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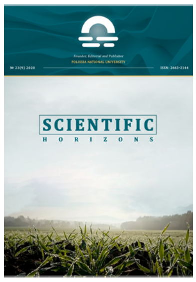

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Productivity of soybean varieties of different maturity groups depending on plant density under drip irrigation in the South of Ukraine

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Abstract. Soybeans are a leading leguminous crop for universal use, therefore, measures aimed at increasing their productivity, including the reasonable selection of varietal resources and optimisation of planting density, will make a significant contribution to the creation of sustainable food production systems. The research aims to determine the effect of plant density on the productivity of soybean varieties of different maturity groups. Field laboratory and statistical (correlation and regression analysis) methods were used in the study. The field experiments were conducted during 2018-2020 on dark chestnut soil of a private agricultural enterprise of the agricultural company "Syvash" in Novotroitsk district of Kherson region. Its maximum values for the cultivation of early ripening varieties were ensured by a plant density of 700 thousand/ha, medium early varieties – 500-700 thousand/ha, and medium ripening varieties – 500 thousand/ha. A strong and very strong correlation between yield and soybean yield index was established. Increasing the length of the growing season contributed to the growth of yields. In the group of early maturing soybean varieties, the Monarch variety was determined to be the most productive. There was no significant difference in the level of yield of varieties within other maturity groups. For each variety, the optimum planting density was determined, at which the maximum grain yield was formed. Longer vegetation contributed to a greater accumulation of protein and fat in the grain. In terms of protein content, the difference between varieties of the same maturity group did not exceed 0.2%, but varieties differed in terms of conditional protein yield per hectare of crops. There was no difference in the fat content of mid-season soybean varieties. Among the early-ripening varieties, the Monarch variety was distinguished by higher oil content, and among the medium-early varieties – by Aratta. The maximum conditional fat yield per hectare of crops was

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also determined for these varieties. A very strong and strong correlation was found between soybean grain yield and protein and fat content, respectively. A very strong correlation was also found between the protein and fat content of the grain. To ensure sustainable production and efficient use of soybeans and soybean by-products, it is advisable to take the results of the study into account in production conditions

Keywords: crop density; yield; grain quality; protein; fat

INTRODUCTION

A well-grounded selection of varietal resources and the establishment of optimal plant density are important measures to increase yields and improve the quality of crop production. Variety is one of the resource-saving elements of cultivation technology. It accounts for up to 30% of the yield increase, and in extreme weather years, it is the variety that plays a crucial role in shaping the productivity of the crop, which must be justified from an economic and energy point of view (FAO, n.d.). Varieties of different genotypic origins do not realise their potential productivity in the same way. Some varieties, in the absence of an optimal background of nutrition and plant protection products, sharply reduce productivity, while other varieties can produce high productivity under any, even unfavourable, growing conditions. That is why production conditions require the introduction of high-yielding varieties with high quality, well adapted to specific soil and climatic conditions. R. Krisdiana *et al.* (2021) argue that variety is the most effective element of the technological process and plays an important role in improving productivity and increasing soybean production. L.G. Biliavs'ka & A.M. Rybal'chenko (2018) report that the realisation of the productivity potential of a soybean variety is determined by its adaptive properties – plasticity and stability. For the arid conditions of Ukraine, the authors propose to use high and medium plastic soybean varieties with high stability of the main quantitative traits.

S. Liu *et al.* (2020) note that soybean yields largely depend on planting density, which is influenced by several different factors, including plant height, number of branches and beans per plant, number of seeds per bean, and seed size. Soybean plants with a significant number of long branches can shade each other, resulting in a lower yield. Soybean varieties with fewer shorter branches or less branched branches should be sown with a higher density of coenosis. P. Ranđelović *et al.* (2020) describe that stem density can affect the branching of soybean plants: at high planting densities, plants will form fewer branches and vice versa. V.A. Furman *et al.* (2022) found that in sparse soybean crops, intensive plant branching occurs, the excessive leaf surface is formed, and a significant amount of beans and seeds are formed, under the weight of which branches can break off in windy conditions. In sparse crops, the lower tier of beans is located close to the soil surface, and uneven maturation of the beans occurs, which leads to a shortfall in yield, while at the same time high individual plant productivity.

Y. Shashkov & S. Tanchyk (2018) note that at the optimal density of coenosis, the leaf surface of soybean plants is evenly illuminated, photosynthetic activity improves, and photosynthetic processes are activated, which has a positive effect on the level of yield. M. Jańczak-Pieniążek *et al.* (2021) point out that optimal plant density is crucial in terms of reducing competition between plants for water, nutrients, light, and other environmental factors. According to the results of field studies conducted in 2017-2019 in Przeclaw (Poland), it was found that at lower planting densities, soybean plants form a larger number of beans and seeds per bean. Seeds are formed in larger sizes and weights. In addition, photosynthesis processes are more efficient in less dense crops due to better illumination. Such crops are more stress-resistant and require less seed material, which has a positive impact on the economic efficiency of production. Based on the results of experimental trials in the southern, central, and northern regions of the United States, J.F. Andrade *et al.* (2019) concluded that soybean crops with narrow row spacing produce higher yields due to earlier row closure and better absorption of photosynthetic active radiation by the crops.

Z. Liao *et al.* (2022) studied the effect of planting density on the growth and development of soybean plants and their yield formation in non-irrigated conditions in China in 2019-2020. Two planting densities were set for the study – 160 and 320 thousand/ha. The results of the field experiment showed that the thickening of soybean crops to 320 thousand plants/ha increased leaf area index by 31.9%, aboveground biomass by 59.4%, and water use efficiency per unit yield by 27.9%. At the same time, grain yield increased by 27.4%. Z.I. Hlupak (2020) notes that crop compaction to certain parameters contributes to the growth of soybean yields, but excessive compaction beyond the optimal parameters negatively affects yields due to the intershading of plants.

Analysis of research results shows that varietal characteristics and plant density play a crucial role in shaping soybean productivity. Varietal characteristics are determined by the genetic characteristics of plants. Each variety has its properties, including drought resistance, disease resistance, maturity, etc. By selecting the right variety, we can significantly increase plant productivity. In this case, the crop density should be optimal. Insufficient plant density can lead to low yields, and too high a density can cause competition between plants for water, nutrients, and light. A reasonable choice of variety and optimal plant density is the key to sustainable production of such a valuable legume crop as soybeans. Therefore, the research aims to determine the effect of plant density on the productivity of soybean varieties of different maturity groups and to establish the relationship between yield and yield index, yield and protein and fat content in grain.

MATERIALS AND METHODS

The research was carried out following the thematic research plan of Kherson State Agrarian and Economic University under the task "Strategic directions of development of adaptive technologies for growing crops under conditions of limited natural and material resources" (state registration number 0117U006764). The field experiments were conducted during 2018-2020 at the university's research site based on a private agricultural enterprise of the agricultural company "Syvash" in the Novotroitsk district of the Kherson region within the Kakhovka irrigation system.

The weather conditions in 2018 and 2019 were dry with very high air and soil temperatures. Hot weather with little precipitation was also observed in the autumn. In 2020, the elevated temperature regime was accompanied by sufficient rainfall, which contributed to the intensive growth and development of soybean crops and the formation of higher grain yields compared to previous years of research, even though soybeans in the experiment were grown under drip irrigation.

The soil of the experimental plot is dark chestnut heavy loamy, residually slightly saline. Agricultural technology of soybean cultivation in the experiment was generally accepted for the conditions of drip surface irrigation in southern Ukraine, except for the factors studied. The soybean predecessor in the experiment was corn. The main soil tillage consisted of two peeling and ploughing, spring tillage – two-track harrowing and pre-sowing cultivation. For pre-sowing cultivation, mineral fertilisers were applied at the rate of $N_{30}P_{60}$, using ammonium nitrate and granulated superphosphate. On the day of sowing, soybean seeds were treated with a strain of nodule bacteria *Bradyrhizobium japonicum* 634b and Maxim XL seed treatment. Sowing was carried out in a wide-row method with row spacing of 45 cm. The pre-irrigation moisture content in the 0-50 cm soil layer was maintained at 80% HB. The crop was harvested in sections when the seeds were fully ripe.

The research was conducted using the "Methodology of field and laboratory research on irrigated lands" (Vozhehova *et al.,* 2014). The experiment is two-factor. Factor A – soybean varieties of different maturity groups selected by the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine: early maturing Diona, Monarch; medium early Aratta, Sofia; medium early Danaya, Svyatogor. Factor B – plant density: 300, 500, 700, 900, and 1100 thousand plants per hectare. Replication – four times, sown area of the third order plot – 75 m^2, accounting area – 50 m^2.

In the studies conducted, the "yield index" was calculated as the ratio of grain weight to the total aboveground mass of plants. The content of total nitrogen in the grain was determined by the Kjeldahl method (State Standards of Ukraine (hereinafter DSTU) ISO 5983:2003) with subsequent conversion to protein content. The mass fraction of fat was determined by the dehydrated residue using a Soxhlet extraction apparatus (DSTU 7491:2013). The construction of polynomial trend lines, calculation of correlation coefficients R^2 and statistical analysis of experimental data were performed using the Agrostat computer program (Ushkarenko *et al.*, 2009). The degree of correlation was determined by the Cheddock scale (Karaeva & Varava, 2016).

Experimental studies of plants (both cultivated and wild), including the collection of plant material, complied with institutional, national, or international guidelines. The authors adhered to the standards of the Convention on Biological Diversity (1992) and the Convention on Trade in Endangered Species of Wild Fauna and Flora (1979).

RESULTS AND DISCUSSION

The yield index characterises the orientation of the processes of using assimilation products to form the grain part of the crop. It was found that this calculated index depended largely on the factors studied. It increased with the increase in the length of the growing season. Thus, according to the averaged data, the yield index of early maturing soybean varieties in the experiment was 0.40, medium early – 0.43, and medium ripe – 0.47 (Table 1).

In the cultivation of early maturing soybean varieties, the lowest yield index was found in the experimental variants with a plant density of 300 thousand plants/ha, and the highest – at a sowing density of 700 thousand plants/ha. The coenosis compaction of up to 700 thousand plants/ha led to an increase in the yield index, further thickening of the plant density already reduced this indicator. The Monarch variety provided a slightly higher yield index in the group of early maturing varieties.

Table 1. *Yield index of soybean varieties of different maturity groups depending on plant density (average for 2018-2020)*

Soybean variety (factor A)	Plant density, thousand units/ha (factor B)					Average by factor A
	300	500	700	900	1100	
Early ripening varieties						
Diona	0.36	0.40	0.43	0.38	0.36	0.39
Monarch	0.37	0.42	0.42	0.43	0.39	0.41

Table 1, Continued

Soybean variety (factor A)	Plant density, thousand units/ha (factor B)					Average by factor A
	300	500	700	900	1100	
On average per factor B	0.37	0.41	0.43	0.41	0.38	0.40
Medium early varieties						
Aratta	0.43	0.43	0.45	0.44	0.42	0.43
Sofia	0.39	0.47	0.44	0.42	0.38	0.42
On average per factor B	0.41	0.45	0.45	0.43	0.40	0.43
Mid-season varieties						
Danaya	0.45	0.48	0.45	0.45	0.41	0.45
Svyatogor	0.53	0.53	0.52	0.47	0.40	0.49
On average per factor B	0.49	0.51	0.49	0.46	0.41	0.47

Source: *compiled by the author*

In the group of mid-early varieties, Aratta had an advantage over Sofia in terms of the yield index, except for the variant with a plant density of 500 thousand plants/ha. The maximum values of the yield index for the cultivation of the Aratta variety were provided by the density of 700 thousand plants/ha, and the Sofia variety – of 500 thousand plants/ha. In the group of medium-ripening soybean varieties, a higher yield index was determined for the cultivation of Svyatogor, only at a plant density of 1100 thousand plants/ha, which was slightly inferior to Danaya. Both varieties provided maximum yield index values at a planting density of 500 thousand plants/ha. Further compaction of the coenosis led to a decrease in this indicator.

In general, the yield index in the experiment ranged from 0.36 to 0.53, which indicates the ability of soybean plants to effectively use dry matter to form grain productivity. A strong and very strong relationship was established between the yield index and grain yield of the studied soybean varieties, which is demonstrated by the constructed polynomial trend lines of dependence and the calculated values of the correlation coefficient R^2 (Fig. 1).

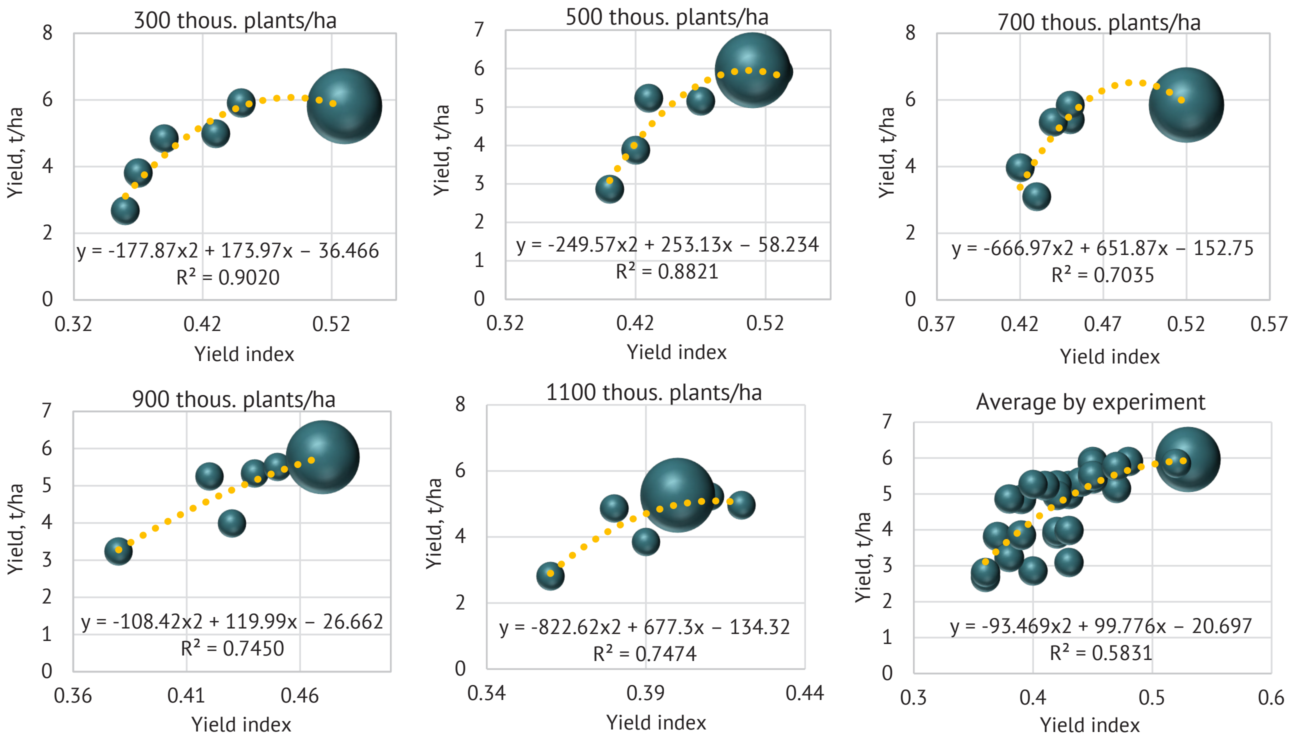

Figure 1. *Polynomial trend lines of the relationship between the yield index and grain yield of soybean varieties (average for 2018-2020)*

Source: *compiled by the author*

The research results show that the yield of soybean grain depended on the studied factors – variety and plant density. With the increase in the duration of the growing season, it increased: on average, the yield of early maturing varieties was 3.42 t/ha, medium early – 5.13 t/ha, medium ripe – 5.71 t/ha (Table 2).

Table 2. *Yield of soybean varieties of different maturity groups depending on plant density (average for 2018-2020)*

Soybean variety (factor A)	Plant density, thousand units/ha (factor B)					Average by factor A
	300	500	700	900	1100	
Early ripening varieties						
Diona	2.68	2.86	3.09	3.23	2.81	2.93
Monarch	3.81	3.88	3.96	3.98	3.85	3.90
On average per factor B	3.25	3.37	3.53	3.61	3.33	3.42
Medium early varieties						
Aratta	4.98	5.23	5.41	5.33	4.96	5.18
Sofia	4.84	5.15	5.33	5.25	4.86	5.09
On average per factor B	4.91	5.19	5.37	5.29	4.91	5.13
Mid-season varieties						
Danaya	5.91	5.91	5.84	5.51	5.23	5.68
Svyatogor	5.81	5.96	5.85	5.77	5.26	5.73
On average per factor B	5.86	5.94	5.85	5.64	5.25	5.71
HIP_{05}, t/ha	by factor A – 0.12-0.15, by factor B – 0.11-0.15					

Source: *compiled by the author*

The Monarch variety had a significant advantage in grain yield in the group of early maturing soybean varieties.

The yield increase concerning the variety Diona, depending on the plant density, ranged from 0.75-1.13 t/ha or 23.2-42.2% (Fig. 2).

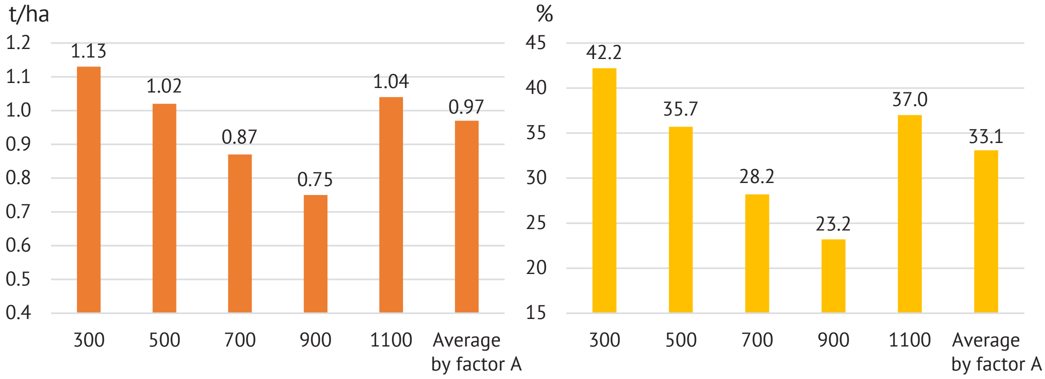

Figure 2. *Increase in grain yield of the Monarch variety compared to the Diona variety (average for 2018-2020)*
Source: *compiled by the author*

In the group of medium early varieties, Aratta was characterised by a slightly higher grain yield. Its increase concerning the variety Sofia was 0.08-0.14 t/ha or 1.5-2.9% (Fig. 3), i.e., it was insignificant and within the error of the experiment (the smallest significant difference NIR_{05} = 0.12-0.15 t/ha).

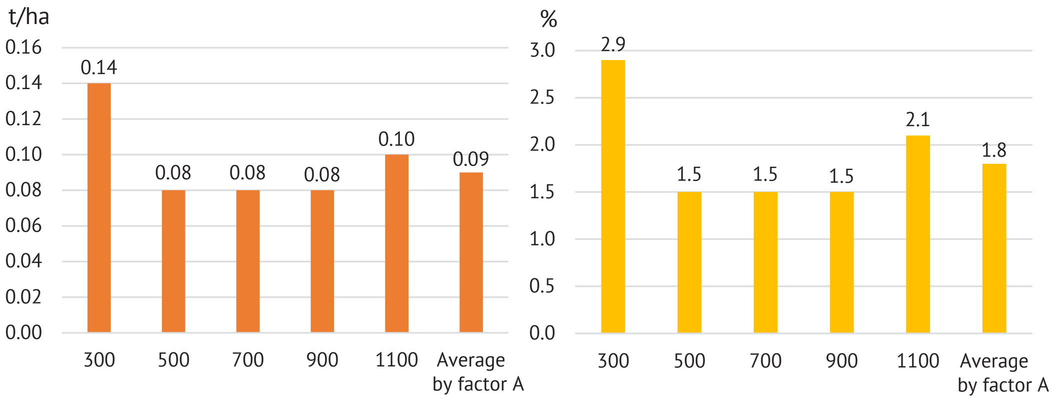

Figure 3. *Increase in grain yield of Aratta variety compared to Sofia variety (average for 2018-2020)*
Source: *compiled by the author*

The difference between the yield data of mid-season varieties Danaya and Svyatogor was also within the error of the experiment, except for the variant with a plant density of 900 thousand/ha, where Svyatogor had a significant advantage over Danaya (Fig. 4).

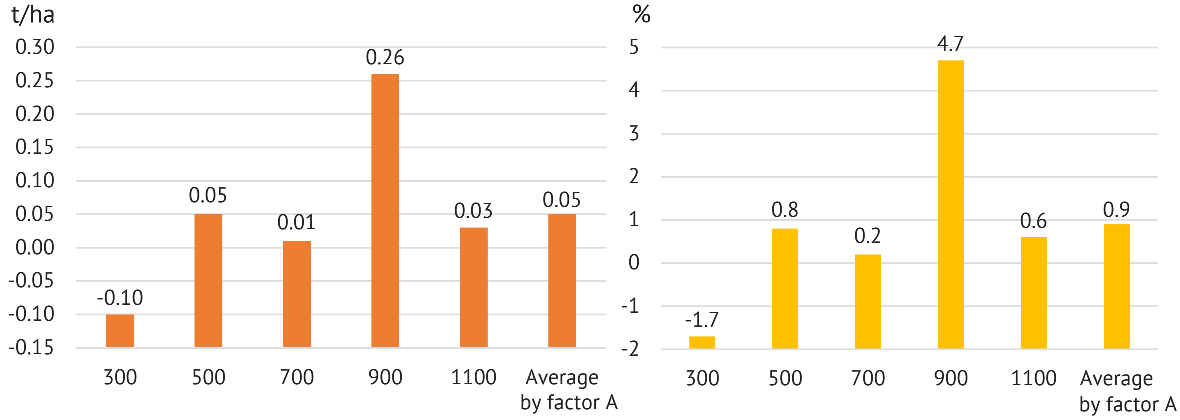

Figure 4. *Increase (decrease) in grain yield of the Svyatogor variety compared to the Danaya variety (average for 2018-2020)*

Source: *compiled by the author*

For varieties of each maturity group, the optimum sowing density was established. The early ripening varieties Diona and Monarch formed the maximum level of grain yield at a plant density of 900 thousand/ha. At the same time, the Monarch variety provided the same level of yield at a plant density of 700 thousand/ha, i.e., this soybean variety is highly plastic in terms of coenosis density. Increasing the stem density to 1100 thousand plants/ha had a negative impact on the productivity of both early maturing soybean varieties under study. The mid-early varieties Aratta and Sofia formed the highest yield level at a plant density of 700 thousand plants/ha (5.41 and 5.33 t/ha), and the mid-season varieties Danaya and Svyatogor – at a plant density of 500 thousand plants/ha (5.91 and 5.96 t/ha).

Not only the level of yields achieved but also the quality of the crops grown is important in implementing modern agricultural technologies. Soybeans are valued primarily for their protein and fat content. These indicators in the experiment largely depended on the genotypic characteristics of the variety. With the increase in the length of the growing season, the protein and fat content in the grain of the soybean varieties under study increased. When growing early ripening varieties, the protein content in the grain averaged 40.2% by a factor, when growing medium early varieties – 40.7%, and medium ripening varieties – 41.2% (Table 3).

Table 3. *Protein and fat content in grain and their conditional yield per hectare of soybean varieties, on average, according to factor B (average for 2018-2020)*

Soybean variety (factor A)	**Content in grain, %**		**Conditional yield per hectare of crops, kg/ha**	
	of protein	**fat**	**of protein**	**fat**
Early ripening varieties				
Diona	40.1	18.1	1175	530
Monarch	40.2	18.4	1568	718
Average on early ripening varieties	40.2	18.3	1372	624
Medium early varieties				
Aratta	40.6	18.8	2103	974
Sofia	40.8	18.2	2077	926
Average for mid-early varieties	40.7	18.5	2090	950
Mid-season varieties				
Danaya	41.1	19.1	2334	1085
Svyatogor	41.2	19.1	2361	1094
Average for mid-season varieties	41.2	19.1	2348	1090
HIP_{05} by factor A, %	0.07-0.09	0.05-0.08		

Source: *compiled by the author*

The difference in this indicator between varieties of the same maturity group did not exceed 0.2%. The early-ripening variety Monarch, the medium-early variety Sofia, and the medium-ripening variety Svyatogor had a slight advantage in protein content in the grain. A much larger difference between varieties of the same maturity group was found in terms of conditional protein yield per hectare of soybean crops. In this case, the Monarch variety exceeded the Diona variety by 393 kg/ha or 33.4%. Despite a slightly lower protein content in the grain, Aratta exceeded Sofia by 26 kg/ha or 1.3% in terms of its conditional yield due to higher yields. In the mid-season group of varieties, Svyatogor was superior in terms of both protein content and conditional protein yield per hectare of crops. A very strong correlation was found between grain yield and protein content according to the Chaddock scale, as evidenced by the calculated correlation coefficient R^2=0.9647 (Fig. 5).

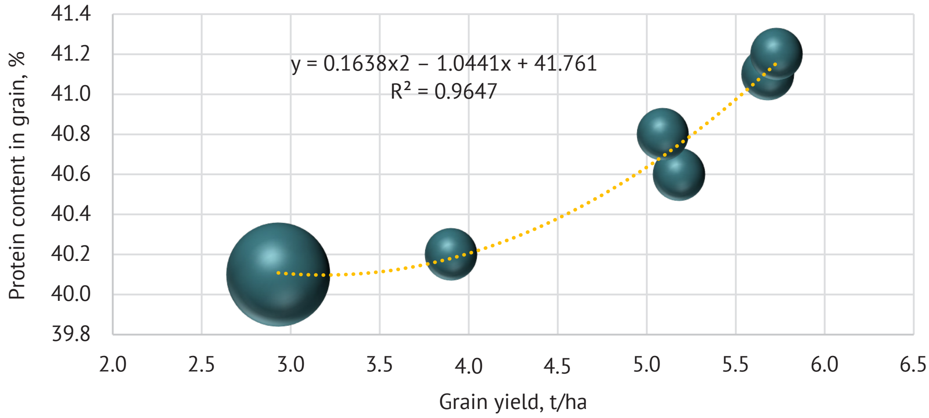

Figure 5. *Correlation and regression model of the relationship between soybean grain yield and protein content*
Source: *compiled by the author*

The fat content in soybean grain also increased with the increase in the duration of the growing season of the studied varieties. When growing an early maturing group of varieties, it was 18.3%, medium early – 18.5%, and medium maturing – 19.1% on average by factor (Table 3). The early maturing variety Monarch surpassed the variety Dion by 0.3% in this indicator of grain quality. An even greater difference was found when growing medium-early varieties. The fat content of Aratta grain was 0.6% higher than that of Sofia. No differences in the fat content of mid-season varieties Danaya and Svyatogor were found. In general, all soybean varieties grown in the experiment met the requirements of DSTU 4964:2008 (2009), according to which the fat content in soybean grain should not be lower than 12%. The Monarch variety had a significant advantage in terms of conditional fat yield per hectare of early maturing varieties. The increase in this indicator compared to the Diona variety was 188 kg/ha or 35.5%. In terms of conditional fat yield per hectare of crops, the mid-early variety Aratta outperformed the variety Sofia by 48 kg/ha or 5.2%. This difference was almost not observed in the cultivation of mid-season soybean varieties – it was minimal in the experiment with a slight advantage of the Svyatogor variety.

The constructed correlation-regression model of the relationship between soybean grain yield and fat content shows a strong degree of correlation, with a correlation coefficient of R^2=0.7412 (Fig. 6).

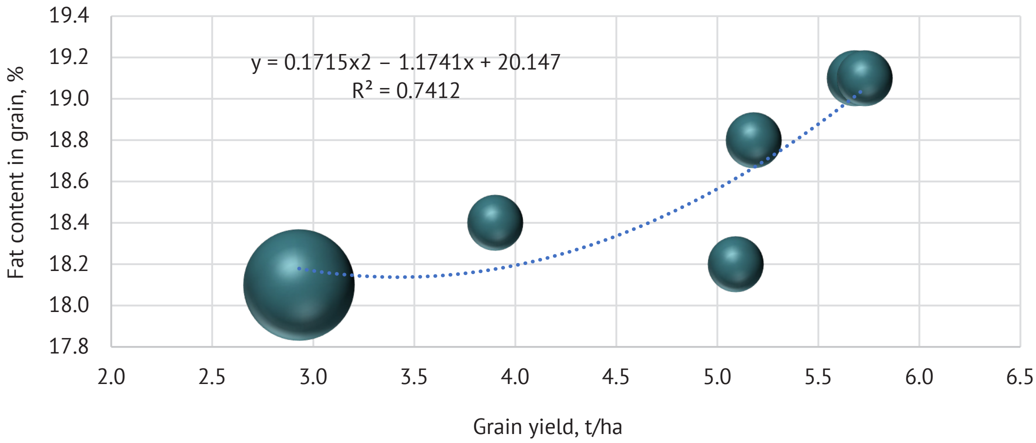

Figure 6. *Correlation-regression model of the relationship between soybean grain yield and fat content*
Source: *compiled by the author*

The relationship between protein and fat content in grain is described by the equation $y=-5.62x^2+454.91x-9187.1$, where y is the fat content in grain and x is the protein content in grain (Fig. 7). A strong correlation was found between these quality indicators: $R^2=0.9342$.

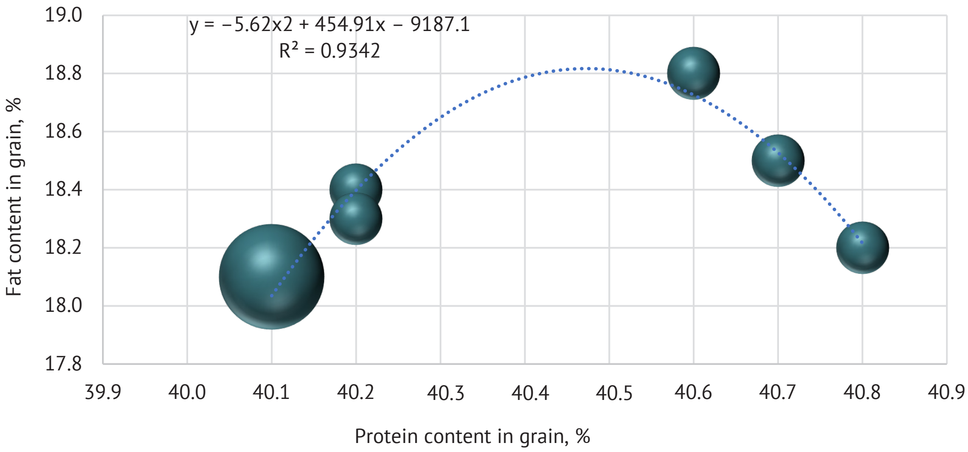

Figure 7. *Correlation-regression model of the relationship between protein and fat content in soybean grain*
Source: *compiled by the author*

The obtained results of the study and the built correlation and regression models of the relationship between grain yield and protein and fat content can be used for programming productivity, sustainable production and efficient use of soybeans and its products.

It is worth noting that other researchers have also noted the dependence of yield, biochemical composition of soybean grain and conditional protein and fat yield on genotypic characteristics of the variety. Thus, according to the results of two years of research (2019-2020), V.V. Liubych *et al.* (2020) found that the protein content in soybean grain can vary from 36.1 to 44.4% depending on the variety. At the same time, only 8 varieties out of 14 had a protein content of ≥40%. The authors also found a significant impact on this indicator of the quality of weather conditions during the years of research. In the vast majority of the varieties studied, moisture deficit and high air temperatures contributed to the formation of a higher protein content in the grain. Only some varieties showed a 4-10% decrease in protein content. These less drought-tolerant varieties were characterised by premature vegetation termination and reduced accumulation of organic matter. The fat content in the grain of the studied varieties ranged from 18.9 to 21.7% and significantly depended on the varietal characteristics and weather conditions of the growing season. As in the current research, a high correlation was found between protein and fat content in soybean grain.

M. Grabovskyi *et al.* (2023) during 2021-2022 studied the quality indicators of soybean grain of Amadea and Aurelina varieties under different variants of fungicidal plant protection. According to the results of the research, it was found that the yield of the Amadea variety on average over two years of research was 2.7-7.7% higher than the yield of the Aurelina variety. At the same time, the yield of both varieties largely depended on the hydrothermal conditions of the year of cultivation. Despite the level of fungicide plant protection, the protein and fat content in the grain of the Aurelina variety was significantly higher compared to the more productive Amadea variety. There was no effect of fungicides on the oil content of the grain, but an increase in protein content was observed.

The effect of plant density on soybean grain yield was studied by W.D. Carciochi *et al.* (2019). To summarise the research results, they used a database based on 78 experiments conducted over two years in different soil and climatic conditions in the USA and Canada. The plant density was studied from 170 to 670 thousand/ha. The obtained yield data were classified into 3 groups: low (LYE), medium (MYE) and high (HYE) yields. According to the results of the research, it was found that soybean grain yield increased with a decrease in the density of coenosis.

The opposite results were obtained in studies conducted in South Dakota (USA). M. Schutte and T. Nleya (2018) studied the effect of row spacing and seeding rates on the grain yield of soybean varieties. In dense crops with a row spacing of 19 cm, the yield was 8-10% higher compared to a row spacing of 76 cm. Increasing the seeding rate contributed to a 3-7% increase in yield. Also, the yield in the experiment largely depended on the length of the growing season of the varieties grown. Similar to the results of our research, varieties with a longer growing season produced higher yields. However, according to the results of studies conducted in non-irrigated conditions in Bulgaria. G. Naydenova and N. Georgieva (2019) observed a decrease in soybean yields with an increase in the length of the growing season, which is associated with better grain filling of genotypes with a shorter growing season. The importance of the length of the growing season in shaping soybean productivity has been reported by other researchers, including M.A. Alam *et al.* (2023).

According to the results of research by F. Chețan *et al.* (2021), conducted during 2017-2019 in the arid conditions of Romania, a significant effect of plant density and weather conditions during the year of cultivation on the yield and quality of soybean grain was found. With an increase in seeding rates, yields increased. The highest level of yield was provided by the seeding rate of 55-65 g/m^2. The compacted crops with two fertilisations with nitrogen and phosphorus fertilisers ensured the formation of grain with high protein and fat content.

R. Vozhehova *et al.* (2020), at the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine, studied the effect of plant density on grain yield of the mid-season soybean variety Svyatogor during 2016-2018. The highest yield level was provided by a sowing density of 600 thousand plants/ha – 4.32-4.47 t/ha in variants with fertilisation. The maximum yield on the unfertilised plots of the experiment was provided by a plant density of 500 thousand plants/ha – 2.91 t/ha. On more compacted crops, a sharp decrease in grain yield was observed, which coincides with the results of research on the cultivation of the Svyatogor variety.

An analytical review of the results of research conducted in different regions of the world suggests that there is currently no consensus among scientists on the impact of plant density on soybean productivity. Each variety has its optimal parameters of productive stem density. Therefore, research on modern soybean varieties of Ukrainian breeding in the soil and climatic conditions of southern Ukraine is relevant, and their results can be used in production conditions.

CONCLUSIONS

According to the results of research on the influence of plant density on the productivity of modern soybean varieties of Ukrainian selection, it was found that each maturity group has its optimal parameters of crop density to form the maximum yield and high grain quality. It was found that with the increase in the length of the growing season, the yield index increased. When growing early maturing soybean varieties, it was 0.40, medium early – 0.43, and medium mature – 0.47. The maximum values of the yield index for the cultivation of early maturing varieties were ensured by a plant density of 700 thousand/ha, medium early varieties – 500 thousand/ha (Sofia) and 700 thousand/ha (Aratta), and medium ripe varieties – 500 thousand/ha. Higher yield indexes within the ripeness group were provided by the early-ripening Monarch variety, the mid-early Aratta variety and the mid-ripening Svyatogor variety. A strong and very strong relationship between the yield index and soybean grain yield was established.

Varietal characteristics and crop density significantly affected the yield of soybean grain. When growing early ripening varieties, it was 3.42 t/ha, medium-early varieties – 5.13 t/ha, and medium-ripening varieties – 5.71 t/ha, i.e. with an increase in the length of the growing season, the yield increased. The Monarch variety had a significant yield advantage in the group of early maturing varieties. There was no difference in yield data between varieties within the mid-early and mid-season groups, it was insignificant. As an exception, it should be noted the cultivation of the mid-season variety Svyatogor at a plant density of 900 thousand/ha, when it had a significant advantage over the variety Danaya. The optimal plant density for soybean varieties of each maturity group was determined: 900 thousand/ha for early maturing, 700 thousand/ha for medium early and 500 thousand/ha for medium maturing varieties.

Soybean varieties with a longer vegetation period formed grain with a higher protein content: early maturing varieties – 40.2%, medium early varieties – 40.7%, medium maturing varieties – 41.2%. No significant difference was found between varieties within the same maturity group for this quality indicator. However, it was determined by the conditional protein yield per hectare of crops. In the group of early ripening varieties, the Monarch variety provided a higher conditional protein yield, in the group of medium early varieties – Aratta, and in the group of medium ripening varieties – Svyatogor. A very strong correlation was found between grain yield and protein content. With the increase in the length of the growing season, the fat content in soybean grain increased: early maturing varieties – 18.3%, medium early varieties – 18.5%, and mid-season varieties – 19.1%. A higher percentage of oil content and conditional fat yield per hectare of crops was found when growing the early-ripening variety Monarch and the medium-early variety Aratta. No difference in these indicators was found in the varieties of the mid-season group. A strong correlation was found between soybean grain yield and fat content, and a very strong correlation between protein and fat content in the grain. A promising area of research is to determine the influence of plant variety and plant density on a wider range of soybean grain quality indicators, considering the versatility of this crop.

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CONFLICT OF INTEREST

None.

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Продуктивність сортів сої різних груп стиглості залежно від густоти стояння рослин в умовах краплинного зрошення півдня України

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Анотація. Соя є провідною зернобобовою культурою універсального призначення, тому заходи, спрямовані на підвищення її продуктивності, зокрема обґрунтований добір сортових ресурсів та оптимізація щільності посівів, дозволять зробити значний внесок у створення стійких систем виробництва продуктів харчування. Метою дослідження було встановити вплив густоти стояння рослин на продуктивність сортів сої різних груп стиглості. У ході роботи використано польові лабораторні та статистичні (кореляційно-регресійний аналіз) методи. Польові досліди проводили впродовж 2018-2020 рр. на темно-каштановому ґрунті приватного сільськогосподарського підприємства агрофірми «Сиваш» Новотроїцького району Херсонської області. Максимальні його значення за вирощування скоростиглих сортів забезпечила густота стояння рослин 700 тис./га, середньоранніх – 500-700 тис./га, середньостиглих – 500 тис./га. Встановлено сильний і дуже сильний кореляційні зв'язки між урожайністю та індексом урожайності сої. Збільшення тривалості вегетаційного періоду сприяло зростанню врожайності. У групі скоростиглих сортів сої більш урожайним визначено сорт Монарх. Суттєвої різниці за рівнем урожайності сортів в межах інших груп стиглості не визначено. Для кожного сорту встановлено оптимальну щільність посівів, за якої формується максимальний рівень урожайності зерна. Триваліша вегетація сприяла більшому накопиченню протеїну та жиру в зерні. За вмістом протеїну різниця між сортами однієї групи стиглості не перевищувала 0,2 %, проте сорти різнились за умовним виходом протеїну з гектару посівів. Різниці за вмістом жиру в зерні середньостиглих сортів сої не встановлено. Із скоростиглих сортів вищою олійністю вирізнявся сорт Монарх, із середньоранніх – сорт Аратта. За вирощування цих сортів визначено і максимальний умовний вихід жиру з гектару посівів. Між урожайністю зерна сої та вмістом у ньому протеїну і жиру встановлено відповідно дуже сильний і сильний кореляційний зв'язок. Дуже сильну кореляцію визначено також між вмістом у зерні протеїну та жиру. Для забезпечення сталого виробництва та ефективного використання сої та продуктів її переробки доцільно одержані результати дослідження враховувати у виробничих умовах

Ключові слова: щільність посівів; урожайність; якість зерна; протеїн; жир