significant changes in the export structure have appeared regarding the geographical dispersion of the beneficiaries.

Transport logistics became much more complicated – 55% fewer products were exported by sea transport in 2022 than in 2021. On the other hand, the share of transportation by road transport has increased significantly. In 2022, the total tonnage of goods exported by road transport increased by 32.4% compared to 2021.

The exports of agricultural products, which usually were carried out by sea, since 2022 were transported on the expense of the use of road, rail, and river, which led to a reduction of the volume of transported products. One cargo ship is capable of moving such a quantity of cargo that would require, for example, about 3,600 trucks or 40 river barges.

In 2022, 60% of grain exports were carried out by river transport, 26% by rail, and 4% by road transport.

Exports were carried out by rail to the ports of Poland and Lithuania, as well as through Austria. The use of railway transport, let alone road transport, turned out to be inefficient from an economic point of view.

European sea terminals have not enough capacity to export additional amounts of products like the ones coming from Ukraine.

Before 2022, the Ukrainian export volume was 60 million tons. In 2021, 8.2 million tons of grains were exported through the Polish ports: Gdansk, Gdynia, Szczecin. But, starting from March 2022, about 25 million tons of grains were exported through Constanta port [31].

Since August 2022, more than 1.7 million tons of agricultural products were exported from the ports of Odesa, Chornomorsk, and Pivdennyi, after the opening of the "Grain corridor".

According to State Statistics Service of Ukraine, a total of 68 ships left the unlocked ports during August, the ports of destination of which are located in 18 countries of the world. During the same period, almost 1.6 million tons were exported through the Danube ports, about a million tons by rail, and more than 600 thousand tons by road [30].

As a result, in March 2022 331.6 thousand tons of agricultural products were exported, then in April – 1.2 million tons, and in June - more than 2.7 million tons, and 3 million tons in July 2022. At the same time, this is significantly less than the 5-6 million tons that were exported monthly by the Black Sea ports before 2022. In general, before the opening of Odesa ports, as of August 1, 2022, almost 8 million tons of agricultural products were shipped, while in 2021, the figure for March-July was more than twice as large – 19.5 million tons. With the start of the implementation of the “grain initiative”, the monthly export of agricultural products increased significantly. In total, in August, Ukraine exported 4.6 million tons of agricultural products, in October and September – 6.9 million tons, and in November – 7.2 million tons [30].

The results of the research made by the Ministry of Agrarian Policy and Food of Ukraine, together with the Kyiv School of Economics, indicated that the total amount of indirect losses in the agricultural sector of Ukraine during the period March-October 2022 amounted to 34.25 billion USD. More than 50% of this amount is due to the losses of producers due to the disruption of logistics flows [13].

In general, we can note the consolidation of the world community around Ukraine`s problems, particularly its economic component. For example, the EU cancelled all customs restrictions on the export of goods and services from Ukraine, which were stipulated by the agreement on the free trade zone. The world community demonstrated unity in solving problems, in particular, economic and logistical ones, which arose as a result of the financial crisis in Ukraine. In particular, the EU canceled customs restrictions and quotas on the export of agricultural products from Ukraine in 2022 and extended this norm until 2023.

Despite the losses of agriculture in 11 months in 2022, Ukraine exported 50.9 million tons of agricultural and food industry products for a total amount of 21.1 billion dollars. In terms of volume, this is by 16.7% less, and in value by 13.7% less than in 11 months of last year [30].

According to Ministry of Agrarian Policy and Food of Ukraine about 7.6 million hectares of arable land have been withdrawn from circulation for an indefinite period. In 2023, the projected cultivated area with grain crops in Ukraine is 8.7 million hectares [13].

In our study, we established the forecast for the year 2023 regarding the gross harvest, based on the sown areas of cereals, and also the forecast of the yield using extrapolation through the construction of a trend line. In the process of calculations, polynomial approximation was used to form the trend line, because the quality of the trend line is the highest – the R^2 coefficient is 0.8717.

The forecasted yield in 2023 is determined at the level of 5.2 tons/ha

In 2023, a decrease in grain yield in Ukraine is expected due to a number of objective reasons. The economic crisis provoked by hostilities significantly narrows the financial possibilities of farmers directly and the state in terms of their support as a whole. We expect a decrease in the amount of fertilizer application, the use of plant protection products, and a violation of the technological process, which will definitely affect an even greater decrease in the yield of grain and other crops.

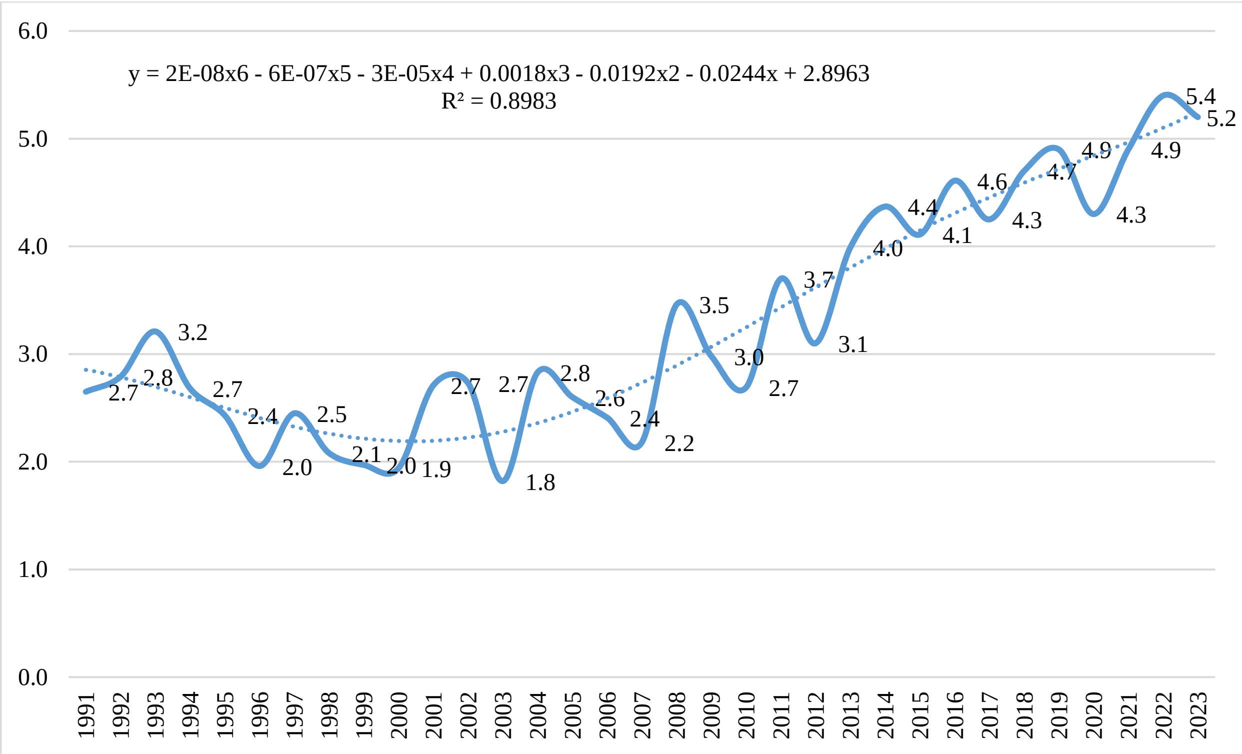

Fig. 5. Forecast of the yield of grains in Ukraine for 2023, tons/ha
Source: calculated by the authors.

The expected reduction in the yield of grain crops as a result of the action of the above-listed reasons relative to the forecast indicator for 2023 may amount to 10-20%. Thus, the average yield of grain crops in Ukraine in 2023 can be predicted at the level of 4.4 t/ha. The factors listed above will have a negative impact on the yield of grain crops, which may cause it to decrease by an additional 10-20% relative to the forecasted indicator in 2023. We believe that the expected yield of grain crops in Ukraine in 2023 will be 4.4 tons on average /Ha.

Taking into account the forecasted amount of acreage under grain crops in Ukraine in 2023 in the amount of 8.7 million hectares. and productivity – 4.4 tons/ha, the expected gross harvest of grain crops will be about 38.1 million tons, which is 55% less than the similar indicator of the pre-war year 2021.

Traditionally, in Ukraine, the lion`s share of the gross harvest of grain went for export, while the share of the harvest needed for domestic needs did not exceed 36% over the last 5 seasons, including on average, food consumption accounted for only about 6%, fodder - 18% [30].

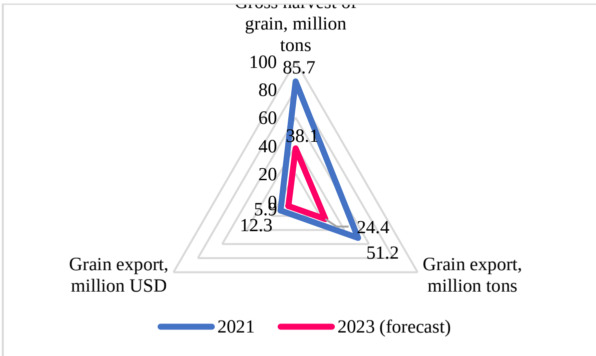

Fig. 6. Projected losses of ukraine from the export of grain crops
Source: [30].

Based on this statement, we can assume that in 2023, Ukraine will use 13.7 million tons of grain for domestic consumption, while it can export about 24.4 million tons, which is 53.2% less than a similar indicator in 2021 (Fig. 6).

CONCLUSIONS

The above provides grounds for asserting that the agricultural sector is extremely important for the Ukrainian economy as a whole. The agrarian branch of the economy is entrusted with the strategic mission of ensuring the country`s food security. As an economic component of the national economy, the agrarian sphere actively forms added value, provides work for the rural population, which contributes to the development of the countryside, loads adjacent branches of production, trade, etc. with orders. Surplus production of agricultural products over domestic demand creates the export potential of domestic agricultural products. High quality and balanced prices make Ukrainian agricultural products highly competitive not only in domestic but also in foreign markets. As a result of the export of agricultural products, Ukraine receives significant foreign exchange earnings, which allows it to balance the foreign exchange market and provides producers with cash to finance economic activities.

The risks that arose in 2022 left a heavy mark on the agricultural sector. The loss of export capacities, a significant reduction in cultivated areas, expensive logistics, and price disparity significantly deepened the economic crisis of the industry. In order to ensure the production of the number of agricultural products necessary for domestic consumption and export, the state needs to take a number of measures, in particular, to provide farmers with the necessary financial support for the proper completion of the production season of the current year, to make efforts to establish effective and uninterrupted logistics for the export of agricultural products, to provide domestic farmers with the necessary political support in the markets of partner countries.

To ensure the required amount of agricultural products for domestic consumption and export, the state should take certain measures. Among them is the provision of necessary financial support to farmers so that they can successfully complete the production season of the current year. It is also necessary to pay due attention to the creation of effective and uninterrupted logistics for the export of agricultural products, as well as to provide political support to domestic farmers in the markets of partner countries. These measures will contribute to the stability and development of the agricultural sector in Ukraine, which is key to ensuring the country's food security and increasing export potential.

REFERENCES

[1]Dziamulych, M., Hrytsenko, K., Krupka, I., Vyshyvana, B., Teslia, S., Tereshko, O., Fadyeyeva, I., 2022, Features of banks` liquidity management in the context of the introduction of the LCR ratio in Ukraine. AD ALTA: Journal of interdisciplinary research. Vol. 12(1). Special Issue XXVII: 148-152.

[2]Dziamulych M., Krupka, I., Andruschak, Y., Petyk, M., Paslavska, R., Grudzevych, Y., Martyniuk, R., 2022, Banking liquidity risk management in Ukraine based on the application of digital and information technologies. AD ALTA: Journal of interdisciplinary research, Vol. 12(2). Special Issue XXIX: 102-107.

[3]Dziamulych, M., Krupka, I., Petyk, V., Zaplatynskyi, M., Korobchuk, T., Synenko, V., Avramchuk, L., 2023, Operational efficiency of Ukraine`s banking system during the war. AD ALTA: Journal of interdisciplinary research, Vol. 13(1). Special Issue XXXII: 164-168.

[4]Dziamulych, M., Moskovchuk, A., Vavdiiuk N., Kovalchuk N., Kulynych, M., Naumenko, N., 2021, Analysis and economic and mathematical modeling in the process of forecasting the financial capacity of milk processing enterprises of the agro-industrial sector: a case study of Volyn region, Ukraine. Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development". Vol. 21(1): 259-272.

[5]Dziamulych, M., Myskovets, I., Zubko, A., Tereshchuk, O., Baidala, V., Voichuk, M., 2022, Formation of the natural resource economics in the system of environmental and economic security. AD ALTA: Journal of interdisciplinary research, Vol. 12(2). Special Issue XXX: 142-146.

[6]Dziamulych, M., Petrukha, S., Yakubiv V., Zhuk, O., Maiboroda, O., Tesliuk, S., Kolosok, A. 2021, Analysis of the socio-demographic state of rural areas in the system of their sustainable development: a case study of Ukraine. Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development". Vol. 21(4): 223-234.

[7]Dziamulych, M., Rogach, S., Shulha, O., Stupen, N., Tendyuk, A., Stryzheus, L. Bilochenko, A., 2023, Management of production resources of agricultural enterprises in Ukraine: a case study of Volyn region. Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development". Vol. 23(1): 179-188.

[8]Dziamulych, M., Sarioglo, V., Kotenko, T., Didkivska, O., Korotkova, D., Talakh, T., Say, V., 2023, Differentiation of income and expenditures of households in the system of formation of the demographic situation in Ukraine. AD ALTA: Journal

of interdisciplinary research. Vol. 13(2). Special Issue XXXV: 111-115.
[9]Dziamulych, M., Stashchuk, O., Korobchuk, T., Mostovenko, N., Martyniuk, R., Strelkova, I., Grebeniuk, N., 2021, Banking innovations and their influence on the formation of digital banking. AD ALTA: Journal of Interdisciplinary Research. Vol. 11(2), Special issue XXI: 108-112.
[10]Dziamulych, M., Yakubiv, V., Shubala, I., Filiuk, D., Korobchuk, L., 2020, Analysis and evaluation of the rural labour market and employment of the rural population: a case study of Volyn region, Ukraine. Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development", Vol. 20(4): 165-174.
[11]Lazaryshyna, I., Antoniuk, N.,, Dobryanskyy, O., Didkivska, O., Rudyk, O., Chudovets, V., Bodakovskyy, V., Kotenko, T., 2023, Financial, accounting, and analytical ensuring of the formation of the anti-crisis potential of financial regulation and control systems in Ukraine under the conditions of digitalization. AD ALTA: Journal of interdisciplinary research. Vol. 13(2). Special Issue XXXV: 101-106.
[12]Marcuta, A., Popescu, A., Marcuta, L., 2021, Study on the role of transfer prices in consolidation of the tax base and in determining the taxable profit of the group of companies. Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development". Vol. 21(1): 487-494.
[13]Ministry of Agrarian Policy and Food of Ukraine, 2022, Review of indirect losses from the war in the agriculture of Ukraine. Second issue, November 10, 2022. https://minagro.gov.ua/, Accessed on April 10, 2023.
[14]Nestorenko, T., 2016, Economic impact of international students on a host city: Case of the university of economics in Bratislava. In Proceedings of Teaching and Education Conferences (No. 3906577). International Institute of Social and Economic Sciences: 180-188.
[15]Nestorenko, T., Morkunas, M., Peliova, J., Volkov, A., Balezentis, T., Streimkiene, D., 2020, A New Model for Determining the EOQ under Changing Price Parameters and Reordering Time. Symmetry. Vol. 12 (9).
[16]Popescu, A., 2015, An Empirical Research on the Bankruptcy Risk Prediction In Romania's Agriculture. Proceedings of 26th IBIMA Conference Innovation Management and Sustainable Economic Competitive Advantage: From Regional Development to Global Growth, Madrid, Spain, Vols. I – VI: 2196-2204.
[17]Popescu, A., 2017, Analysis of sheep and goats livestock and milk and meat production in Romania, 2007-2016. Scientific Papers-Series Management Economic Engineering in Agriculture and Rural Development, Vol. 17(4): 267-279.
[18]Popescu, A., 2003, Financial analysis in dairy farming. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Series Zootechnics and Biotechnologies (Buletinul Universitatii de Stiinte Agricole si Medicina Veterinaria Cluj-Napoca Seria Zootehnie si Biotehnologii). Vol.59: 11-14.
[19]Popescu, A., 2014, Research regarding the use of discriminant analysis for assessing the bankruptcy risk of agricultural companies. Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development". Vol. 14(4): 193-200.
[20]Popescu, A., 2017, Trends and correlations in Romania's agro-food foreign trade in the period 2007-2016. Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development". 17(4): 293-303.
[21]Popescu, A., Alecu, I. N., Grigoras, M. A., 2009, Economic profitability and interest rate–fundamentals of firm financing decisions. Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development". Vol. 9(2): 129-130.
[22]Popescu, A., Dinu, T. A., Stoian, E., 2019, Efficiency of the agricultural land use in the European Union. Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development". 19(3): 475-486.
[23]Popescu, A., Dinu, T. A., Stoian, E., Serban, V., 2020, Turnover's impact on profitability in the commercial companies dealing with dairy farming. Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development". 20(1): 437-445.
[24]Popescu, A., Marcuta, A., Tindeche, C., Angelescu, C., Marcuta, L., 2020, Profit and profitability of the commercial companies dealing with dairy farming. Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development". 20(1): 447-460.
[25]Popescu, A., Stanciu, M., Antonie, I., 2022, Livestock and milk and meat production in the top five EU countries rearing sheep and goats, 2012-2021. Scientific Papers Series "Management, Economic Engineering in Agriculture & Rural Development". Vol. 22(3): 515-530.
[26]Popescu, A., Stanciu, M., Stanciu, C., 2023, Romania's vegetal production in the post access period to the European Union. Scientific Papers Series "Management, Economic Engineering in Agriculture & Rural Development". Vol. 23(1): 627-638.
[27]Serdiuk, N. Yu., 2015, The foreign language teachers' pedagogical reflection of their activities and speech during a teaching practice at school. Psycholinguistics. Vol. 18(2): 95-103.
[28]Shmatkovska, T., Britchenko, I., Voitovych, I., Lošonczi, P., Lorvi, I., Kulyk, I., Begun, S., 2022, Features of banks` liquidity management in the context of the introduction of the LCR ratio in Ukraine. AD ALTA: Journal of interdisciplinary research, Vol. 12(1), Special Issue XXVII: 153-156.
[29]Shmatkovska, T., Kulinich, T., Dziamulych, M., Rogach, S., Bilochenko, A., Serdiukova, O., 2022, Analysis of investment efficiency in the agricultural sector of Ukraine on the basis of sustainable

development. Scientific Papers Series “Management, Economic Engineering in Agriculture and Rural Development”. Vol. 22(3): 649-657.

[30]State Statistics Service of Ukraine, http://www.ukrstat.gov.ua, Accessed on April 10, 2023.

[31]Tkachov, V., 2023, Europe's infrastructure is not ready to "digest" Ukrainian exports. Retrieved from: https://elevatorist.com/interview/103-valeriy-tkachov-infrastruktura-yevropi-ne-gotova-perevariti-ukrayinskiy-eksport, Accessed on April 10, 2023.

[32]Voloshyna, S., Provolotska, O. Lazaryshyna, I., Nieizviestna, O., Skliar, N., 2019, Analytical assessment of the jewellery market in Ukraine. Economic Annals-XXI. Vol. 176(3-4): 65-79.

[33]Voronenko, I, Klymenko, N., Nahorna, O., 2022, Challenges to Ukraine’s Innovative Development in a Digital Environment. Management and Production Engineering Review. Vol. 13(4): 48-58.

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STRATEGY FOR THE DEVELOPMENT OF CORN GROWING TECHNOLOGY UNDER CLIMATE CHANGE

Raisa VOZHEHOVA[1], Tetiana MARCHENKO[1], Yurii LAVRYNENKO[1], Olena PILIARSKA[1], Viktor SHARII[1], Andrii TYSHCHENKO[1], Vira BOROVYK[1], Serhii MISHCHENKO[2], Lyubov KOBYZEVA[3], Tetiana KHOMENKO[4]

[1]Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, 24, Mayatska doroga Str., Khlybodarske, Odesa district, Odesa region, 67667, Ukraine, Phone/Fax: +38 0552361196, +38 0954429212, +38 0505545633, +38 0997779934, +38 0954545086, +38 0992090161, +38 09850807; E-mail: icsanaas@ukr.net, tmarchenko74@ukr.net, lavrin52@ukr.ne, olena.piliarska@gmail.com, viktor.sharii@ukr.net, tischenko_andriy@ukr.net, veraborovik@meta.ua
[2]Institute of Bast Crops of the National Academy of Agrarian Sciences of Ukraine, 45 Tereshchenkiv Str., Hlukhiv, Sumy region, 41400, Ukraine, Phone/Fax: +38 0687981198; E-mail: serhii-mishchenko@ukr.net
[3]The Plant Production Institute nd. a. V. YA. Yuriev of the National Academy of Agrarian Sciences of Ukraine, 142 Heroiv Kharkova Ave., Kharkiv, 61060, Ukraine, Phone/Fax: +38 0509330286; E-mail: l.n.kobyzeva@gmail.com
[4]Ukrainian Institute for Plant Variety Examination, 15 Henerala Rodymtseva Str., Kyiv, 03041, Ukraine, Phone/Fax:+38 0663398398; E-mail: tatiana_7@i.ua

Corresponding author: olena.piliarska@gmail.com

Abstract

The results of research on the impact of sowing dates on economic efficiency, yield, and harvest moisture of corn hybrids of different FAO groups in the conditions of the Southern Steppe of Ukraine are presented. The genotypic response of corn hybrids of different FAO groups to sowing dates was established. From an economic and agrotechnical point of view, each group of FAO corn hybrids in the irrigation conditions of southern Ukraine has its optimal sowing period. Cultivation of corn hybrids of the FAO group 400–500 in the early (April 15) and late (May 15) sowing periods is associated with a certain risk for production with the possibility of a loss of net income in the range of 21–46% (350–790 EUR/ha). These hybrids are the most productive (13.61–15.13 t/ha of grain) under optimal sowing dates (25.04–05.05) and the most profitable (1,473–1,714 EUR/ha) under irrigation conditions. Corn hybrids with FAO 190–290 have the prospect of being used in organic production without the use of herbicides during the late sowing period (May 15). Corn hybrids FAO 300–390 can be used with high efficiency at optimal sowing times, however, their sowing in early and late periods can be risky due to low cold resistance and high harvest humidity in some wet years.

Key words: *corn, hybrids, FAO groups, productivity, harvesting moisture, economic efficiency*

INTRODUCTION

Over the last decades, the yield of grain crops on a global scale has increased significantly. The increase in productivity was mainly due to selection and genetic improvement of the varietal composition, increase in the productivity potential of genotypes, adaptability to the variability of agro-climatic factors, tolerance to stress factors of biotic and abiotic origin. This emphasizes the importance of the main direction in increasing productivity – selection and genetic developments, which, according to the testimony of leading scientists, provide the main increase in productivity and gross harvests in recent years [17, 7, 13].

Today, the main grain crop in the world is corn (*Zea mays* L.). The fundamental task of increasing the yield and expanding the area of corn cultivation is the use of hybrids adapted to certain geographical areas and adapted to specific technologies. This question becomes especially relevant in the conditions of climate change in the direction of aridification. The rapidly progressing change in the Earth's climate, caused by global warming, is probably one of the biggest threats to the development of natural ecosystems, the agro-industrial complex, the economy and humanity in general, as warned by annual studies by climatologists [1]. In this direction of research, the development of models of adaptive technologies is of primary importance for the growth of corn productivity in agro-ecological zones suffering from global climate changes in the direction of aridity, soil erosion and temperature stress [18, 9].

Selection and technological research on the improvement of adaptation of corn growing systems under conditions of climate change in the direction of aridity becomes relevant precisely in the conditions of the arid Steppe of Ukraine, where the aridity of the climate is increasing, but the duration of the growing season of corn is also lengthened due to the increase in effective temperatures, which allows the use of a wide range of corn hybrids of different maturity groups from FAO 190 to FAO 500. Therefore, the question of developing a technology for ultra-early, optimal and late sowing periods of corn hybrids in the conditions of the Southern Steppe of Ukraine for a more complete use of the bioclimatic potential of the region arises.

Previous studies by scientists have established that the improvement of the technology of growing corn hybrids of various FAO groups is of particular relevance in the context of climate change in the direction of increasing the sum of effective temperatures and extending the duration of the growing season by up to 10%. In the conditions of the arid Steppe of Ukraine, the only limiting factor for the cultivation of intensive innovative corn hybrids is the lack of natural precipitation. This problem is successfully solved by artificial irrigation using different watering methods. Global and regional climate changes, manifested in an increase in the temperature regime against the background of a decrease in precipitation, require the adaptation of elements of corn cultivation technology, taking into account breeding achievements and increasing the bioclimatic potential of the region [6].

Crops with a high need for water, such as corn, need special adaptation to temperature stress, which is accompanied by climatic changes and increased temperature during the growing season. An important indicator of the efficiency of the cultivation technology is the water productivity (WP). There is considerable scope for improving the water productivity of plants under conditions of climate change in the direction of warming [15].

The genotypic response of hybrids to the sowing time was determined. It has been established that an increase in temperature accelerates the ontogenesis of hybrids of different maturity groups. Early-maturing hybrids showed greater yield stability at different sowing times and at different locations. Late-maturing hybrids were more productive at early sowing times, and early-maturing hybrids at late times were at the same level as late ones, or exceeded them [19].

Early sowing times in southern Ukraine can be risky due to insufficient soil temperature, therefore corn hybrids that germinate at a soil temperature of 8°C were created through selective development. These are mostly precocious hybrids with siliceous grains [5]. Such hybrids are suitable for use in the northern regions of Ukraine and have prospects for use in the southern regions during very early sowing periods. When sowing corn, it is necessary to take into account the individual reaction of hybrids. Breeding programs for the creation of precocious hybrids of corn with increased cold resistance, which are able to germinate at a soil temperature of +6°C, are quite in demand today. Sowing of such hybrids can be carried out in the beginning of the term [4].

Heat stress is the biggest threat to future global corn production. Adaptation of corn to future climate changes in the direction of warming requires a better understanding of plant response to temperature increase [14].

Corn grain yield consists of different proportional contributions of factors at all stages of organogenesis. For a better understanding of the influence of climatic and technological effects on the yield of corn, comprehensive studies are needed that determine the influence of soil, climatic conditions, sowing dates and biological features of the genotype. The date of sowing can play an important role in the formation of yield, grain quality, minimization of biotic and abiotic stresses [11].

A detailed analysis of the relationship between growing technologies and growing season weather showed that corn yield reflects two components – yield potential and potential losses caused by weather and pests. It has been proven that the introduction of adaptive genotypes affects the yield potential, and excess heat reduces soil moisture reserves and the efficiency of nitrogen use [10].

An analysis of corn production in the U.S. Corn Belt has shown that yield increases over the past 40 years are the result of continuous genetic improvement, improvements in growing techniques, and the synergistic effect of improved genetics and agronomy. Increasing yields in the future may be difficult as on-farm corn yields approach potential, but an important element of efficient production is agrotechnical measures that reduce input costs and increase profits [8].

The genetic potential of corn hybrids can be correlated with the timing of sowing. Thus, Indian studies have established optimal sowing rates for certain varieties of corn. The timing of sowing significantly affects the productivity of products and, what is important for farmers, provides an opportunity to forecast the maximum gross profit, net profit and regulate the ratio of profit and costs [16].

The date of sowing in regions with a temperate climate is determined by weather conditions during the pouring of grain. Corn plant growth rates at grain filling were slower in late plantings due to low daily incident radiation and radiation use efficiency. The effective duration of grain pouring depended on the presence of assimilates and on the speed of grain pouring when sowing was late. A decrease in the source of assimilates in the later sowing period led to a lower mass of grain at harvest. It was established that the effective rate of grain pouring was strongly influenced by temperature [3].

The timing of sowing determines the processes of plant growth and development, as well as the formation of its productivity, the immunological state of crops. Until now, there are ongoing discussions regarding the timing of corn sowing. Science and practice discuss both earlier, compared to the optimal, and later sowing dates. Researchers note that the influence of sowing dates on corn yield is closely related to weather conditions during seed germination and at the beginning of plant development. The early sowing period can be more effective than the following one, and when sowing in cold and unheated soil and the return of cold weather, it can be inferior to it [2].

Growing corn using modern technologies, among which an important element is the correct selection of hybrids according to FAO groups and optimal sowing times in accordance with agro-ecological conditions, will allow to significantly increasing its productive potential and the level of corn production. In the Southern Steppe of Ukraine, the traditional recommended date for sowing corn was from April 25 to May 5 [22]. Such sowing dates took into account soil warming to 12–14°C, sufficient soil moisture, the possibility of using post-emergence herbicides and the use of mainly medium-ripening FAO 300–390 corn hybrids under irrigation conditions and early-ripening FAO 190–290 hybrids without irrigation. An increase in the sum of effective temperatures, an increase in the duration of the frost-free period, which has been observed in recent years in the south of Ukraine, allows growing hybrids with an extended growing season and higher potential yield.

Thus, the issue of technology development for ultra-early, optimal and late sowing periods of corn hybrids in the conditions of the Southern Steppe of Ukraine is acute. Analyzing data from the review of literary sources, we can draw a conclusion: the sowing period is one of the agrotechnical techniques that has a significant impact on the formation of corn grain yield. Scientists do not have a single opinion about the right temperature at which it is advisable to start sowing corn. Therefore, the study of the impact of sowing dates on the yield and economic efficiency of growing innovative corn hybrids of different FAO groups in the conditions of drip irrigation of the Southern Steppe of Ukraine is relevant for the stabilization of corn grain production.

The purpose of research – to determine the effect of sowing dates on economic efficiency, yield, and harvest moisture of corn hybrids of different FAO groups in the conditions of the Southern Steppe of Ukraine.

MATERIALS AND METHODS

The research was conducted during 2018–2020 at the experimental field of the Institute of Irrigated Agriculture of the NAAS, located in the subarid zone of the Southern Steppe of Ukraine under drip irrigation conditions. A two-factor experiment was conducted using the method of split randomized blocks [20]. The research was carried out in four repetitions. The sown area of the plots was 50.0 m^2, the accounting area was 30.0 m^2.

During the years of the study, the weather conditions were typical for the South of Ukraine with the amount of precipitation ranging from 150 to 170 mm. Insufficient precipitation is compensated by irrigation, the pre-irrigation soil moisture level was 80% of the lowest moisture content in the 0–50 cm layer, which is the optimal regime for all FAO groups.

Factor A – sowing period (date): April 15, April 25, May 5, May 15.

Factor B – innovative corn hybrids with different maturity groups: precocious Stepovyi (FAO 190), DN Meotyda (FAO 190); middle early Skadovs`kyi (FAO 290), DN Halateia (FAO 250); medium-ripe Inhul`s`kyi (FAO 350), DN Zbruch (FAO 350); middle-late Arabat (FAO 420), DN Anshlah (FAO 420).

RESULTS AND DISCUSSIONS

Our experimental studies in the irrigated conditions of the Southern Steppe of Ukraine showed that the timing of sowing significantly affects the development of plants, the formation of the grain yield of corn hybrids of different FAO groups. Depending on the factors of the experiment, corn plants fall into different agrometeorological conditions, grow and develop in different ways, and have different productivity. During the research period 2018–2020, the grain yield of corn hybrids of different FAO groups varied depending on the sowing dates from 8.03 to 15.92 t/ha (Table 1).

According to the results of the conducted research, it was established that under irrigation conditions, corn hybrids of different FAO groups showed the maximum yield during the late sowing periods (May 5 and 15).

Thus, the precocious hybrid Stepovyi (FAO 190) showed the maximum grain yield in 2018 and 2019 for sowing on 05.05 – 9.14 and 9.75 t/ha, respectively, in 2020 for sowing on 05.05 – 9.37 t/ha. The minimum yield of 8.15 t/ha was shown for sowing on 04/15, yield reduction – 0.92 t/ha, or 9.9% of the maximum yield for the optimal sowing period of 05/05.

The hybrid DN Meotyda (FAO 190) also showed the maximum grain yield in 2018, 2019 for sowing on 05.05 – 8.97 and 9.34 t/ha, in 2020 for sowing on 05.15 – 9.26 t/ha. The minimum yield of 8.04 t/ha was shown for sowing on April 15, but the average decrease in yield was insignificant – 0.82 t/ha, or 9.1%.

The mid-early hybrid Skadovs`kyi (FAO 290) also showed the maximum grain yield in 2018 and 2019 for sowing on 05.05 - 12.56 and 12.85 t/ha, in 2020 for sowing on 05.15 – 12.92 t/ha. The minimum yield was 8.67 t/ha for sowing on April 15, the decrease in yield was more significant and amounted to 4.18 t/ha, or 33.3%.

The mid-early hybrid DN Halateia (FAO 250) showed the maximum grain yield in 2018, 2019 for sowing on 05.05 – 12.72 and

13.34 t/ha, in 2020 for late sowing on 05.15 – 13.56 t/ha. The minimum productivity of 8.74 t/ha was shown for sowing on 15.04 with a decrease in productivity of 4.60 t/ha, or 28.1%. The medium-ripe hybrid Inhul`s`kyi (FAO 350) showed the maximum grain yield in 2018, 2019 for sowing on 05.05 – 13.51 and 14.17 t/ha, in 2020 for sowing on 05.15 – 13.85 t/ha. The minimum yield of 8.92 t/ha was shown for early sowing on April 15. The yield reduction was 5.25 t/ha, or 36.8%.

Table 1. Grain yield of corn hybrids of different FAO groups depending on sowing dates, t/ha (estimated grain moisture content 14%)

Sowing period, days (factor A)	Hybrid (factor B)	Years of research			Average for 2018-2020	On average, by factor B
		2018	2019	2020		
April 15	Stepovyi (FAO 190)	8.15	8.54	8.35	8.35	8.85
	DN Meotyda (FAO 190)	8.04	8.43	8.16	8.21	8.66
	Skadovs`kyi (FAO 290)	9.43	10.72	8.67	9.61	11.35
	DN Halateia (FAO 250)	9.52	10.91	8.74	9.72	11.58
	Inhul`s`kyi (FAO 350)	10.61	10.35	8.92	9.96	12.14
	DN Zbruch (FAO 350)	10.85	10.92	9.14	10.30	12.47
	Arabat (FAO 420)	10.54	11.24	9.89	10.56	13.74
	DN Anshlah (FAO 420)	10.03	10.36	9.23	9.87	13.36
	Average by factor A	**9.65**	**10.18**	**8.89**	**9.57**	
April 25	Stepovyi (FAO 190)	8.34	8.92	8.54	8.60	
	DN Meotyda (FAO 190)	8.03	8.87	8.35	8.42	
	Skadovs`kyi (FAO 290)	11.64	11.92	9.74	11.10	
	DN Halateia (FAO 250)	11.73	12.13	10.17	11.34	
	Inhul`s`kyi (FAO 350)	12.25	12.61	10.56	11.81	
	DN Zbruch (FAO 350)	12.56	12.92	10.92	12.13	
	Arabat (FAO 420)	14.27	14.54	12.83	13.88	
	DN Anshlah (FAO 420)	14.04	14.23	12.56	13.61	
	Average by factor A	**11.61**	**12.02**	**10.46**	**11.36**	
May 5	Stepovyi (FAO 190)	9.14	9.75	8.93	9.27	
	DN Meotyda (FAO 190)	8.97	9.34	8.77	9.03	
	Skadovs`kyi (FAO 290)	12.56	12.85	11.23	12.21	
	DN Halateia (FAO 250)	12.72	13.34	11.35	12.47	
	Inhul`s`kyi (FAO 350)	13.51	14.17	12.25	13.31	
	DN Zbruch (FAO 350)	13.73	14.54	12.92	13.73	
	Arabat (FAO 420)	15.56	15.92	13.91	15.13	
	DN Anshlah (FAO 420)	15.34	15.63	13.84	14.94	
	Average by factor A	**12.69**	**13.19**	**11.65**	**12.51**	
May 15	Stepovyi (FAO 190)	8.75	9.36	9.37	9.16	
	DN Meotyda (FAO 190)	8.54	9.15	9.26	8.98	
	Skadovs`kyi (FAO 290)	12.12	12.43	12.92	12.49	
	DN Halateia (FAO 250)	12.66	12.12	13.56	12.78	
	Inhul`s`kyi (FAO 350)	13.15	13.47	13.85	13.49	
	DN Zbruch (FAO 350)	13.34	13.65	14.15	13.71	
	Arabat (FAO 420)	15.25	15.34	15.62	15.40	
	DN Anshlah (FAO 420)	14.64	15.15	15.21	15.00	
	Average by factor A	**12.31**	**12.59**	**12.99**	**12.63**	
LSD_{05}		**0.21**	**0.19**	**0.25**		

Source: Own calculation.

The medium-ripe hybrid DN Zbruch (FAO 350) showed the maximum grain yield in 2018, 2019 for sowing on 05.05 – 13.73 and 14.54 t/ha, in 2020 for sowing on 05.15 – 14.15 t/ha. The minimum yield of 9.14 t/ha was shown for sowing on 15.04 with a decrease in yield of 5.40 t/ha, or 37.2%.

The mid-late hybrid Arabat (FAO 420) showed the maximum grain yield in 2018, 2019 for sowing on 05.05 – 15.56 and

15.92 t/ha, in 2020 for sowing on 05.05 – 15.62 t/ha. The minimum yield of 9.89 t/ha was shown for sowing on April 15. The yield reduction was 6.03 t/ha, or 38.3%. The hybrid DN Anshlah (FAO 420) showed the maximum grain yield in 2018, 2019 for sowing 05.05 – 15.34 and 15.63 t/ha, in 2020 for sowing 5.05 – 15.21 t/ha. The minimum yield of 9.23 t/ha was shown for sowing on April 15, with a decrease in yield of 6.40 t/ha, or 41.1%. Summarizing the productivity indicators, we observe that the productivity of all hybrids decreases with the use of early sowing dates. However, a minimal difference in yield at different sowing times was observed in precocious hybrids FAO 190. The decrease in yield at early sowing times was insignificant – in the range of 9.1–9.9%, which indicates their cold resistance. However, the grain yield of these hybrids was also low (in the range of 8–9 t/ha), which indicates their low productivity potential. These hybrids were created according to programs of cold resistance and early ripening, so their use may be appropriate for sowing in relatively cold soil.

In the modern conditions of agro-industrial production, when the cost of energy carriers has increased significantly, the creation of corn hybrids of different groups of maturity with a rapid return of moisture during ripening is an actual direction of selection. The intensity of grain moisture loss largely depends on the conditions of the external environment, in particular weather factors: temperature, relative humidity. The rate of moisture release by grain is determined not only by environmental conditions, but also by heredity. Low harvesting moisture of corn grain is primarily determined by the duration of the vegetation period, while the factor of early maturity is dominant [12].

Table 2 shows grain moisture data before harvesting. During the 2018-2020 research, this indicator for the grain of hybrids of different FAO groups before harvesting fluctuated within the hybrid maturity group and sowing dates. The grain moisture of all corn hybrids of different maturity groups at the time of harvesting was in the range from 12.1 to 27.0%, which indicates the extreme importance of studying this indicator as the main indicator of the technology of growing corn with high efficiency and profitability. Different sowing dates and FAO groups of hybrids determine the variation of this indicator. Increased moisture content of grain above 14%, in addition to the main additional costs for drying grain, increases costs for transportation, storage, loss of grain quality from fungal diseases and entomophages, which have been spreading in recent years under irrigation conditions [21].

The cost of dried grain can also be lower due to damage to the grain by cracks and fungal mycelia, so production is extremely interested in low harvesting humidity. Low harvesting moisture also depends on harvesting dates, and the delay in harvesting and postponement of dates to late autumn does not bring the expected natural drying of grain due to low rates of moisture transfer at low temperatures and secondary moistening during autumn rains. The maximum grain moisture content varied from 12.5% in hybrids FAO 190 to 27.0% in hybrids corn FAO 420 for sowing on May 15. The minimum moisture content of the grain varied from 12.1% to 14.9% for the studied hybrids of different FAO groups for sowing on April 15. With regard to the dependence of the harvesting moisture on the maturity groups of the hybrids, a clear pattern was observed – the minimum grain moisture characteristic of the hybrids FAO 190 Stepovyi and DN Meotyda – 12.1–13.1%, the maximum - in the hybrids FAO 420 Arabat and DN Anshlah – 14.8– 27.0%. The moisture content of hybrids FAO 250–290 in the early, optimal and late periods was almost at the same level. Thus, almost all hybrids, except for the FAO 420 hybrids, had the basic moisture content of the grain during all sowing periods, which allowed not carrying out the drying of the grain after harvesting, to bear losses from additional transportation and price discounts. This is important in the process of using energy-saving technologies for growing corn. The difference in grain moisture depending on the time of sowing was more clearly defined in hybrids with an extended growing season. These are such hybrids as Arabat and DN Anshlah. During the late sowing periods, the moisture content of the grain of these hybrids increased in some years by 10.7–11.2%, compared to the early ones. The difference in grain moisture between the early and optimal term (May 5) in Arabat and DN Anshlah hybrids was much smaller (from 1.9 to 2.5%). This indicates that the ripening period of these genotypes fell on August, a month when low relative air humidity, high day and night temperatures are observed, which contributes to accelerated moisture transfer and a decrease in grain moisture to optimal indicators for harvesting by a combine with direct threshing. Improving the elements of varietal agrotechnics of corn hybrids of different maturity groups provides an opportunity to increase crop productivity. It is not enough to determine the efficiency of any complex of agricultural measures only by the change in the level of the harvest, because the costs of its cultivation are not taken into account, therefore, it is necessary to determine not only the agrotechnical, but also the economic efficiency.

Table 2. Harvesting grain moisture of corn hybrids depending on the sowing dates, % (2018–2020)

Sowing period, days (factor A)	Hybrid (factor B)	Years of research			Average for 2018-2020	On average, by factor B
		2018	2019	2020		
April 15	Stepovyi (FAO 190)	12.1	12.2	12.5	12.3	12.5
	DN Meotyda (FAO 190)	12.2	12.4	12.7	12.4	12.7
	Skadovs`kyi (FAO 290)	12.5	12.6	12.6	12.6	13.0
	DN Halateia (FAO 250)	12.8	12.7	12.7	12.7	13.1
	Inhul`s`kyi (FAO 350)	13.4	13.5	13.5	13.5	13.7
	DN Zbruch (FAO 350)	13.4	13.5	13.6	13.5	14.0
	Arabat (FAO 420)	14.1	14.3	14.8	14.4	18.1
	DN Anshlah (FAO 420)	14.8	14.9	14.9	14.9	18.2
	Average by factor A	**13.2**	**13.3**	**13.4**	**13.3**	
April 25	Stepovyi (FAO 190)	12.3	12.4	12.5	12.4	
	DN Meotyda (FAO 190)	12.6	12.7	12.8	12.7	
	Skadovs`kyi (FAO 290)	12.7	12.8	12.9	12.8	
	DN Halateia (FAO 250)	13.0	12.9	12.8	12.9	
	Inhul`s`kyi (FAO 350)	13.6	13.7	13.7	13.7	
	DN Zbruch (FAO 350)	13.7	13.8	13.9	13.8	
	Arabat (FAO 420)	14.5	15.3	15.8	15.2	
	DN Anshlah (FAO 420)	14.8	15.9	15.7	15.5	
	Average by factor A	**13.4**	**13.7**	**13.8**	**13.6**	
May 5	Stepovyi (FAO 190)	12.4	12.6	12.6	12.5	
	DN Meotyda (FAO 190)	12.8	12.9	12.9	12.9	
	Skadovs`kyi (FAO 290)	12.9	13.0	13.6	13.2	
	DN Halateia (FAO 250)	13.0	13.1	13.5	13.2	
	Inhul`s`kyi (FAO 350)	13.1	13.5	13.6	13.4	
	DN Zbruch (FAO 350)	14.1	14.2	14.1	14.1	
	Arabat (FAO 420)	15.5	17.3	17.8	16.9	
	DN Anshlah (FAO 420)	15.8	16.9	17.7	16.8	
	Average by factor A	**13.7**	**14.2**	**14.5**	**14.1**	
May 15	Stepovyi (FAO 190)	12.5	12.8	13.1	12.8	
	DN Meotyda (FAO 190)	12.7	12.9	12.9	12.8	
	Skadovs`kyi (FAO 290)	13.2	13.1	14.1	13.5	
	DN Halateia (FAO 250)	13.1	13.5	14.5	13.7	
	Inhul`s`kyi (FAO 350)	13.5	13.8	14.9	14.1	
	DN Zbruch (FAO 350)	14.5	14.6	14.8	14.6	
	Arabat (FAO 420)	25.2	25.1	26.9	25.7	
	DN Anshlah (FAO 420)	25.0	24.9	27.0	25.6	
	Average by factor A	**16.2**	**16.3**	**17.3**	**14.1**	

Source: Own calculation.

In the process of economic analysis of indicators of the cultivation of corn hybrids, the conditional net profit of the cultivation of corn hybrids of different FAO groups for different sowing periods was calculated. The results of the economic analysis of cultivation indicate that the FAO group of the hybrid, the sowing period significantly affect the indicators of the economic efficiency of crop cultivation (Table 3).

Table 3. Conditionally net profit when growing corn hybrids of different FAO groups depending on the sowing time in the conditions of the Southern Steppe of Ukraine under irrigation, EUR/ha

Sowing period, days (factor A)	Hybrid (factor B)	Years of research			Average for 2018-2020	On average, by factor B
		2018	2019	2020		
April 15	Stepovyi (FAO 190)	605	785	825	738	779
	DN Meotyda (FAO 190)	584	664	795	681	749
	Skadovs`kyi (FAO 290)	647	707	874	743	1,059
	DN Halateia (FAO 250)	813	735	893	814	1,171
	Inhul`s`kyi (FAO 350)	888	746	925	853	1,165
	DN Zbruch (FAO 350)	1,012	934	967	971	1,246
	Arabat (FAO 420)	976	875	885	912	1,388
	DN Anshlah (FAO 420)	894	846	976	905	1,355
	Average by factor A	**802**	**787**	**893**	**827**	
April 25	Stepovyi (FAO 190)	620	724	854	733	
	DN Meotyda (FAO 190)	574	708	815	699	
	Skadovs`kyi (FAO 290)	1,122	969	1,053	1,048	
	DN Halateia (FAO 250)	1,145	998	1,121	1,088	
	Inhul`s`kyi (FAO 350)	1,124	1,064	1,192	1,127	
	DN Zbruch (FAO 350)	1,165	1,108	1,254	1,176	
	Arabat (FAO 420)	1,523	1,439	1,585	1,516	
	DN Anshlah (FAO 420)	1,492	1,392	1,534	1,473	
	Average by factor A	**1,096**	**1,050**	**1,176**	**1,107**	
May 5	Stepovyi (FAO 190)	740	830	915	828	
	DN Meotyda (FAO 190)	713	873	884	823	
	Skadovs`kyi (FAO 290)	1,262	1,108	1,303	1,124	
	DN Halateia (FAO 250)	1,294	1,215	1,321	1,277	
	Inhul`s`kyi (FAO 350)	1,415	1,327	1,475	1,406	
	DN Zbruch (FAO 350)	1,446	1,433	1,596	1,492	
	Arabat (FAO 420)	1,724	1,653	1,764	1,714	
	DN Anshlah (FAO 420)	1,693	1,649	1,756	1,699	
	Average by factor A	**1,286**	**1,261**	**1,377**	**1,308**	
May 15	Stepovyi (FAO 190)	694	774	984	817	
	DN Meotyda (FAO 190)	667	746	965	793	
	Skadovs`kyi (FAO 290)	1,153	1,212	1,592	1,319	
	DN Halateia (FAO 250)	1,232	1,574	1,704	1,503	
	Inhul`s`kyi (FAO 350)	1,106	1,263	1,455	1,275	
	DN Zbruch (FAO 350)	1,134	1,395	1,503	1,344	
	Arabat (FAO 420)	1,335	1,234	1,657	1,409	
	DN Anshlah (FAO 420)	1,237	1,203	1,584	1,341	
	Average by factor A	**1,070**	**1,175**	**1,431**	**1,225**	

Source: Own calculation.

According to the stock exchange, the price of a ton of corn grain in 2018 was EUR 153/t, in 2019 it was EUR 146/t, and in 2020 it was EUR 170/t. It was calculated that the highest profits in the steppe zone of Ukraine are provided by hybrids with FAO more than 400 (on average 1,355 and 1,388 EUR/ha), however, the variation of profit from the cultivation of these hybrids was also the largest - from 1,764 EUR/ha in 2020 for sowing on 05.05 up to 846 euros/ha in 2019 for sowing on 05.04. The halving of profit is explained by the negative impact of early sowing on grain yield in late-ripening hybrids and the increase in costs for bringing wet grain to conditions.

In the conditions of modern production, it is necessary to take into account not only the maximum profit of one year, because the share of corn in crop rotations of southern Ukraine with irrigation is 12–33%. The next crops in the crop rotation after corn can be winter wheat, barley, rapeseed, therefore, the timing of corn grain harvesting is of great importance in corn cultivation. The terms of harvesting corn grain with a moisture content of no more than 14% directly depend on the genotype of the hybrid and the time of sowing. Thus, Stepovyi, DN Meotyda corn hybrids during the sowing period of 15.04 had dry grain (less than 13%) from mid-August and this made it possible to prepare the soil qualitatively for sowing winter crops – wheat, barley, rapeseed. Corn hybrids with FAO 290–420, due to the late harvesting period, could no longer guarantee the quality of soil preparation for sowing winter crops.

Corn hybrids with FAO 190–290 have the prospect of being used in organic production without the use of herbicides due to late sowing dates (May 15). Such sowing dates allow for 2–3 pre-sowing cultivations to destroy weeds.

Corn hybrids FAO 300–390 can be used with high efficiency at optimal sowing times, but their sowing in early and late periods can be risky due to low cold resistance and high harvest humidity in some wet years.

The favorable conditions of the Southern Steppe of Ukraine, namely the optimal temperatures for the growth and development of corn plants, the presence of irrigation, make it possible to grow all groups of ripeness, including late-ripening forms up to FAO 500. The most productive in the south of Ukraine, with the mandatory presence of irrigation, are hybrids of corn of the late-ripening group FAO. However, it should be noted that corn hybrids with FAO 400–500 at late sowing times may not form ripe grain every year due to insufficient effective temperatures and a cool, wet autumn.

Previous studies have established that in the third decade of September and October, grain moisture is significantly delayed and is not 1.2–1.5%, as in August – the first half of September, but decreases to 0.1–0.5% [21]. The main reason for the decrease in the rate of grain moisture release, starting from the second half of September, is a decrease in night temperatures to 10°C, which significantly slows down the ripening process. During the late sowing period, the phase of grain filling in the FAO 400–500 hybrids falls precisely on this period, which is reflected in the indicators of the grain moisture content, therefore, the cultivation of corn hybrids of the FAO 400-500 group at the late sowing period is associated with a certain risk for production.

In the researches of other authors, it was established that in regions with a moderate climate, the formation of the potential yield of corn can be limited by solar radiation and temperature conditions. Such restrictions are more harmful during the grain ripening period than during the grain filling period [22].

Our research is confirmed by the previous reports of scientists that the timing of sowing significantly adjusts indicators of productivity, quantity and quality of cobs and maximum net profit [16]. The results of such studies should be taken into account in the effective production of agricultural products in specific agro-climatic zones.

Climate changes require adjustment of corn cultivation technologies by US farmers, and the main element of improved technologies are innovative hybrids that provide a profitable economy of production [10]. Our research also confirms this conclusion about the need to determine the interaction of the genotype with agroclimatic factors that shape the yield and profitability of growing corn in the conditions of the dry Steppe of Ukraine.

CONCLUSIONS

In the agroclimatic conditions of the Southern Steppe of Ukraine, under irrigation, the genotypic response of corn hybrids of different FAO groups to the sowing dates was established. From an economic and agrotechnical point of view, each group of FAO corn hybrids in the irrigation conditions of southern Ukraine has its optimal sowing period.

Cultivation of corn hybrids of the FAO group 400–500 in early and late sowing periods is associated with a certain risk for production with the possibility of a loss of net income in the range of 21–46% (350–790 EUR/ha). These hybrids are the most productive (13.61–15.13 t/ha of grain) under optimal sowing dates (25.04–05.05) and the most profitable (1,473–1,714 EUR/ha) under irrigation conditions.

Corn hybrids with FAO 190–290 have the prospect of being used in organic production without the use of herbicides during the late sowing period (May 15). Hybrids of this maturity group show a minimal reaction to the timing of sowing. In early periods, they can be used in crop rotations as precursors for winter crops.

Maize hybrids FAO 300–390 can be used with high efficiency at optimal sowing times, however, their sowing in early and late periods can be risky due to low cold resistance and high harvest humidity in some wet years.

REFERENCES

[1]Birch, E.L., 2014, A Review of “Climate change 2014: Impacts, adaptation, and vulnerability” and “Climate change 2014: Mitigation of climate change”, Journal of the American Planning Association, 80(2):184–185.

[2]Cantarero, M.G., Lugue, S.F., Rubiolo, O.J., 2000, Effects of sowing date and plant density on grain number and yield of a corn hybrid in the central region of Córdoba, Argentina. J. Agric. Sci., 17:3–10.

[3]Cirilo, A.G., Andrade, F.H., 1996, Sowing date and kernel weight in corn, Crop Science, 36(2):325–331.

[4]Dang, J., Liang, W., Wang, G., Shi, P., Wu, D., 2016, A preliminary study of the effects of plastic film-mulched raised beds on soil temperature and crop performance of early-sown short-season spring corn (*Zea mays* L.) in the North China Plain, The Crop Journal, 4(4):331–337.

[5]Dzyubetsky, B.V., Cherchel, V.Yu., 2017, Grain yields of corn speedy hybrids of various varieties, Bulletin of Agrarian Science (In Russian), 8:19–23.

[6]Gadzalo, Ya.M., Vozhehova, R.A., Kokovikhin, S.V., Bilyaeva, I.M., Drobitko, A.V., 2020, Scientific substantiation of corn cultivation technologies on irrigated lands taking into account hydrothermal factors and climate change, Irrigated Agriculture, 73:21–26.

[7]Gilliham, M., Able, J.A., Roy, S.J., 2017, Translating knowledge about abiotic stress tolerance to breeding programmers, Plant Journal, 90(5):898–917.

[8]Grassini, P., Specht, J.E., Tollenaar, M., Ciampitti, I., Cassman, K.G., 2015, High-yield corn–soybean cropping systems in the US Corn Belt, in: Sadras, V.O, Calderini, D.F. (Eds.), Crop Physiology, Academic Press., pp. 17–41.

[9]Hatfield, J.L., 2016, Increased temperatures have dramatic effects on growth and grain yield of three corn hybrids, Agricultural & Environmental Letters, 1(1), 150006.

[10]Huffman, W.E., Jin, Y., Xu, Z., 2018, The economic impacts of technology and climate change: New evidence from US corn yields, Agricultural Economics, 49(4):463–479.

[11]Koca, Y.O., Canavar, Ö., 2014, The effect of sowing date on yield and yield components and seed quality of corn (*Zea mays* L.), Scientific Papers. Series A. Agronomy, LVII:227–231.

[12]Lavrynenko, Yu. O., Marchenko, T.Yu., Nuzhna, M.V., Bodenko, N.A., 2018, FAO 150–490 corn hybrid models for minds, Plant Varieties Studying and Protection, 14(1):58–65.

[13]Lavrynenko, Yu. O., Laser, P.N., Jokich, D.R., Plotkin, S.Ya., Tverdokhlib, O.Ya., 2004, Ecological and genetic uncertainty is a sign of productivity and additional consumption of grains with ripening corn hybrids in agricultural crops, Taurian Science Bulletin, 32:54–66.

[14]Lizaso, J.I., Ruiz-Ramos, M., Rodríguez, L., Gabaldon-Leal, C., Oliveira, J.A., Lorite, I.J., Sánchez, D., García, E., Rodríguez, A., 2018, Impact of high temperatures in corn: Phenology and yield components, Field Crops Research, 216:129–140.

[15]Molden, D., Oweis, T., Steduto, P., Bindraban, P., Hanjra, M.A., Kijne, J., 2010, Improving agricultural water productivity: Between optimism and caution, Agricultural Water Management, 97(4):528–535.

[16]Singh, G., Kumar, S., Singh, R., Singh, S.S., 2015, Growth and yield of Baby Corn (*Zea mays* L.) as influenced by varieties, spacings and dates of sowing, Indian Journal of Agricultural Research, 49(4):353–357.

[17]Tester, M., Langridge, P., 2010, Breeding technologies to increase crop production in a changing World, Science, 327(5967):818–822.

[18]Troyer A.F., 2006, Adaptedness and heterosis in corn and mule hybrids, Crop science, 46(2):528–543.

[19]Tsimba, R., Edmeades, G.O., Millner, J.P., Kemp, P.D., 2013, The effect of planting date on corn grain yields and yield components, Field Crops Research, 150:135–144.

[20]Vozhehova, R.A., Lavrynenko, Yu.O., Malyarchuk, M.P., 2014, Methods of field and

laboratory studies on irrigated lands; Kherson: Grin D.S., 316 p.

[21]Vozhehova, R., Marchenko, T., Lavrynenko, Y., Piliarska, O., Zabara, P., Zaiets, S., Tyshchenko, A., Mishchenko, S., Kormosh, S., 2022, Productivity of lines – parental components of corn hybrids depending on plant density and application of biopreparations under drip irrigation, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(1):695–704.

[22]Zubets, MV., Sitnik, V.P., Bezugliy, M.D. et al., 2010, Scientific foundations of agroindustrial production in the steppe zone of Ukraine. Kiev, Agrarian Science, 986 p.

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THE RESPONSE OF *NIGELLA SATIVA* PLANTS TO DIFFERENT NATURAL AND CHEMICAL FERTILIZERS UNDER MEDITERRANEAN CONDITIONS

Tammam YAGHI[1, 2], Awadis ARSLAN[3], Hussam SAEED[4], Abeer ELMOUHAMMAD[5]

[1]General Commission for Scientific Agricultural Research (GCSAR), Syria, Phone: +963999523036; E-mail: tammam.yaghi@gmail.com
[2]University of Bucharest, Faculty of Biology, Romania, Phone: +963999523036; E-mail: tammam.yaghi@gmail.com
[3]University of Nevada Reno, Department of Natural Resources and Environmental Science. Reno, NV 89512, USA. Phone:+19495336421; E-mail: awadisarslan@yahoo.com
[4]Scientific Agricultural Research Center (SARC) at Salamiyah. GCSAR, Hama, Syria. Phone: +963966321083, E-mail: hussamsaeed973@gmail.com
[5]Agricultural Scientific Research Center at Homs, Homs, GCSAR, Syria. Phone+963937291969; E-mail: aaabmd821@gmail.com

Corresponding author: tammam.yaghi@gmail.com

Abstract

The paper studied the impact of integrated plant nutrients management strategy (IPNM) on the agricultural return during current Syrian crisis through the application of camel manure and chemical fertilizers on the black cumin quantitatively and qualitatively. The fertilization treatments were denoted as T_2 [N_{120}-P_{30}-K_{30}], T_3 [N_{120}-P_{30}-K_{60}], T_4 [5 t. ha^{-1}camel manure], and T_5 (½ [T_3 + T_4]), respectively. The no-fertilizer treatment (T_1) was considered as control. Soil fertility, irrigation water use efficiency (IWUE), and oil content were considered. Results have showed that organic manure(camel dung)decreased soil pH and OC/ON ratio and increased the availability of nutrients in the soil. What led the black cumin to respond by significantly increasing the following productive parameters: plant height, roots depth, number of primary and secondary branches,..etc. The treatment T_5 recorded the highest IWUE values (5.2 and 6.2 kg.ha^{-1}.mm^{-1}) and the best oil content (33.3% and 34.2%) in the two seasons, respectively. Furthermore, the applied IPNM strategy had remarkably increased fertilization efficiency and economical feasibility (profit/ total costs) in the order of T_5>T_4>T_3>T_2 compared to T_1.

Key words: *IPNM, camel manure, black cumin, oil content, fertilization efficiency.*

INTRODUCTION

Medicinal plants are a unique type of natural product requiring special consideration due to their potential impact on people's health. Therefore, improving the productivity and quality of various medicinal and aromatic plants like black cumin in Syria was an ultimate goal in the latter decade. Aromatic plants containing volatile and fixed oils belongs to this family (Ranunculaceae) [16]. And they are currently an important source of the income of Syria for local consumption and export. Black cumin is water and fertilizer demanding crop, whereas, the availability of water during growth season is very crucial to hasten flower emergence, seed set, and seed yield [15, 7]. A lack of fertilizer applications may lead to yield reduction, though moderate fertilization is important to get optimum yield. The varieties of the black cumin sometimes select the fertilization efficiency. For example, the Exotic variety produced maximum grain yield (3.43 g. $plant^{-1}$ and 2.30 t. ha^{-1}) at (N_{120}-P_{40}-K_{60} kg. ha^{-1}) level of fertilizers compared to the other black cumin's varieties like BARI $kalozira^{-1}$, Faridpur local and Natore local in Bangladesh [4]. Black cumin gives a significant response to the fertilizer application on the most of the productive parameters (plant height, number of primary branches, number of secondary branches, chlorophyll content,..etc. However, the highest yield obtained was reported from the use of both organic and inorganic sources of nutrients in an integrated manner [2, 35]. However, [39] showed that the interaction of N and P with a rate 60/40 kg. ha^{-1} NP significantly ($p<0.01$) influenced different growth and yield parameters except for 1,000 seed weight of black cumin. Furthermore, [30] have proven that the combined application of 7.5 t. ha^{-1} cattle manure and 100 kg. ha^{-1} NPSB fertilizer can promote the economically feasibility of black cumin in study area (Guder, Ethiopia). The harsh financial circumstances have been forcing Syrian farmers to choose the most available economic fertilizers for their crops. A thing which has led them to add organic manures and inorganic fertilizers but without any scientific concept. When looking at this idea scientifically, the combined use of organic compost along with chemical fertilizer has been widely recognized as an effective IPNM strategy for the sustainability of agricultural production systems in several world regions [5, 17].

The adoption of an appropriate IPNM strategy doesn't only enhance crop production and increases the economic returns to farmers but also maintains soil fertility and supports environmental preservation [28]. [18] have proven that Organic Carbon (OC) / Organic Nitrogen (ON) ratio in camel manure is less than that one in goat manure.

Recently, some researchers have proven that there is a huge benefit caused by the usage of camel dung considering it as promising organic manure compared to the other cattle dung [1].

It does not only contain a huge amount of ON compared to the amount of OC but can be consider it as a source of renewable energy [29]. Furthermore, [11] have recommended camel manure compared to goat, swine, sheep, and poultry manures, whereas, the OC/ON ratio ranged in the following order: cattle (59)> goat (32) = swine (31)> sheep (25)> camel (21)> poultry (14). Thus, camel manure would be more desirable of these natural fertilizers because of its small OC/ON ratio. What would increase soil organic matter that would have a powerful effect on its development, fertility, and available moisture [3].

On the grounds of the previous information, there was urgent need to conduct innovative methods can minimize agricultural inputs like chemical fertilizer. For this purpose, it is essential to use camel dung after treating it as a manure in plant production, especially in low organic matter agricultural soils. In this context, this study aimed to reveal the combined effect of applying camel manure and chemical fertilizers to the soil at different levels on seed yield and some quality parameters of black cumin.

MATERIALS AND METHODS

The experiment was conducted at Scientific Agricultural Research Center, SARC at Salamiyah district (35° 00' N, 37 02' E and 480.8 m altitude), Hama Governorate, Syria. It specializes in breeding, reproducing animals and producing crops.

Salamiyah forms about 37.1% of available arable land of Hama governorate; the average annual precipitation and evaporation from February to Jun were 177.3 mm and 545.5 mm, during successive 2020-2021 growth seasons respectively.

Therefore, irrigation is essential for good quality optimal crop yield. At 0-20 cm soil depth characteristics of the experimental fields were clay loam: high in clay (42%), low in silt (20%) and a pH of 7.31, organic matter (2.31%), total N (0.13%) and organic carbon (1.34%). Available phosphorus content of the soil was 11.2 mg/kg while potassium was 560 mg/kg. Available soil water holding capacity was 98.7 mm for 0-60 cm depth. Furthermore, hand Beerkan infiltration methods have been used and their results in the same type of soil were compared with SPAW software results [33], for accurate timing of irrigation through defining the water that can be added to reach the field capacity in each soil layer until 60 cm depth during growing of the similar plants to black cumin concerning the root depth [6, 26].

The soil is well-drained yellow and very poor in organic matter. Thus, it is very suitable to plant this type of medical plants (*Nigella sativa* L.), [22, 36].

The results of a chemical analysis of camel dung show that it's rich in carbon and nitrogen, among other beneficial nutrients such as Mg, K, and Na, etc. Moreover, when we compared this manure with other animals' manure in SARC, we noticed that it contains the lowest levels of carbon. On the other hand, nitrogen levels were higher than those in goat manure. Thus, the ratio of organic carbon and organic nitrogen (OC/ON) was 17.5 as given in Table 1. These results were in the same line with those obtained by [18].

Table 1. Chemical properties of camel dung.

pH (1:2.5 H_2O)	OC (%)	Total nitrogen (%)	Avail-P (mg/kg)	CEC (meq 100^{-1} g^{-1})	EC (dS m^{-1})	OM (%)
7.2	11.22	0.64	29.3	69.1	0.14	23.3

Source: The results of soil analysis at Homs Research Center's lab, GCSAR, Syria.

Daily climate data were collected from Feb 9 until Jun 30 during 2020-2021 successive growth seasons. Furthermore, the ET_0 had been calculated by using two programs (ET_0 Calculator and New_LocClim 1.10 software).

Experimental treatments, planting, cultural practices, and drip irrigation system design

The study was conducted using complete randomized block design (CRBD) with four replications. Experimental treatments were T_1 (control, without fertilizer), T_2 [N_{120} P_{30} K_{30} (kg. ha^{-1})], T_3 [N_{120} P_{30} K_{60} (kg. ha^{-1})], T_4 [camel manure (5 t. ha^{-1})], and T_5 (½ [T_3 + T_4]), whereas, the soil was very rich in potassium and the rest amounts of chemical balance like N and P were added according to the best results and the recommendations in the same place for the same crop (*Nigella sativa* L.), [21]. The experimental area consisted of a total of 20 plots. The area of each plot was 6 m^2 (2*3 m), and the total area was 231 m^2 (21*11 m). To prevent the interaction between irrigation treatments, 1.5 m space between the experimental plots and 1 m between the complete blocks were left. Besides, two rows in each plot were left out of the assessment due to the edge's effect, and the remaining area formed the harvest plots, (Fig. 1).

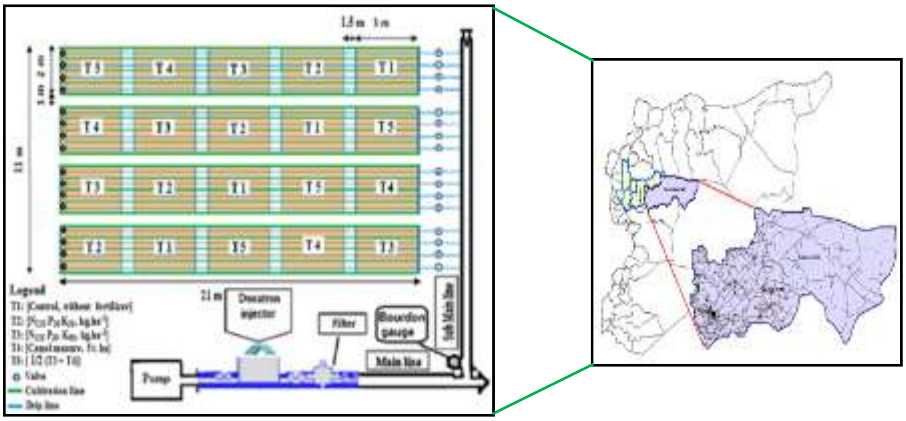

Fig. 1. Layout of site of study area at Salamiyah in Hama governorate deriving from it the scheme clarifying the design of trial (the plots of the different fertilizers treatments).

Source**:** The results of scientific research which was listed into the research plan of Natural Resources Researches administration, 2017-2021, GCSAR. Syria.

Fig. 1 expresses that there are 4 drip lines for 5 cultivation lines in each plot. Each line was equipped with external drippers (GR, 8 L. h^{-1}). The distance between two lines was 0.5 m. Based on technical advice received from soil lab staff, K (Potassium oxide, K_2O) wasn't needed while the nitrogen fertilizers (N, 120 kg. ha^{-1}), phosphorous (P, 30 kg. ha^{-1}) were needed. The N and P have been added in the form of Urea [CO $(NH_2)_2$, 46% N] and Triple

Super Phosphate TSP [46% P_2O_5], respectively. Half of the total chemical nutrients amount (fertilizers) and all of natural nutrients amount were given during the preparation of soil. The remaining amount was given with irrigation as equal amounts during the period of irrigation by dividing into the number of irrigations. Local variety of black cumin was used as plant material and its seeds were planted with a planting density of 4 kg. ha^{-1}. Farming operations such as reseeding, weeding and irrigation were followed continuously. Moreover, pesticides were used once in the two seasons.

Irrigation water, evapotranspiration, and productivity

The volume of irrigation water requirement for each treatment was calculated according to the squared area:

$$I = ET_c * Sd \quad ....(1)$$

where:
ETc is crop evapotranspiration (mm), Sd is irrigation water ratio (Sd = 50% according to [12].

$$WUE = Y / (I+P_e) \quad ....(2)\ [25]$$

where:
WUE is water use efficiency (kg. ha^{-1}. mm^{-1}), I is irrigation water amount (mm), P_e is effective rainfall (mm) = 0.6 P (precipitation, mm) if P<75%, P_e = 0.8 P if P>75 mm. $month^{-1}$, Y is seed yield obtained from the treatments (kg. ha^{-1}).

The reproductive and vegetative parameters

Data were collected from the inner rows of each plot to avoid the border effect. The following seed yield and yield contributing parameters were observed.

Ten randomly selected plants from each plot were used for counting the following parameters:

The number of branches per plant, plant height, root depth, length of capsule, capsule diameter, number of seeds per capsule, number of capsules per plant, fresh seed yield per plant, dry seed yield per plant, 1,000 seed weight, seed yield, dry matter and harvest index: Harvest index was calculated as follow:

$$HI = [Y / (Ps+Y)] * 100 \quad ....(3)\ [12]$$

where:
HI is harvest index (%), Y is an economical seed yield (kg. ha^{-1}), Ps is straw yield (kg. ha^{-1}).

Black cumin quality analysis

Fertilization efficiency (Fe):

$$Fe\ (\%) = [(Y-Y_0)/Y_0]*100 \quad ....(4)\ [10, 24]$$

where:
Fe is increasing productivity caused by the usage of fertilizer (%), Y is seed or fixed oil yield obtained from the fertilization treatments, Y_0 is seed or fixed oil yield obtained from the untreated treatment (control).

Fixed oil content:

Fixed oil yield per hectare was calculated based on seed oil content and seed yield obtained per hectare and expressed in kilograms per hectare:

$$\text{Fixed oil yield} = \text{Oil content} \times \text{Seed yield} \quad ....(5)$$

where:
the fixed oil yield (kg. ha^{-1}) and oil content (%) which was determined using the method of oil extraction described by [9].

$$Oil = [(W_2-W_1) / S] * 100 \quad ....(6)\ [37]$$

where:
Oil is oil content (%), W_1 is weight of the empty flask (g), W_2 is weight of the flask and the extracted oil (g), S is weight of the sample (g).

Statistical analysis and economical study

We had employed the univariate analysis of variance using a statistical package for social science (SPSS software) to analyze the collected data. The difference between treatment means was compared by Duncan's Multiple Range Test (DMRT) at 0.05 statistical significance level. Furthermore, economical study (statistical approach) was performed through deducing the ratio between the profit and the total costs for each treatment.

RESULTS AND DISCUSSIONS

The traced effect of the fertilizer on the soil and the phenological black cumin phases

Soil analysis results before planting showed the soil is clay loam in texture and it was found to be moderately alkaline with a pH of 8.4 as an average in the two first and second depths. The application of different fertilizers through T_2, T_3, T_4, and T_5 has led to a slight decrease in pH level after harvesting from 8.5 (season 1) and 8.7 (season 2) in T_1 and to 6.95 (1) and 7.20 (2) in T_5, which was different from the initial soil sample pH level during two seasons, respectively as given in Table 2.

Consequently, the application of organic manure had led to get a moderate surface soil pH compared to soil receiving only chemical fertilizers. These results were in line with those obtained by [23, 30]. It is therefore advisable to apply organic fertilizer (camel manure, CM) to experimental site to reduce the high pH level. Similar data were reported by [31]. Organic carbon before planting was 1.065% as an average in the two first depths and increased noticeably after adding the fertilizers particularly the mixed fertilizers in treatment T_5. That can be explained through the role the mixed fertilizers had acted in maintaining the organic matter status of the soil. Furthermore, the change in both of the total N and P after harvest revealed that incorporation of CM and chemical fertilizer could improve the fertility status of the soil. Improving in the soil nutrient contents with the application of pelleted cow manure (PCM) might be a result of buildup in the organic carbon [34], solubilization of different organic nitrogenous compounds into a simple and available form, and conversion of unavailable P into available form at the time of decomposition of manure. The application of organic and inorganic fertilizers is widely known to ameliorate soil N and P statuses [27]. What explains why the soil of treatments T_4 and T_5 that received CM only or CM and chemical fertilizers have had higher N and P contents after harvest. Whereas the total soil N content reached 0.28 %, and the traced amount of the available (P) achieved 17.1 mg/kg as a maximum. Similar data were reported by [19]. The status of soil fertility had been reflected by black cumin plants obviously when tracking the number of days to get emergence, flowering and phenological maturity. The results have showed that days to 50% emergence of black cumin seeds was not significantly ($p<0.05$) influenced by the different fertilization treatments (T_2, T_3, T_4, and T_5) compared to the treatment (T_1). That stage had spent about 15-17 days after sowing at all treatments, these results were in agreement with those obtained by [39, 4]. This might be due to the reason that seed used its own nutrients and left unused fertilizer applied to the soil before the root emerged [38]. While there were obvious differences between the mentioned treatments to get the flowering and phenological maturity phases. The usage of organic fertilizer itself in treatment T_4 prolonged the appearance of flowers compared to the other treatments (T_2, T_3 and T_1). That might be because the camel dung enhanced the soil pH and its temperature to be more suitable to support the vegetative unit first and to create the flowers second. That was also confirmed by treatment T_5 compared to the rest of the treatments. Similar data were reported by [8, 32].

Whereas, after 76 days (season 1) and 75 days (season 2) and 73 d (1) and 72 d (2), the flowers appeared in both of treatments T_1 and T_2 in the two seasons, respectively. The same spent about 89 d (1) and 82 d (2) in the treatment T_3 and about 90 d (1) and 94 d (2) in the treatment T_4 and 94 d (1) and 93 d (2) in the treatment T_5. That delay in the fertilization treatments can be explained by excessive nitrogen and phosphorus what resulted in prolonged vegetative growth of the plant. These results were in line with those obtained by [39, 30]. In the same context, the phenological maturity initialed in T_1 and T_2 (after approximately 90 d (1)- 91 d (2), and T_3 103 d (1) - 104 d (2), then T_4 105 d (1) - 106 d

(2) and lastly in T_5 107 d (1) - 110 d (2) in the two seasons, respectively. These results were agreed with those obtained by [20].

Table 2. Selected physio-chemical properties of soil after harvesting the black cumin during the two seasons 2020-2021, which had been analyzed in the labs of Homs, Hama and Damascus researches centers, GCSAR.

Fertilization Treatments	Depth (cm)	pH (1:5)	EC (1:5) (dS m^{-1})	OM (%)	OC (%)	TN (%)	Av.P (mg/kg)
First season-2020							
T_1 (control, without fertilizer)	0-30	8.5	0.41	1.81	1.05	0.16	10.2
	30-60	8.3	0.51	1.47	0.85	0.09	6.02
T_2 [N_{120} P_{30} K_{30} (kg. ha^{-1})]	0-30	8.6	0.57	2.25	1.31	0.17	12.1
	30-60	8.9	0.67	2.34	1.36	0.16	12.5
T_3 [N_{120} P_{30} K_{60} (kg. ha^{-1})]	0-30	8.22	0.71	2.51	1.46	0.2	13.3
	30-60	8.1	0.79	2.39	1.39	0.14	14.2
T_4 [camel manure (5 t. ha^{-1})]	0-30	7.31	0.89	4.2	2.44	0.25	14.9
	30-60	7.7	0.82	5.6	3.26	0.24	14.8
T_5 (½ [T_3 + T_4])	0-30	6.95	0.92	5.2	3.02	0.24	16.1
	30-60	7.10	0.99	5.8	3.37	0.22	16.9
Second season-2021							
T_1 (control, without fertilizer)	0-30	8.7	0.34	1.61	0.94	0.17	14.7
	30-60	8.61	0.44	1.33	0.77	0.07	7.2
T_2 [N_{120} P_{30} K_{30} (kg. ha	0-30	8.80	0.5	2.41	1.40	0.19	12.3
	30-60	8.87	0.61	2.5	1.45	0.15	12.1
T_3 [N_{120} P_{30} K_{60} (kg. ha^{-}	0-30	7.01	0.73	2.42	1.41	0.19	13.4
	30-60	7.53	0.87	2.36	1.37	0.16	14.1
T_4 [camel manure (5 t. ha-1)]	0-30	7.41	0.88	4.55	2.64	0.27	14.8
	30-60	7.35	0.87	5.81	3.37	0.28	14.1
T_5 (½ [T_3 +T_4])	0-30	7.20	0.93	5.7	3.31	0.25	16.7
	30-60	7.31	0.95	6.2	3.61	0.24	17.1

Source: The results of soil analysis at Homs Research Center's lab for the first season while the same parameters were analyzed at Damascus and Homs Research Centers' labs for the second season, GCSAR, Syria.

Impact of the applied different fertilizers on the black cumin vegetative growth parameters.

There were significant differences for the studied plant attributes (plant height, branches number [only primary and secondary], dry matter, roots depth and harvest index) between treatments (T_5 and T_4) and treatments (T_3, T_2 and T_1) as presented in Table 3. While, there were no significant differences in tertiary branches number, roots depth, dry matter and harvest index at the chemical treatments (T_2 and T_3) in the two seasons. The treatment T_4 had the highest harvest index, while the treatment T_1 had the smallest. It may be due to the residual positive effect in soil after adding the fertilizers carefully.

The significant distinction of T_4 and T_5 compared with the rest of the treatments can be explained by the unprecedented effect of the usage of camel dung which improved soil's OC/ON ratio and simultaneously it regulated the relation between water, air, and plant in this type of yellow soil. This organic fertilizer made soil more dynamic and effective than the usage of recommended chemical ones only for this type of plant [31]. Furthermore, nitrogen and phosphorus have an enhancing effect on the vegetative growth of plants by increasing cell division, elongation, and the varietal variability to absorb the nutrients from the soil. That has also been confirmed through the finding of [13] who reported that organic manure and inorganic fertilizer supply most of the essential nutrients at growth stage resulting in increase of growth variables including plant height, roots depth and branches number,..etc. [14] also reported the highest plant height (78 cm) from the integrated application of 7.5 t ha^{-1} camel manure and seeds inoculation by Azotobacter and Azospirillium. They have ensured the importance of the integrated application of organic and inorganic fertilizers particularly the camel dung to obtain good growth parameters as in our study (Table 3). Furthermore, the study has also showed that there were also significant differences between the number and diameter of capsule as well as seeds number per capsule especially after the application of the IPNM in T_4 and T_5 but no tangible differences regarding the 1,000 seeds weight between the two treatments T_2 and T_3 and the treatment T_1 (control). Similar data were reported by [4]. Thus, it can be said that the difference was semi significant between the chemical fertilization treatments and the treatment (control) while was an extraordinarily significant after the application of the organic fertilization.

Table 3. The main effects of IPNM strategy application on growth parameters and yield components of black cumin during the two seasons 2020- 2021 at Salamiyah Research Center, GCSAR, Syria.

Fertilization Treatments	Plant height (cm)	Primary branches number	Secondary branches number	Tertiary branches number	Dry matter per plant (g)	Roots depth (cm)	Harvest Index (HI) (%)	Diameter of capsule (cm)	Empty capsules per plant	Capsules per plant	Seeds per capsule	1,000 seeds weight (g)
First season-2020												
T_1	12.5e	4.9dc	5.8e	1.2b	0.6e	9.4d	39.9c	0.5e	3.1a	4.e	75.2de	2.0d
T_2	25.1d	5.4dc	7.4dc	2.7ba	1.7dc	18.0cb	57.5ba	0.9d	2.2b	10.1d	77.4d	2.5cb
T_3	36.2cb	5.4c	9.1c	3.26a	1.9c	18.4cb	56.0ba	0.9c	2.0c	14.8c	88.3cb	2.7b
T_4	37.4b	6.1ba	12.4b	3.4a	3.0ba	19.2b	58.3a	1.0ba	0.4d	18.7b	88.6b	2.9b
T_5	43.3a	6.3a	14.5a	3.33a	3.4a	23.8a	55.4ba	1.2a	0.2d	23.3a	92.1a	3.2a
CV (%)	7.3	6.63	10.1	13.4	0.67	11.1	7.1	3.11	1.7	6.9	5.7	3.1
LSD. $_{0.05}$	**	**	**	**	**	**	**	**	**	**	**	*
Second season-2021												
T_1	14.3e	4.8d	6.1ed	1.2cb	0.77e	10.9e	43.1d	0.6e	4.5a	5.1e	70.2dc	2.3dc
T_2	23.7d	5.6cb	6.4d	1.7b	1.8d	17.4d	46.0cb	0.8d	1.4b	7.0d	71.5c	2.4c
T_3	35.0c	5.4cb	8.9c	1.8b	3.1cb	22.2c	48.8cb	1.0c	1.2c	18.5cb	80.6b	2.4c
T_4	42.2b	5.9b	10.6b	4.4a	3.6ba	23.3b	52.5a	1.1b	0.3d	20.1b	87.98a	2.9b
T_5	47.2a	6.5a	13.8a	4.8a	4.2a	27.2a	49.1b	1.3a	0.5d	28.4a	88.4a	3.6a
CV (%)	9.8	7.1	9.4	11.5	0.88	9.88	8.2	2.88	2.1	8.4	5.3	2.8
LSD. $_{0.05}$	**	**	**	**	**	**	**	**	**	**	**	*

Means followed by different letter (s) within a parameter differed significantly by DMRT at $P \leq 5$ %.
Source: The results of the 2nd step of the scientific research which had been listed into the plan of Natural Resources Researches Administration, General Commission for Scientific Agricultural Research (GCSAR), Syria.

Economic feasibility of IPNM strategy on black cumin.

This study assured the importance of fertilization management to increase black cumin yield components. That was obvious in T_4 and T_5, whereas seeds yield has increased to reach (1,234.6 kg. ha^{-1} - 1,631.5 kg. ha^{-1}) and (1,879.2 kg. ha^{-1} - 1,904.1 kg. ha^{-1}) in T_4 and T_5 in the two seasons, respectively. What led also to improve IWUE to reach 5.2 kg. ha^{-1}. mm^{-1} and 6.2 kg. ha^{-1}. mm^{-1} at the two treatments respectively. Moreover, the applied management enhanced oil content to achieve the highest values (31.2% - 33.3%) and (31.7% - 34.2%) in T_4 and T_5 in the two seasons, (Table 4). That could be explained not only because of high nitrogen concentration but also due to better physiological equilibrium of NPK in the two added amounts according to N_{120}-P_{30}-K_{30} and N_{120}-P_{30}-K_{60} first as well as the integrated management of the camel dung with the chemical fertilizer existing in the treatment T_3, second. Furthermore, it could explain the difference between the treatments (T_3 and T_2) effects on the yield and yield components through the best physiological equilibrium of NPK which has been expressed by the treatment T_3 more than the treatment T_2 despite they have the same quantity of nitrogen. Moreover, we cannot ignore the regulated water supplies through drip irrigation system, which can provide the required water at the suitable time. The thing might make nutrients uptake easier. Although it had been given about 50 % of the potential evapotranspiration (ET_P), irrigation water amounts were 239.34 mm and 222.2 mm through two seasons, respectively. A thing that expresses the huge gap between the precipitation and evaporation in the study area. The results of study also indicated that IPNM treatments significantly increased the fertilization efficiency (Fe) in the order of T_5> T_4> T_3>T_2 compared to the treatment T_1 (control, without fertilizer).

The T_5 treatment has achieved the highest fertilization efficiency (151% and 399%) regarding the black cumin seed yield and the fixed oil yield, respectively. The lowest values of Fe (31% and 64%) were at the treatment (T_2) according to both of yields of seed and fixed oil respectively (Fig. 2). These results are also in agreement with those of [32] who concluded that the IPNM strategy based on organic manures positively affected the yields of seed and oil too.

Results of economic feasibility and statistical analyses have indicated that the fertilization management on black cumin was successful and beneficial in the dry environments. However, the best profit could be achieved only after the application of IPNM strategy with organic manures such as the camel dung. The (profit/total costs) ratio values were at (T_5 and T_4) higher than the rest of the fertilization treatments (T_2, T_3 and T_1).

The treatments with organic manures whether the treatment T_4 or the treatment T_5 excelled all the treatments achieving 260.3%-267.5% and 345.8%-339.02% in both seasons respectively as given in Table 4. While this ratio didn't differ much between the chemical fertilization treatments and the control.

Table 4. The economical study of black cumin crop clarifying oil content, oil yield and IWUE during 2020-2021 growth seasons (DMRT at $P \leq 5$ %).

Fertilization Treatments	Seed yield (kg. ha^{-1})	Oil content (%)	Oil yield (kg. ha^{-1})	IWUE (kg. ha^{-1}. mm^{-1})	Seed product value ($. ha^{-1})	Oil product value ($. ha^{-1})	Fertilizer costs ($. ha^{-1})	Harvest costs ($. ha^{-1})	Total costs ($. ha^{-1})	Profit to total cost (Seed yield) (%)	Oil extraction costs ($. ha^{-1})	Profit to total cost (Oil yield) (%)
First season-2020												
T_1	700.5e	18.2e	127.5e	2.2d	1883.5e	12967e	0	123.0	708.0	166.03	3267.8	226.2
T_2	1082.8d	25.7dc	278.3d	3.4cb	2767d	24515d	285.8	132.0	1134.8	187.5	6178.3	235.2
T_3	1128.6c	27.8c	313.75c	3.6b	3036c	27638c	310.6	132.4	1310	169.6	6965.3	233.9
T_4	1234.6b	31.2ba	385.2b	3.9b	3321b	33932b	65	155.9	1032.9	260.25	8551.4	254.0
T_5	1631.5a	33.3a	543.3a	5.2a	4389a	47859a	187.7	189.7	1330.4	267.5	12061.3	257.4
CV (%)	402	3.7	47	1.8	6090	7777	-	-	-	-	-	-
Second season-2021												
T_1	634.3 e	16.3ed	103.4e	2.1cd	1706e	9109e	0	110.0	709.5	140.45	2357.5	197.0
T_2	808.0 d	17.9d	144.6d	2.6c	2174d	12738d	291	124.0	862.3	152.12	3296.8	206.3
T_3	1204.8c	20.2c	243.4c	3.9b	3241c	21441c	311.3	158.1	1047.7	209.34	5549.5	225.0
T_4	1879.2b	31.7ba	595.7b	6.1a	5055ba	52475ba	70	173.7	1134	345.77	13582	255.8
T_5	1904.1a	34.2a	651.2a	6.2a	5122a	57364a	188.8	190.8	1166.7	339.02	14847	258.2
CV (%)	377	4.3	66	2.3	5498	7659	-	-	-	-	-	-
$LSD_{0.05}$	**	**	**	**	**	**	-	-	-	-	-	-

Source: The results of the 2nd step of the scientific research which had been listed into the plan of Natural Resources Researches Administration, General Commission for Scientific Agricultural Research (GCSAR), Syria.

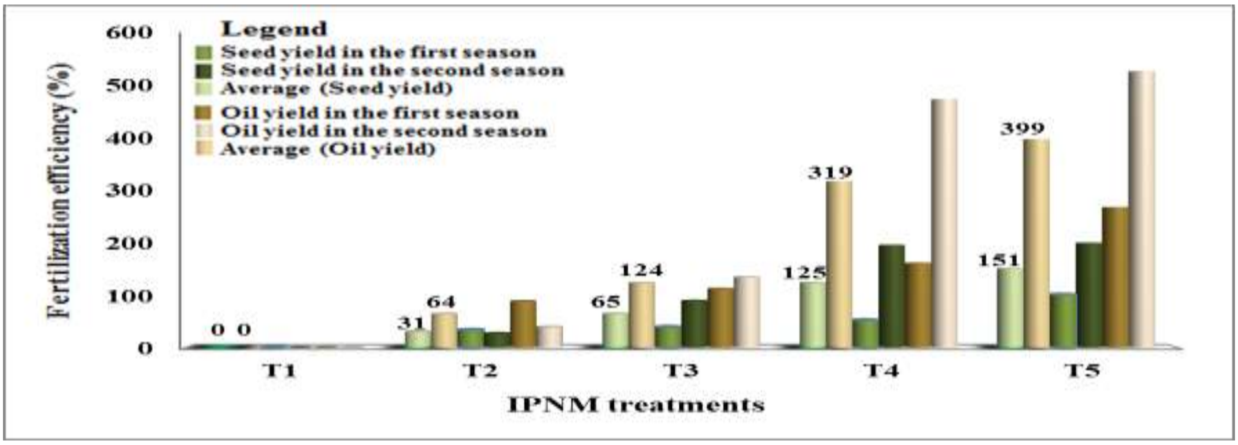

Fig. 2. The fertilization efficiency (Fe) of black cumin during the two seasons and as an average which was calculated by the increase in seed yield and the increase in oil yield.

Source: The results of the 2nd step of the scientific research which had been listed into the plan of Natural Resources Researches Administration, General Commission for Scientific Agricultural Research (GCSAR), Syria.

By considering the costs of oil extraction, the ratio (profit/total costs) would change but still the treatment T_5 has the first rank between the other treatments. Thus, we found that it could consider black cumin an economical crop in the dry environment first, as well as fertilizing it with an organic manure such as camel dung would make it the one of the richest crops locally, second.

CONCLUSIONS

This research interprets an important part of the integrated plant nutrients management strategy (IPNM) through studying the effect of several types of recommended chemical and organic fertilizers on Nigella sativa crop quantitatively and qualitatively.

Generally, the usage of fertilizer made black cumin productivity better. However, organic fertilizer (camel dung) added a bulk footprint on soil and plant. The camel dung has enhanced the soil fertility through moderating soil pH, increasing plant nutrients, and raising bio-activation energy through increasing the soil temperature and the ability of its enzymes. What led black cumin to give vegetative growth better than the one who grows under only chemical fertilizers effect or that untreated one with fertilizer. This was also reflected by increasing the black cumin seed yield and the rest of other yield components later.

We cannot deny the role of balanced chemical fertilizers in improving the black cumin production and yield, but the economic feasibility and environmental security issue remain the final arbiter. The results of this experiment have showed that the black cumin respond to organic fertilizer much, whereas the treatments (T_5 and T_4) have achieved the highest economic feasibility (profit/total costs) compared to the rest of the other treatments regarding the seed yield first and the oil yield, second.

To confirm our research results more, we suggest following and testing the application of other organic fertilizers whether caused by animal source like cows, sheep, goat, poultry or any source else on this crop. That will certainly save money and keep the environment clean too.

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REFERENCES

[1]Abdel-Rahman, E. H., Alzahrani, F. S., Sulieman, A. E., 2020, Potential of camel dung as promising organic manure in Saudi Arabia. Advancements in life sciences. International Quarterly Journal of Biological Sciences. Vol. 7(4), 202-207.

[2]Abou el-leel, O. F., Maraei, R. W., Aly, A. A., 2019, Studying the response of *Nigella sativa* plants to different fertilizers. Annals of Oradea University, Fascicula Biology. Vol. XXVI, Issue: 1, pp. 14-20.

[3]Al-Barakah, N.I., F., 2019, Comparison of composts quality prepared by wide range of organic wastes. J. Agric. Crop Res. 7(12): 215-223.

[4]Ali, M. M. K., Hasan, M. A., Islam, M. R., 2016, Influence of fertilizer levels on the growth and yield of black cumin (*Nigella sativa* L.). The Agriculturists, 13 (2), 97-104. https://doi.org/10.3329/agric.v13i2.26596.

[5]Al-Suhaibani, N., Selim, M., Alderfasi, A., El-Hendawy, S., 2020, Comparative performance of integrated nutrient management between composted agricultural wastes, chemical fertilizers, and biofertilizers in improving soil quantitative and qualitative properties and crop yields under arid conditions. Agronomy, 10, 1503. [Google Scholar] [CrossRef].

[6]Angulo-Jaramillo, R., Bagarello, V., Prima, S. D., Gosset, A., 2019, Beerkan Estimation of Soil Transfer parameters (BEST) across soils and scales. Journal of Hydrology 576:239-261. DOI:10.1016/j.jhydrol.2019.06.007.

[7]Ariafar, S., Forouzandeh, M., 2017, Evaluation of humic acid application on biochemical composition and yield of black cumin under limited irrigation condition. Bulletin de La Société Royale Des Sciences de Liège, 86 (special issue), 13-24.

[8]Brempong, M. B., Addo-Danso, A., 2021, Improving soil fertility with organic fertilizers. DOI: 10.5772/intechopen.103944.

[9] Calmen, C. E., 1970, An evaluation of five methods for the quantitative determination of cyclopropenoid. Journal of Analytical Official Associated Chemistry Society. 53(6):1209 1213.

[10]FAO, 2004, Scaling soil nutrient balances. FAO Fertilizer and Plant Nutrition Bulletin no.15, 132 pp.

[11] Gbenou, B., Adjolohoun, S., Ahoton, L., Houndjo, D. B. M., Saïdou, A., Houinato, M., Sinsin, B. A., 2017, Animal dung availability and their fertilizer values in a context of low soil fertility conditions for forage seed and crops production in Benin (West Africa). American Journal of Agricultural Research AJAR, 2:12.

[12]Ghamarnia, H., Khosravy, H., Sepehri, S., 2010, Yield and water- use efficiency of (*Nigella sativa* L.) under different irrigation-treatments in a semi-arid region in the West of Iran. J Med-Plants Res 4 (16), 1612-1616. DOI: 10.5897/JMPR09.376.

[13]Gonzalez, D., Alvarez, R., Matheus, J., 2001, Comparison of three organic fertilizers for the production of sweet corn (*Zea mays saccharata*). Proc. Int. Am. Soc. Trop. Hortic., 45: 106-109.

[14]Hadi, M. R. H. S., Ghanepasand, F., Darzi, M. T., 2015, Evaluation of biofertilizer and camel manure effects on quantitative yield of Nigella sativa L. International Journal of Agricultural and Biosystems Engineering, 9 (8), 890–893.

[15]Hadi, M. R. H. S., Darzi, M. T., Riazi, G., 2016, Black cumin (*Nigella sativa* L.) yield affected by irrigation and plant growth promoting bacteria. Journal of Medicinal Plants and By-Products, 2016(2), 125-133.

[16]Hannan, A., Rahman, A., Sohag, A., et al., 2021. Black cumin (*Nigella sativa* L.): A comprehensive review on phytochemistry, Health Benefits, Molecular Pharmacology, and Safety. Nutrients 13(6), 1784; https://doi.org/10.3390/nu13061784.

[17]Hasnain, M., Chen, J., Ahmed, N., Memon, S., Wang, L., Wang, Y., Wang, P., 2020, The effects of fertilizer type and application time on soil properties, plant traits, yield and quality of tomato. Sustainability, 12, 9065. [Google Scholar] [CrossRef].

[18]Irshad, M., Eneji, A. E., Hussain, Z., and Ashraf, M., 2013, Chemical characterization of fresh and composted livestock manures. Journal of soil science and plant nutrition. http://dx.doi.org/10.4067/S0718-95162013005000011.

[19]Islam, M.A., Islam, S., Ayasha, A., Md Habibur, R., Dilip, N., 2017, Effect of organic and inorganic fertilizers on soil properties and the growth, yield and quality of tomato in Mymensingh, Bangladesh. Agriculture, 7, 18. [Citation Time(s):3].

[20] Kar, S., Bandyopadhyay, A., Dutta, A., Mondol, A. R., 2012, Studies on effects of nitrogen and spacing on growth and yield of black cumin (*Nigella sativa* L.) under alluvial plains of Bengal. In proceeding of state level seminar on production and management practices in West Bengal.

[21]Khurshid, A. A., Adla, W., Kattaa, A., Alkatib, O., 2019, Effect of NPK fertilization on the productivity of black cumin and nutritional balance determination by applying Diagnosis and Recommendation Integrated System (DRIS). Syrian Journal of Agricultural Research (SJAR). 6 (3), Pp 351-363.

[22]Killinger, E., 2018, Special garden project delft Blue Nigella basics of Nigella care. United Sates Department of Agriculture, 1-4.

[23]Kingery, W. L., Wood, C. W., Delaney, D. P, 1993, Impact of long term application of broiler on Environmentally related properities. J. Environ. Qual. 23: 139- 147.

[24]Maske, S. N., Munde, G. R., Maske, N. M., 2015, Effect of manures and fertilizer on brinjal (*Solanum melongena* L.) CV Krishna. BIOINFOLET-A Quarterly Journal of Life Sciences, 12 (3b), pp. 678-679.

[25]Michael, A. M., 1978, Irrigation theory and practice. Viskas- Publishing House PVTLTD: New Delhi. Pp. 448- 584.

[26]Mubarak, I., Mailhol, J. C., Angulo-Jaramillo, R., Ruelle, P., 2009, Temporal variability in soil hydraulic properties under drip irrigation, Geoderma 150 (1-2):158-165. DOI: 10.1016/j.geoderma.2009.01.022.

[27]Ngome, A. F., Becker, M., Mtei, M. M. K. F., 2011, Maize productivity and nutrients use efficiency in Western Kenya as affected by soil type and crop management. International Journal of Plant Production. 7: 517-536.

[28]De Boer, I. J. M., Van Ittersum, M. K., 2018. Circularity in agricultural production, Wageningen University & Research. Pp 71.

[29]Parthasarathy, P., Fernandez, A., Singh, D. K., Al-Ansari, T., Mackey, H. R., Rodriguez, R., Mazza, G., Tirkey, J. V., McKay, G., 2022. Thermogravimetric analysis of camel dung, date stone, and their blend for pyrolytic, kinetic, and thermodynamic studies. Cleaner Chemical Engineering. Volume 4, 100072.

[30]Rabuma, S., Azene, M., Nepir, G., 2022, Influence of blended NPSB fertilizer rates and cattle manure on growth, yield and yield components of Black cumin *(Nigella sativa* L.*)* in Guder, Ethiopia. American Journal of Chemical and Biochemical Engineering. Vol 6(1), 6-20.

[31]Roba, T. B., 2018, Review on: The effect of mixing organic and inorganic fertilizer on productivity and soil fertility. Open Access Library Journal, 5: e4618. https://doi.org/10.4236/oalib.1104618.

[32] Sanjeeva, M. B., Rao, E. G., Venkatachalapathi, V., 2019, Studies on sources and levels of organic manures on yield, yield attributes and quality of black cumin (*Nigella sativa* L.). Int. J. Curr. Microbial. App. Sci. 8(08):2687-2693. Doi: http://doi.org/10. 20546/ijcmas.2019. 808.311.

[33]Saxton, K. E., Willey, P. H., 2006, The SPAW model for agricultural field and pond hydrologic simulation. Chapter 17 in: Mathematical Modeling of Watershed Hydrology, V. P. Singh and D. Frevert, Editors; CRC Press. pp.401-435.

[34]Saviozzi, A., Cardelli, R., 2013, Organic matter characteristics, biochemical activity and antioxidant capacity of soil amended with different organic materials. Archives of Agronomy and Soil Science, http:// dx. doi.org/10.1080/03650340.2013.76744.

[35]Sen, A., Khade, S., Jana, J., Choudhury, P., 2019, Effect of integrated nutrient management on growth, yield and quality attributes of black cumin (*Nigella sativa* L.) var. rajendra shyama grown under Terai region of West Bengal. Journal of Spices and Aromatic Crops, 28(1), 61–65.

[36]Shariq, I. M., Israil, A. M., Iqbal, A., Brijesh, P., 2015, Morpho-physiological characterization of seeds and seedlings of *Nigella sativa* Linn.: Study on Indian

germplasm. International Research Journal of Biological Sciences, 4 (4), 38-42.

[37]Shnrwe, B. M., Ahmed, R. M., 2022, Response of yield and chemical composition of black cumin to different fertilizer in Sulaimani region. Iraqi Journal of Agricultural Sciences –2:53(4):901- 910.

[38]Siraj, M., 2018, Effects of blended NBSB fertilizer rates on growth, yield and yield related traits of potato (*Solanum tuberosum* L.) varieties under irrigation in Degem District, Central Highland of Ethiopia. American Journal of Bioscience and Bioengineering. 9(1): 21-32.

[39]Yimam, B., Nebiyu, A., Mohammed, A., Getachew, M., 2015, Effect of nitrogen and phosphorus fertilizers on growth, yield and yield components of Black cumin (*Nigella sativa* L.) at Konta district, South West Ethiopia. Journal of Agronomy 14 (3): 112-120.

PERFORMANCE AUDIT REGARDING THE MANAGEMENT OF AGRICULTURAL SUBSIDY FUNDS

Silvia ZAHARCO, Elena PETREANU

Moldova State University, 60 Alexe Mateevici Street, MD-2009, Chisinau, Republic of Moldova, Mobile: +373 795 44 676; Email: silvia.zaharco@usm.md, elena.petreanu@usm.md

Corresponding author: silvia.zaharco@usm.md

Abstract

This paper studied the performance audit regarding the management of the agricultural sector subsidy funds in order to determine to what extent the actions undertaken boosted the agricultural development process in the Republic of Moldova. The analysis revealed that the activity of subsidizing agriculture is primarily aimed at increasing competitiveness and the sustainable development of the agri-food sector. This situation leads to the modernization of the agri-food chain, facilitating access to capital markets for agricultural producers, adapting to climate changes and mitigating their effects on agricultural production, increasing rural employment opportunities, developing agricultural businesses, etc. The data on the subsidy activity were taken from the database of the Agency for Intervention and Payments for Agriculture from the Republic of Moldova, which is responsible for managing the subsidy fund. The results of the study highlight a fairly efficient management of financial means for subsidizing the national agricultural sector.

Key words**:** *audit, competitiveness, sustainable development, investment, performance, subsidy*

INTRODUCTION

Agriculture is the determining sector of the Republic of Moldova, with most related fields (economic, social, cultural); it defines the way of life in the countryside and the standard of living of the rural population. In this context, the need to support the agricultural sector is urgent.

The most important mechanism for supporting the agricultural sector in the Republic of Moldova is subsidy. Granting subsidies is an effective tool for attracting investments in agriculture, which strengthens the development capacities of this sector.

Currently, the policy of subsidizing the agricultural sector is regulated by the Law on Subsidization in Agriculture and the Rural Areas, which establishes the general principles of state policies to encourage and boost agricultural activities and the development of the rural environment, the conditions for the distribution of financial means, as well as adjusting the subsidy procedure to European practices.

The sustainable development of the agricultural sector can be ensured by achieving the following objectives: increasing the competitiveness and sustainable development of the agricultural sector; ensuring the sustainable management of natural resources; sustainable rural socioeconomic development [8].

Considering the importance of the agricultural sector for the national economy, the improvement of the agricultural subsidy system is in the permanent sights of the state, its efficiency representing an important tool in order to promote economic growth and reduce poverty in rural areas. During the last years, a more complex and multidimensional approach to this system has been tried in order to identify an optimal mechanism for selecting the directions for allocating subsidies.

Thus, at the initial stage of subsidization, the support areas were oriented towards credit stimulation, the creation of technological stations of machines and the subsidization of agricultural works. Since 2006, they have extended to the establishment of fruit plantations, the support of the animal husbandry sector, the subsidization of agricultural risk insurance, the support of the promotion and development of ecological agriculture, the stimulation of investments in the procurement of agricultural machinery and equipment, the compensation of the excise duty on diesel fuel, etc. From 2022, Local Action Groups from the Republic of Moldova can access subsidies for the implementation of the LEADER program, through which the creation of rural development opportunities is supported by identifying local needs, strengthening the development capacity of the economic environment and improving the organizational skills of local communities [7].

The financial means for subsidizing are allocated from the National Fund for the Development of Agriculture and the Rural Areas. This fund integrates all the budget means, including those from the development partners, intended to finance the financial support measures approved by the Government [2].

The value and structure of the National Fund for the Development of Agriculture and the Rural Areas is approved annually based on the provisions of the State Budget Law. Thus, in 2022, the fund constituted 1,500 million MDL, which was later increased by 17%, constituting 1,750 million MDL. For the year 2023, 1,500 million lei were also allocated [10].

The analysis of the subsidy directions indicates that the Government of the Republic of Moldova is oriented towards a series of support measures aimed at increasing investments in performing agricultural activities. Thus, in this work we will present the support measures for agricultural producers used by the Government in the period 2017-2022 from the subsidy fund, their characteristics and implications in the sustainable development of the agricultural sector. At the same time, the effectiveness of the performance regarding the management of the subsidy fund and its contribution to the fulfillment of the main objectives pursued within the subsidy policy was evaluated. In this sense, the activities that benefited from financial support were examined.

MATERIALS AND METHODS

The research on the topic of the paper mostly focused on the data of the Agency for Intervention and Payments in Agriculture (AIPA). The information presented by the Ministry of Agriculture and Food Industry and the National Bureau of Statistics was also consulted.

The study audited the use of the funding granted for the development of the agricultural sector in the period 2017-2022. The audit focused on the management of the subsidy fund and its contribution to the fulfillment of the main objectives pursued within the agricultural development policy. In this sense, the activities that benefited from financial support were examined, using the following methods and procedures: observation, comparison, descriptive analysis, tabular method, graphic method.

RESULTS AND DISCUSSIONS

An important component of the agricultural sector development program is its subsidy. The subsidy represents the non-refundable and non-taxable payment, granted for increasing the competitiveness and sustainable development of the agricultural sector, ensuring the sustainable management of natural resources, sustainable socioeconomic development of the rural environment [8].

The subsidizing activity in agriculture is oriented towards the achievement of a series of objectives, based on the provisions of the Common Agricultural Policy (CAP) and aimed at supporting the increase in the productivity of agricultural production, ensuring a fair standard of living for the rural population, stabilizing markets and ensuring reasonable prices for consumers of agri-food products (Fig.1).

- the modernization of the agri-food chain in order to comply with the requirements of the European Union regarding food safety and quality requirements
- facilitating access to capital, markets, input and output markets for farmers
- increasing the added value in the agri-food sector through the development of the primary and final processing infrastructure
- the implementation of modern natural resource management practices
- the implementation of environmentally friendly production technologies, of ecological products
- adapting to climate changes and mitigating their effects on agricultural production
- development of access infrastructure and services in the rural environment
- increasing employment opportunities in non-agricultural fields and increasing incomes in rural areas
- the balanced development of rural territories through the involvement of the local community in rural development
- development of micro, macro and medium farmers businesses

Fig. 1. The fundamental objectives of subsidizing the agricultural sector in the Republic of Moldova
Source: based on data from the Guide of Common Agricultural Policy [5].

The identified subsidy objectives show us that the Government has a fundamental role in establishing and implementing support measures aimed at increasing the performance of agricultural activities. But, most of these interventions were based on the allocation of financial support with the absence of a long-term strategy. Financial aid was often offered to compensate for fuel price increases or to subsidize autumn plowing intended to give an expected immediate impact [4].

Following the audit of the subsidy measures, it can be found that, during the development of the subsidy process, they did not have a stable character, changing over the years as a field of action and as names. Starting from 2017, measures were established that more or less targeted the same field of action. Thus, in order to increase the competitiveness of the agri-food sector, two support measures are provided, in the composition of which several sub-measures are designated to stimulate investments in various agricultural activities (Fig. 2).

Measure 1. Investments in agricultural holdings for restructuring and adaptation to European Union standards

- **Submeasure 1.1** Stimulating investments for the production of vegetables and fruits on protected land
- **Submeasure 1.2** Stimulating investments for the establishment, modernization and clearing of perennial plantations
- **Submeasure 1.3** Stimulating investments for the procurement of conventional agricultural equipment and machinery
- **Submeasure 1.4** Stimulating investments for equipment and technological renovation of animal farms
- **Submeasure 1.5** Stimulating the procurement of breeding animals and maintaining their genetic background
- **Submeasure 1.7** Stimulation of crediting agricultural producers by commercial banks and non-banking financial institutions
- **Submeasure 1.7A** Stimulating the risk insurance mechanism in agriculture

Measure 2. Investments in the processing and marketing of agricultural products

- **Submeasure 1.6** Stimulating investments for the development of postharvest and processing infrastructure
- **Submeasure 1.8** Stimulating the establishment and operation of groups of agricultural producers

Fig. 2. Financial measures to support investments made in order to increase the competitiveness of the agri-food sector
Source: based on data from the Agency of Interventions and Payments in Agriculture [1].

Within the limits of the available data, furhter we will briefly analyze the situation for each submeasure.

Management of the investment subsidy fund for the production of vegetables and fruits on protected land

One of the targeted measures provides for the subsidization of investments for the production of vegetables and fruits on protected land, in order to increase the productivity, quality and competitiveness of the respective sector. The support is granted for the partial compensation of the cost of new modules of greenhouses, solariums, tunnels, equipment and machinery, construction and covering materials (Table 1).

In 2022, financial aid in the amount of 12.6 million MDL was requested for the construction and/or reconstruction of greenhouses, solariums and tunnels (33% less compared to 2021) for 115 investment objects. In fact, 5.8 million MDL were

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authorized for payment (28.4% less than in 2021) for 55 investment objects. As a result, 499.6 ha of agricultural land intended for the production of fruits and vegetables on protected land were built and modernized, which is 2.3% less than the previous year. We observe a fluctuation of all indicators during the analyzed period, which is caused both by the amount of the subsidy fund and by the needs of agricultural producers.

Table 1. Subsidizing investments in the production of vegetables and fruits on protected land

Years	Financial aid: requested		Financial aid: granted		Area, ha					
	Investment objects	Amount, mil. MDL	Investment objects	Amount, mil. MDL	TOTAL	Winter greenhouses	Open field	Solariums	Tunnels	Mulching
2017	58	12.6	43	9.3	57.0	25.6	21.5	4.2	5.5	-
2018	92	11.3	89	10.9	112.6	33.0	46.4	10.3	1.07	21.95
2019	74	8.04	40	4.9	238.8	40.5	45.4	8.7	9.3	135.3
2020	129	11.9	35	3.3	764.0	473.2	57.4	9.5	3.1	221.0
2021	158	19.1	65	8.1	511.6	63.3	96.0	25.1	2.3	324.9
2022	115	12.6	55	5.8	499.6	31.7	42.5	7.8	35.3	382.3

Source: based on data from the Agency of Interventions and Payments in Agriculture [2].

In 2022, financial aid in the amount of 12.6 million MDL was requested for the construction and/or reconstruction of greenhouses, solariums and tunnels (33% less compared to 2021) for 115 investment objects. In fact, 5.8 million MDL were authorized for payment (28.4% less than in 2021) for 55 investment objects. As a result, 499.6 ha of agricultural land intended for the production of fruits and vegetables on protected land were built and modernized, which is 2.3% less than the previous year. We observe a fluctuation of all indicators during the analyzed period, which is caused both by the amount of the subsidy fund and by the needs of agricultural producers.

Management of the investment subsidy fund for the establishment, modernization and clearing of perennial plantations

The fundamental objective of this subsidy submeasure is to increase the productivity and competitiveness of the fruit, grape, apple tree and aromatic crops production sectors, such as the oil rose, lavender, hyssop, yarrow. The financial aid is granted for the clearing of plantations with an expired exploitation term, the implementation of advanced technologies for the establishment and maintenance of plantations, increasing the quality of production in accordance with international standards, equipping perennial plantations with anti-hail, anti-rain and anti-freeze systems.

Within this submeasure, in 2022, 46.1 million MDL were allocated for subsidizing 345 investment items, which constitutes 37.5% of the total number of requests. Of these, 208 requests for financial aid were submitted for subsidy, in the amount of 43.9 million MDL for the establishment of 963.2 ha of fruit plantations; 98 investment projects, in the amount of 19.7 million MDL, for the establishment of 315.7 ha of wine plantations. The dynamic analysis shows a continuous reduction of the financial aid granted under this submeasure, although the number of requests is increasing (Fig. 3).

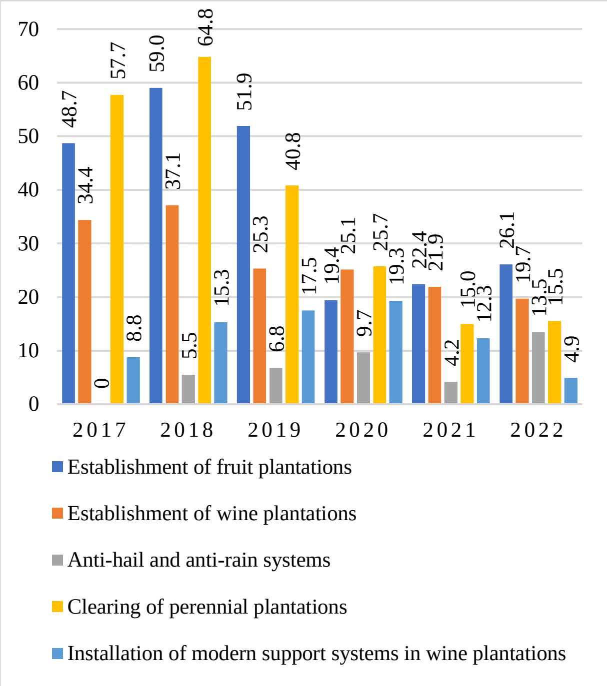

Fig. 3. The financial aid granted to stimulate investments in the establishment, modernization and clearing of perennial plantations, mil. MDL

Source: based on data from the Agency of Interventions and Payments in Agriculture [2].

Management of the investment subsidy fund for the procurement of conventional agricultural machinery and equipment

By facilitating the access of agricultural producers to high-performance techniques and machinery, the productivity and competitiveness of the agricultural sector is increased. For this purpose, in 2022, 293.1 million MDL were disbursed to the account of agricultural producers, from which 4,097 units of agricultural machinery and equipment were purchased (Table 2).

Table 2. Financial aid granted for the procurement of conventional agricultural machinery and equipment

Years	Requests for financial support, applications submitted	Financial aid, mil. MDL	Purchased agricultural machinery and equipment, units
2017	2,073	222.0	3,921
2018	2,225	217.3	4,386
2019	2,054	211.8	3,628
2020	1,931	208.7	2,507
2021	2,414	297.4	3,938
2022	2,578	338.2	4,097

Source: based on data from the Agency of Interventions and Payments in Agriculture [2].

Starting from 2017 until 2020, the amount of financial aid granted for the procurement of conventional agricultural equipment and machinery shows a continuous decrease. In 2021, that amount increased by 42.5% compared to the previous year, after which in 2022 it shows a reduction by 1.4%.

We can mention that, for the year 2022, some changes related to this submeasure were made, which brought dissatisfaction among farmers in the country, especially those who bought large-capacity agricultural machinery. Thus, the beneficiaries of the financial aid were the farmers who purchased tractors with a capacity of up to 200 horsepower and combines with a power of up to 260 horsepower [6].

Management of the investment subsidy fund for the use and technological renovation of animal farms

The livestock sector is an important branch of agriculture, having an important contribution to the formation of the agricultural GDP. During the last years, various variations of the livestock have been recorded. Thus, the number of cattle increased in 2022 compared to 2017 by 42.6%, and of pigs – by 13%. The goat population showed a significant increase, increasing 5.3 times in 2022 compared to 2017.

At the same time, there is a reduction in the number of sheep by 2.1%, of horses – by 75%, of domestic rabbits – by 14.9%, of poultry – by 23.6% [15].

In the last 2-3 years, the activity of the animal husbandry sector has been negatively affected by multiple causes, in particular, the exorbitant increase in the price of energy resources, the increase in the price of fodder and their shortage, the increase in interest on loans. In order to stimulate the organization and technological modernization of livestock farms, the Government of the Republic of Moldova grants subsidies to offset the cost of new technological equipment purchased by farmers, provided that it has been fully paid for, including the construction or reconstruction of animal farms (Fig. 4).

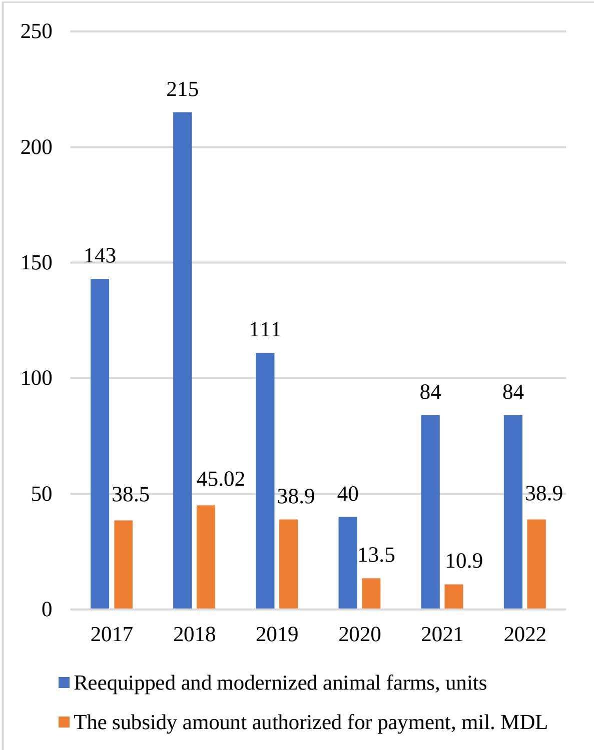

Fig. 4. Financial aid granted for the use and technological renovation of animal farms
Source: based on data from the Agency of Interventions and Payments in Agriculture [2]

During the period under analysis, there is a reduction in the number of animal farms repurposed and modernized on account of subsidies granted from 143 to 84 units (by 41.3%), although the number of requests for financial support is continuously increasing, with 395 requests being submitted in the year 2022. Thus, the share of authorized requests in the last year constituting 21.3% of the total number of requests.

Management of the investment subsidy fund for the procurement of breeding animals and the maintenance of their genetic background

Currently, in the Republic of Moldova, 49 animal farms are certified in the breeding category, of which cattle – 21, pigs – 1, sheep – 11, goats – 1, horses – 1, poultry – 1, beekeepers – 13 [12].

The breeding category (farm animal, with breed certificate, used for breeding) constitutes a performance, which offers advantages to the brood stock owner, including subsidies. The financial aid is granted to improve the herd of animals by partially compensating the investments in the procurement of breeding animals.

Table 3. The financial aid granted for the procurement of breeding animals

Years	Financial aid, mil. MDL	Livestock, heads					
		Cattle	Pigs	Sheep and goats	Rabbits	Poultry	Bees
2017	10.1	318	1,212	557	-	-	2,488
2018	12.	10	8	12	-	-	38
2019	9.5	656	462	944	-	-	3,335
2020	7.5	867	454	454	-	94,448	16,652
2021	13.0	701	100	671	1,228	51,664	1,771
2022	22.1	905	998	816	92	73,028	3,159

Source: based on data from the Agency of Interventions and Payments in Agriculture [2].

Although, during the analyzed period, investments in livestock and poultry vary from year to year, we still observe an increasing trend. Starting from 2020, subsidies are granted for partridges, which in 2022 decreased by 22.7% compared to 2020, but increased by 41.4% compared to 2021. In 2021, for the first time financial aid was granted for procurement of gilt rabbits, which decreased drastically in the following year – by 92.5% (Table 3).

Compared to previous years, in the last year of analysis, the amount of subsidies granted to stimulate investments in the purchase of breeding animals increased significantly, which indicates the increased interest of farmers in the development of the respective sector.

Management of the investment subsidy fund for the development of post-harvest and processing infrastructure

For the development of the post-harvest and processing infrastructure, investments in the procurement and modernization of fruit and vegetable storage refrigerators are subsidized; machinery for processing, drying and freezing fruits, vegetables, cereals, oilseeds, sunflowers, etc.; equipment for primary processing, refrigeration, packaging and storage of meat and milk.

The financial aid granted to agricultural producers for the development of post-harvest and processing infrastructure is carried out in the form of compensation and is determined as a percentage rate of the investment value [6].

The development of the post-harvest and processing infrastructure is the most requested area of investment, the value of the requested subsidies totaling 444.3 million lei in 2022. The compensated amount, however, constituted only 92.8%. In the period of 2020-2022, there is a significant reduction in the financial aid granted, which is on average 57.9% lower than that granted in the period of 2017-2019 (Fig. 5).

Analyzing the types of investments made by agricultural producers for the development of the post-harvest and processing infrastructure, we can state that the largest share in the total number of equipment purchased belongs to refrigerators (about 26.7%) and grain processing equipment (about 39%).

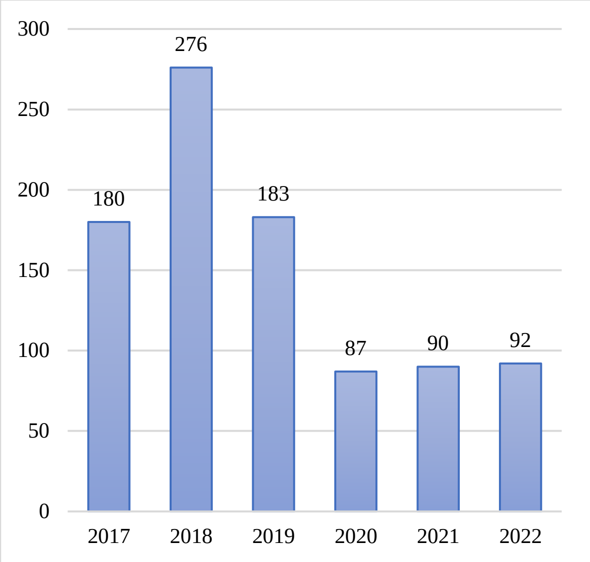

Fig. 5. Financial aid granted for the development of post-harvest and processing infrastructure, mil. MDL
Source: based on data from the Agency of Interventions and Payments in Agriculture [2].

Management of the subsidy fund for crediting agricultural producers by commercial banks and non-bank lending organizations

Agriculture is a complex branch that involves multiple expenses and investments, which agricultural producers do not have according to their needs. To ensure an uninterrupted activity, they often resort to credit. Thus, the submeasure in question is intended to ensure the access of agricultural producers to financial resources by crediting them from commercial banks and non-bank lending organizations registered on the territory of the Republic of Moldova.

The credits accessed by farmers are used for seeds and planting material; fuel and lubricants; fertilizers and protective means; greenhouse modules and other materials for the construction or reconstruction of greenhouses, solariums and tunnels; agricultural machinery and equipment; anti-hail and anti-rain equipment; technological equipment for equipping and renovating the entity; domesticated animals and birds; the construction and technological equipment of agro-tourism guesthouses, etc.

16.6 million MDL were disbursed on the account of agricultural producers in 2022, which is 76.4% less than in 2017. The highest amount authorized for payment was in 2018, amounting to 91.0 million MDL, and the lower one in 2020, being only 12.2 million MDL, although the number of subsidy requests was quite high (2501 files in the amount of 133.3 million MDL).

Most credits were accessed by agricultural producers from C.B. Moldova Agroindbank S.A. – 34% on average over the analyzed period (Fig. 6).

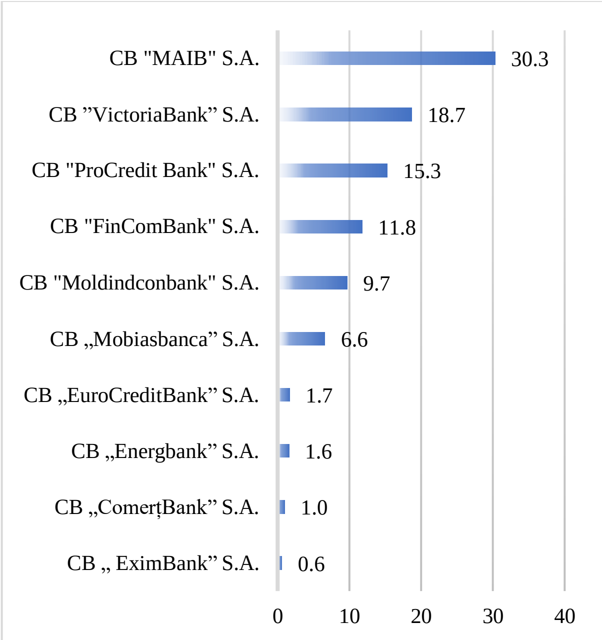

Fig. 6. The share of credits accessed by agricultural producers applying for subsidies in the year 2022, %
Source: based on data from the Agency of Interventions and Payments in Agriculture [2].

Crediting in agriculture is negatively influenced by a number of specific factors, which generate potential financial risks. An objective factor is that the activity of many agricultural producers is characterized by an increased instability of the financial situation, being seen by credit companies as vulnerable debtors. Another reason would be the low attractiveness of agricultural crediting, given the fact that, as a rule, bank transactions with agricultural loans are less profitable. In the Republic of Moldova, a behavior of indulgence of the banks towards the farmers, who are often in a precarious financial situation, has emerged, with the banks often yielding little to the interest rate or commissions. Considering the duration of the economic circuit in agriculture, which is essentially extended due to the particularities of the production cycle in phytotechnics and animal husbandry, we can conclude that the term of agricultural credit is relatively extended. All these factors generate a decrease in banks' profits, a fact that determines their financial behavior [16, p. 69].

A factor generating risk is the guarantee of loans in agriculture. Many farmers, especially small farmers, have few highly liquid assets, which makes banks reluctant to grant loans.

Management of the subsidy fund for the risk insurance in agriculture

Agricultural insurance is treated as a specific category of property insurance, providing insured protection against a specific set of risks. Any risk event has a negative impact on the activities of agricultural producers from a financial point of view. Within the agricultural insurance contract, the insurer provides financing against total or partial destruction caused by various natural calamities, diseases, injuries and other damages provided by the insurance conditions [14, p. 173].

The purpose of granting subsidies for the insurance of risks in agriculture is to stimulate agricultural producers to insure their assets against various risks specific to agricultural activities. The object of insurance in agriculture is [9]:

- agricultural crops harvest – financial losses as a result of obtaining a harvest of agricultural crops below the planned level, due to torrential rains, floods, early frosts, hail, excessive drought, burning of cereal crops, attack by harmful organisms, etc.;
- the quality of agricultural crops harvest – financial losses as a result of the decrease in the quality of the harvest of agricultural crops, due to torrential rains, floods, early frosts, hail, excessive drought, attack by harmful organisms, etc.;
- animals, poultry, fish, bees – financial loss as a result of the destruction or slaughter of animals, their illness, accidents, dangerous meteorological phenomena, fires, intoxication, asphyxiation, etc.

The financial aid provided for the insurance of risks in agriculture is granted in the form of subsidizing the insurance premiums of agricultural producers, based on contracts for insurance of production risks in agriculture [6].

In recent years, the amount of subsidies for the insurance of risks in agriculture has increased significantly. Thus, in the years 2017-2020, the value of subsidies for the insurance of risks in agriculture reached about 6.35 million MDL per year, and in the last two years this increased to 50-60 million MDL (Fig. 7).

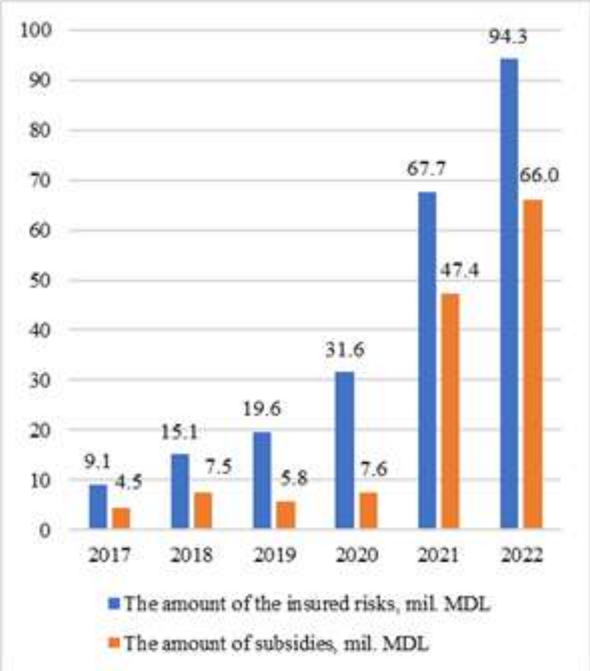

Fig. 7. The financial aid granted for the stimulation of the risk insurance mechanism in agriculture
Source: based on data from the Agency of Interventions and Payments in Agriculture [2].

The increase in the amount of subsidies to stimulate the risk insurance mechanism in the agricultural sector denotes the awareness of agricultural producers of the importance of agricultural production insurance, as well as the willingness of insurance companies to guarantee risks in agriculture.

Management of the subsidy fund for the establishment and operation of groups of agricultural producers

A group of producers is any legal person, with the exception of non-commercial organizations, made up of agricultural producers, whose main purpose is the joint marketing of the agricultural products of the group members [11].

The group of producers is a convenient development platform through which small farmers can acquire new opportunities and skills for the development of their own business, and their individual assertion and bargaining power increase with the formation or joining of a producer group, which consists of farmers with similar activities, have the same problems and pursue common development goals [13].

The creation of groups of agricultural producers opens new opportunities for economic development by attracting local, zonal or regional advantages and which allows the integration of agriculture in the demands of the competitive market and makes national agriculture competitive on a European level [17, p. 88].

The presence of the competition between individual agricultural producers should also be taken into account. World experience shows that cooperatives have much more opportunities to establish cooperation with consumers, intermediaries, processing and marketing enterprises than individual farmers. The same applies to joint ownership of expensive equipment and machinery, which is a great difficulty for individual farms [3, p. 123].

That's why, the association movement of agricultural producers through the formation of producer groups is significantly favored by the state through several certain instruments, among which we highlight the granting of subsidies.

The fundamental objective of this subsidy direction is to strengthen cooperation and association between agricultural producers, which will have the effect of increasing the income obtained from agricultural activities, sustainable growth of the economic performance and competitiveness of agricultural production, reducing production costs, increasing exports of agricultural and agri-food products. We specify that the financial support is granted only for the first five years of activity of the group of producers, starting from the date of recognition of the respective group [6] and is calculated based on the value of the production sold annually by the group of producers [11].

In 2017, subsidies were granted for 2 groups of producers in the amount of 371.8 thousand MDL. In the following years, the amount of subsidies has been much more modest, even if the number of groups of agricultural producers who obtained financial support has been increasing. Thus, in 2018 the amount of subsidies was substantially reduced, amounting to only 1.2 million MDL. Subsequently, it shows an increase of up to 3.9 million MDL in 2022, i.e. 3.25 times (Fig. 8).

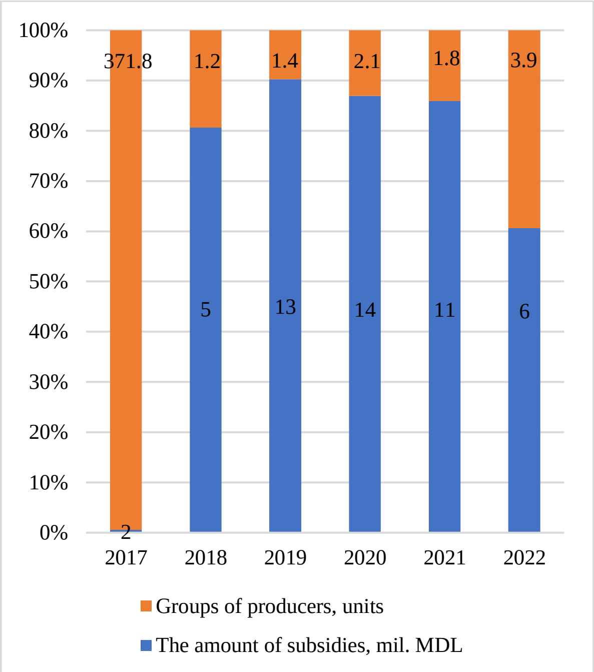

Fig. 8. The financial aid granted to stimulate the establishment and operation of groups of agricultural producers
Source: based on data from the Agency of Interventions and Payments in Agriculture [2].

Generalizing the presented information, we can say that in the audited period 2017-2022, the financial aid granted to agricultural producers registers various oscillations, caused both by the interest of farmers towards certain subsidizing directions, and by the available amount of budget funds and those disbursed by development partners. In 2022, 2,663 subsidy applications were received and paid in the amount of 434,162.40 thousand MDL. From the total number of subsidy requests, the largest share belongs to those related to investments for the procurement of conventional agricultural machinery and equipment – 47.2% in the amount of 162,855.20 thousand MDL. Investments in the establishment and operation of groups of agricultural producers have the lowest share, constituting 0.9% of the amount of 3,891.60 thousand MDL, a fact caused by the small number of requests (Table 4).

Table 4. The financial aid granted to increase the competitiveness of the agri-food sector through restructuring and modernization, 2022

Subsidy directions	Number of subsidized requests	Amount of subsidy paid, thousand MDL
Production of vegetables, fruits, aromatic, seasoning and medicinal plants on protected land	52	5,695.00
Establishment, modernization and clearing of perennial plantations	345	46,080.20
Procurement of conventional agricultural equipment and machinery	1,257	162,855.20
Equipment and technological renovation of animal farms	103	38,927.10
Procurement of breeding animals and maintaining their genetic background	34	22,045.90
Development of post-harvest and processing infrastructure	225	82,764.30
Crediting of agricultural producers	150	16,620.60
Risk insurance in agriculture	491	55,282.50
Establishment and operation of groups of agricultural producers	6	3,891.60
TOTAL	**2,663**	**434,162.40**

Source: based on data from the Agency of Interventions and Payments in Agriculture [2].

The subsidy activity contributes to the implementation, monitoring, control and evaluation of agricultural development policies. Only the synthesis of subsequent evaluations of the management of the subsidy fund is able to demonstrate the contribution of the state's financial support to the fulfillment of the general objectives of the agrarian policies.

CONCLUSIONS

The efficient allocation of subsidy funds is a precondition for increasing the performance of the agricultural sector.

The rigorous operation of the agricultural subsidy mechanism leads to the stimulation and encouragement of investments in this field, to the creation of jobs, the reduction of poverty, the mitigation of migration from the rural to the urban environment, but also abroad, as well as to the increase of food safety and security.

The state's financial aid to the agricultural sector is timely and must be developed by identifying and diversifying additional sources of allocation. It is necessary to direct subsidy policies towards the development of sectors with added value.

Most of the subsidy fund in the period 2017-2022 was used for technical capacity building activities. At the same time, the balance between the different types of financial aid has changed. Subsidy budgets have remained relatively stable in absolute terms.

In order to stimulate insurance in agriculture, it is necessary to offer attractive service packages for agricultural producers, thus stimulating them to insure their investment objects. At the same time, there is a need to create and develop a risk management culture in agriculture.

Cooperation and association of agricultural producers is hindered, in particular, by mentality, lack of mutual trust between members, difficulties in coordinating joint activities, lack of management skills.

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REFERENCES

[1]Agency for Intervention and Payments in Agriculture (AIPA), 2022, Subsidy Regulation 2017-2021 Support Measures.

[2]Agency for Intervention and Payments in Agriculture (AIPA), 2023, Analytical report regarding the management of financial resources allocated from the National Fund for Agricultural and Rural Areas Development

[3]Borshchevskyy, V., Kaplenko, H., Kulish, I., Pak, N., Pikulyk, O., 2022, Historical review of agricultural cooperation: world trends and Ukrainian realities. In: Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 22(4): 123-132.

[4]Cimpoieș, L., 2021, Agricultural support policy in Moldova: a key factor to agricultural development? In: Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 21(2): 169-176.

[5]Common Agricultural Policy: Information Guide, 2013 http://aei.pitt.edu/75450/3/Common-Agricultural-Policy.pdf , Accessed on 26.04.2023.

[6]Government Decision, 2017, Government Decision No. 455 from 21.06.2017 regarding the distribution of funds from the National Fund for the Agricultural and Environmental Development. In: Official Monitor No. 201-213 from 23.06.2017.

[7]Government Decision, 2022, Government Decision No. 277 from 27.04.2022 regarding the approval of the Regulation on the granting of advance subsidies for local development through the implementation of the LEADER Program. In: Official Monitor No. 134 from 29.04.2022.

[8]Law on Subsidies in Agriculture and Rural Areas, 2023, Law No. 71 from 31.03.2023. In: Official Monitor No. 134-137 from 20.04.2023.

[9]Law on Subsidized Insurance in Agriculture, 2020, Law No. 183 from 11.09.2020. In: Official Monitor No. 267-271 from 16.10.2020.

[10]Law on State Budget, 2022, Law No. 359 from 22.12.2022. In: Official Monitor No. 435-437 from 28.12.2022.

[11]Law on groups of agricultural producers and associations thereof, 2013, Law No. 312 from 20.12.2013. In: Official Monitor No. 47-48 from 25.02.2014.

[12]List of zootechnical farms with breeding animals, 2022 https://www.madrm.gov.md/ro/content/lista-fermelor-zootehnice-de-pr%C4%83sil%C4%83?fbclid, Accessed on 23.05.2023.

[13]MACP, 2020, Groups of Producers. Practical guide: from the first steps to profitability and growth.

[14]Marin, L., 2019, Classification of risks in agricultural insurance. In: Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 19(4): 173-178.

[15]National Bureau of Statistics: Agriculture https://statistica.gov.md/files/files/publicatii_electronice/Anuar_Statistic/2022/16_AS.pdf, Accessed on 03.05.2023.

[16]Stratulat, O., 2022, Agricultural credit in the national banking system: analyses, trends, perspectives. In: Journal Economica, No. 1(119): 63-72.

[17]Zaharco, S., 2019, Cooperation of agricultural producers: barriers to association and solutions to overcome them. In: Journal Studia Universitatis Moldaviae, No. 7(127): 87-92.