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DETERMINATION OF THE OPTIMAL AREAS FOR MEDICINAL AND AROMATIC PLANTS CULTIVATION IN UKRAINE DEPENDING ON WATER AND HEAT SUPPLY

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Medicinal and aromatic plants are increasing in importance each year. More and more people prefer natural medicines, manufactured using raw materials from the mentioned above plants, over synthetic drugs. Therefore, the demand for medicinal and aromatic plants on the global market is always stable and high. Ukraine, as an agricultural country with favourable soil and climate conditions, has great prospects to enter the global market for medicinal and aromatic plants. The lack of scientific knowledge about the crops' cultivation technologies and little scientific support regarding this subject restrains the development of this branch of agrarian sector. This study is devoted to the important and relevant issue of classification of medicinal and aromatic plants, which are common in Ukraine, according to the characteristics of their water and heat supply requirements, with a further geographical allocation of the plants within the territory of Ukraine according to the distribution of natural water and heat supply and their correspondence to the biological traits of the plants. The classification of the territory of Ukraine by water supply was conducted by the indices of soil moisture regime and aridity index, while the classification of the country's territory by heat supply was performed using average temperatures of July and January as the hottest and the coldest months, respectively. The classification of the medicinal and aromatic plants by their biological traits was conducted through the generalization of current scientific knowledge about the mentioned crops. As a result of classification work, the territory of Ukraine was sub-divided into the areas, which are the most suitable for cultivation of concrete medicinal and aromatic plants considering the biological requirements of the latter. Further, crop mapping was performed for visualization of the study results. The maps, created as a result of the study, have no analogues in Ukraine and are of great importance for reasonable allocation of the main production centres for each group of the studied plants. The study has both practical and scientific importance and will benefit to the development of medicinal and aromatic plants cultivation in Ukraine.

Key words: *aridity, biological traits, classification of the territory, crop mapping, ecological zoning.*

Вожегова Р.А., Ливид П.В., Лавренко С.О. Встановлення оптимальних зон для вирощування лікарських і ефіроолійних культур в Україні залежно від забезпечення вологою і теплом

З кожним роком все більшого значення набувають лікарські та ароматичні рослини. Все більше людей віддають перевагу натуральним лікам, виготовленим із сировини вищезгаданих рослин, а не синтетичним препаратам. Тому попит на лікарські та ароматичні рослини на світовому ринку завжди стабільний і високий. Україна, як аграрна країна зі сприятливими ґрунтово-кліматичними умовами, має великі перспективи

виходу на світовий ринок лікарських і ароматичних рослин. Відсутність наукових знань про технології вирощування цих культур та слабке наукове забезпечення цього питання стримує розвиток цієї галузі аграрного сектора. Дане дослідження присвячене важливому та актуальному питанню класифікації лікарських і ароматичних рослин, поширених в Україні, за особливостями їх потреб у воді та теплозабезпеченні з подальшим географічним розміщенням рослин на території України відповідно до розподілу природного водо- і теплозабезпечення та їх відповідності біологічним особливостям рослин. Класифікацію території України за вологозабезпеченістю проводили за індексами режиму вологості ґрунту та індексом аридності, а за теплозабезпеченістю – за середніми температурами липня та січня як найтепліших та найхолодніших місяців, відповідно. Шляхом узагальнення сучасних наукових знань про зазначені культури проведено класифікацію лікарських і ароматичних рослин за їх біологічними ознаками. У результаті класифікаційної роботи територію України було поділено на райони, які є найбільш придатними для вирощування конкретних лікарських і ароматичних рослин з урахуванням біологічних потреб останніх. Далі було виконано картографування посівів для візуалізації результатів дослідження. Карти, створені в результаті дослідження, не мають аналогів в Україні і мають велике значення для обґрунтованого виділення основних центрів виробництва для кожної групи досліджуваних рослин. Дослідження має як практичне, так і наукове значення та буде корисним для розвитку вирощування лікарських і ароматичних рослин в Україні.

Ключові слова: *посушливість, біологічні особливості, класифікація територій, картування культур, екологічні.*

Problem statement. In recent decades, global market of herbal medicine has drastically increased. According to the data of Food and Agriculture Organisation (FAO), at the end of the last century, it reached up to 100 billion US dollars. This is mainly due to the transfer of people to natural remedies if possible. The global population is reluctant to use synthetic drugs if there is an herbal alternative. According to the World Health Organization (WHO), 80% of the population in underdeveloped nations and 60% of the global population both rely nearly exclusively on herbal medicine for their basic medical needs. Therefore, the demand for medicinal and aromatic plants is growing each year and the annual growth rate, claimed by the WHO, is approximately 15% [1, 2].

Analysis of recent research. Current phytomedicine uses about 21,000 species of different plants to cure a wide variety of chronic and acute diseases and pathological conditions [3]. Scientific herbal medicine uses the remedies that are produced using just about 180 species of medicinal and aromatic plants, which have been proven to contain active substances with positive action on certain pathological processes and agents. According to recent studies, the demand for high-quality raw material, used to prepare herbal drugs, on the global market is stable. The volume of medicinal and aromatic plants global market is assessed to be about 600,000 tons annually, with the greatest share of the United States and developed European countries, such as Germany, France, Italy, Great Britain, Switzerland, Sweden, etc. [1]. As the global market for herbal remedies grows, the share of raw materials, obtained from cultivated, not wild-life, medicinal plants increase [4]. Thus, the cultivation of medicinal and aromatic plants is of increasing importance for both current agriculture and pharmacology. Furthermore, its profitability is high, making this field of crop production attractive for farmers and stakeholders [1, 5].

Task setting. As Ukraine has great potential in medicinal plants production owing to favourable soil and climatic conditions, the issue of scientific basis for these crops' cultivation is relevant. Currently, there is a great gap in scientific and theoretical knowledge on the cultivation of medicinal and aromatic plants [6]. Domestic scientific research on the subject is limited, and even basic questions remain unresolved. Among them, there

is a problem of ecological allocation of different plant species by the territory of the country to provide the highest productivity at the expense of the most comprehensive use of natural resources, which are available in Ukraine. Our study is devoted to solving the question of the optimal zoning of the Ukrainian territory for the cultivation of medicinal and aromatic plants considering the current state of natural water and heat supply in the country. In addition to classification, crop mapping is performed for a better visual presentation of the classification results.

Presentation of the material of research. The classification of common medicinal and aromatic plants, which are already cultivated or could be introduced into agriculture in Ukraine, was developed using the characteristics of the requirements of plants for the supply of heat and water. The basis for the classification is scientific publications by domestic and foreign authors, who studied and fixed the biological features of medicinal and aromatic plants, as well as the State Register of plant varieties suitable for dissemination in Ukraine in 2023 (dated April 2023) (Ministry of Agrarian Policy and Food of Ukraine, 2023). To sum up, the studies by Kustova (2013), Ivashchenko et al. (2014), Andabjadid et al. (2015), Shevchenko et al. (2017), Padalko (2018), Hajj et al. (2019), Khomina & Zelinska (2019), Shevchenko et al. (2019), Ushkarenko et al. (2020) were analysed and generalised in the form of classification tables for water supply requirements (Table 1) and heat (Table 2) supply requirements [7–15]. In total, 36 medicinal and aromatic plants were classified.

Table 1

Classification of medicinal and aromatic plants by their requirements to water supply

Requirements of the plants to water supply	Plants names in Latin	Colour scheme for mapping
Low and low-intermediate	*Antennaria dioica, Helichrysum arenarium, Salvia* spp., *Hyssopus officinalis, Potentilla recta, Lavandula angustifolia, Artemisia dracunculus, Crocus sativus, Silybum marianum, Coriandrum, Leonurus cardiaca*	
Intermediate	*Centaurea cyanus, Cichorium intybus, Convallaria majalis, Asarum europaeum, Pulmonaria obscura, Carex brevicollis, Thymus serpyllum, Malva excisa, Agrimonia eupatoria, Alchemilla micans, Carum carvi, Echinácea purpúrea, Chamomilla recutita, Stevia rebaudiana, Anisum vulgare, Hyoscyamus niger, Valeriana officinalis, Leuzea carthamoides*	
Upper-intermediate and high	*Acorus calamus, Symphytum officinale, Galium verum, Argentina anserina, Argentina anserina, Althaea officinalis, Mentha piperita*	

The classification of the territory of Ukraine by natural water supply was taken from the studies by Lykhovyd [16, 17], where the zoning was performed using the aridity index and the soil moisture regime, and the mapping of the territory of Ukraine is presented as in Figure 1 (for aridity index) and Figure 2 (for irrigation requirements based on the combined aridity index and soil moisture regime.

Table 2

Classification of medicinal and aromatic plants by their requirements to heat supply*

Requirements of the plants to heat supply	Plants names in Latin	Colour scheme for mapping
Low and low-intermediate	*Carum carvi, Coriandrum, Anisum vulgare, Mentha piperita, Artemisia dracunculus, Asarum europaeum, Carex brevicollis, Thymus serpyllum*	
Intermediate	*Lavandula angustifolia, Hyoscyamus niger, Valeriana officinalis, Leuzea carthamoides, Hyssopus officinalis, Leonurus cardiaca, Chamomilla recutita, Silybum marianum, Stevia rebaudiana*	
Upper-intermediate and high	*Salvias pp*, *Crocus sativus*	

*Note: * – as the number of scientific studies for heat requirements of the medicinal and aromatic plants is limited, not all the crops, enrolled in the water requirements classification, are presented here.*

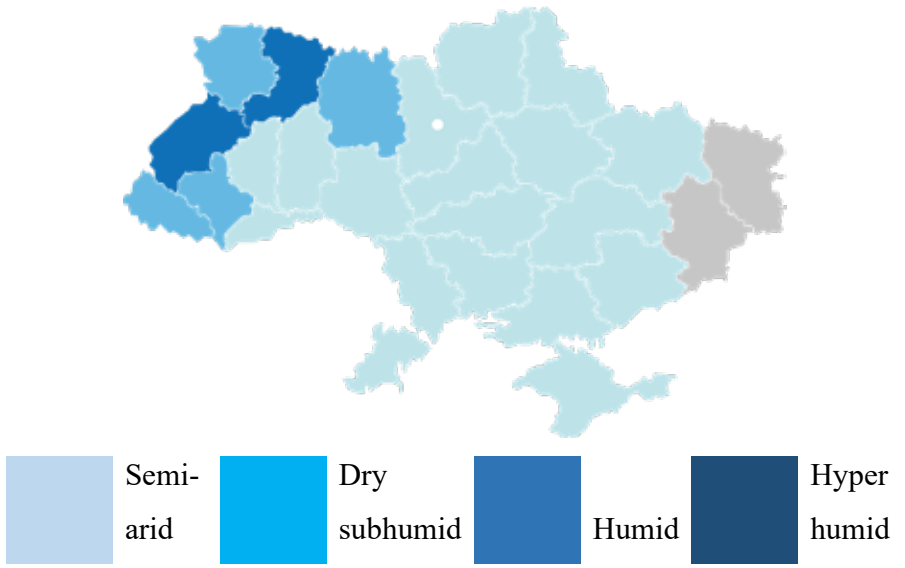

Fig. 1. Aridity index in Ukraine for the period 2010–2020

The classification of the territory of Ukraine by natural heat supply was created using the data in the Figures 3 and 4, provided by Kukharuk [18], by the principle, described in the Table 3, mainly focusing on the average monthly temperatures during the hottest (July) and the coldest (January) months.

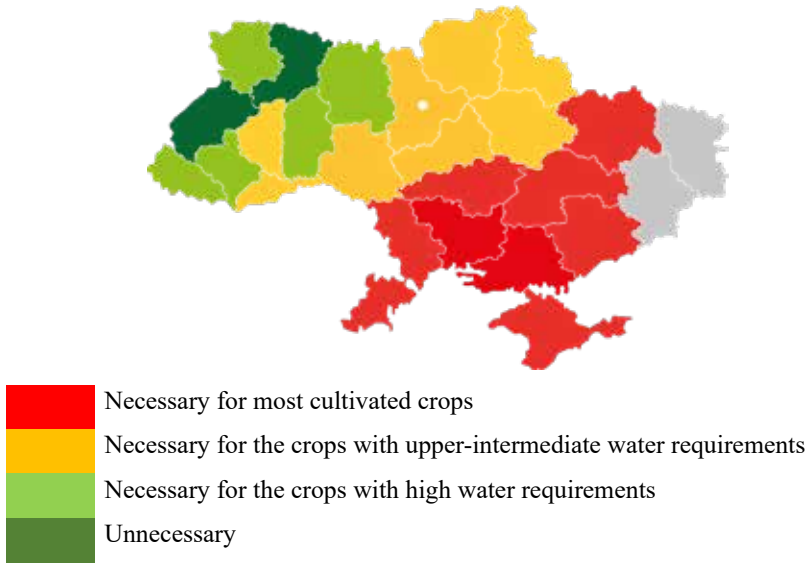

Fig. 2. Irrigation needs in Ukraine for the period 2010–2020

Fig. 3. Distribution of average July temperatures by the territory of Ukraine as for 2020

Fig. 4. Distribution of average January temperatures by the territory of Ukraine as for 2020

Table 3

Classification of the territory of Ukraine based on the heat supply in the coldest winter month (January) and the hottest summer month (July)

Average July temperature	Average January temperature	Class of heat supply	Colour scheme	Suitable for the plants with heat demands
23+	+1…-3	Very high		Upper-intermediate and high
23+	-3…-6	High		Upper-intermediate and high
23+	-6+	Moderate		Intermediate
20+	-3…-6	Moderate		Intermediate
20+	-6+	Low		Low and low-intermediate
17+	-3…-6	Low		Low and low-intermediate
17+	-6+	Very low		Low and low-intermediate

As a result of the classification, the map of the territory of Ukraine, sub-divided into the heat supply zones, was created (Figure 5).

Fig. 5. Heat supply zones of Ukraine as for 2020

The maps, presented in Figures 1, 2, and 5, were used in the medicinal and aromatic crop mapping, considering the requirements of the crops, classified in Tables 1 and 2. The creation of the figures presented in the study was conducted using Adobe Illustrator software. The requirements of the studied crops were compared to the water and heat supplies of each region of Ukraine and then mapped with the corresponding colour scheme to provide geographical information about the optimal allocation of different medicinal and aromatic plants.

As a result of the study, the zoning of Ukraine for the cultivation of the studied medicinal and aromatic plants in rainfed conditions was developed on the principle of satisfying their water requirements (Figure 6). It is obvious that the southern and south-eastern regions of the country are optimal for the cultivation of medicinal and aromatic plants with low water requirements, as these regions lack natural humidification. The central and northern parts of the country can satisfy the demands for water of most medicinal and aromatic plants, while the most demanding crops could be cultivated without irrigation in the western regions only.

The zoning of Ukraine for the cultivation of the studied medicinal and aromatic plants according to the principle of satisfying their heat requirements was also performed to look deeply into the prospects of each region of the country in the field of the crops production. The most heat-demanding crops, like Salvia species and Crocus sativus, could be cultivated in the open field conditions in all the southern regions and partly in the eastern regions of the country. Central regions of Ukraine are favourable for the cultivation of crops with intermediately demanding heat supply requirements, while most Western regions (excluding Zakarpattia), Northern, and North-Eastern regions are favourable for the plants with low and low-intermediate heat requirements only (Figure 7).

Fig. 6. Zoning of Ukraine for the cultivation of the studied medicinal and aromatic plants in the rainfed conditions by the principle of satisfying their water requirements

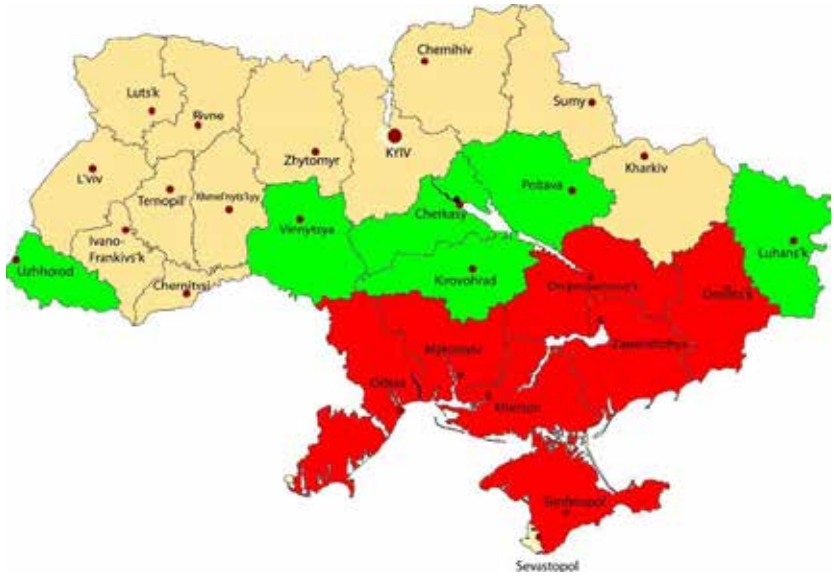

Fig. 7. Zoning of Ukraine for the cultivation of the studied medicinal and aromatic plants by the principle of satisfying their heat requirements

The classification and allocation of the prospective medicinal and aromatic plants by the territory of Ukraine, which is presented in current study, is the first one to be conducted for Ukraine. This classification and crop maps have no analogues in Ukraine. However, it must be admitted that somewhat similar approaches to the classification

of the territory of Ukraine for its suitability for different crop cultivation were taken by other researchers. For example, the study by Dobriak et al. [19] proposes the classification of the territory of Ukraine for major crop cultivation suitability based on the fertility and ecological properties of the soils. And the work by Dobriak et al. (2009) and Dobriak & Nedashkivska (2013) provides agroecological principles and methodology for zoning the arable lands of Ukraine for crop cultivation, as well as insights on the importance of scientifically sound and relevant land classification to avoid negative environmental loads connected with agricultural activity and guarantee the highest possible productivity of Ukrainian agricultural land [20, 21]. We believe that our results are complementary to the mentioned above studies, as the territory classification for medicinal and aromatic crops was not put into light by the quoted authors, and the issue of water and heat resource supply in the classification was studied from other points of view [22]. Besides, no crop mapping was conducted either. Therefore, the results of current research are of great importance for the sustainable development of crop production in Ukraine, especially in terms of providing for the successful entrance of the country into the global market for medicinal and aromatic plants.

Conclusions and proposals. The results of the study provide an insight on zoning of the territory of Ukraine for the cultivation of some medicinal and aromatic plants. The classification of the medicinal and aromatic plants by their requirements for water and heat supply eases cultivation technology practices adoption and development, while the maps of the crops' prospective areas, presented in the paper, have no analogues in Ukraine, and are of great importance for reasonable allocation of main production centres for each group of the studied crops, thus enhancing the productivity of the branch. Therefore, the study has both practical and scientific importance, and will favour the development of medicinal and aromatic plants cultivation branch of the agricultural sector of Ukraine.

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