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RESEARCH OF VALUABLE ECONOMIC INDICATORS IN SOME SPECIES OF ESSENTIAL OIL PLANTS FOR BUILDING PRODUCTIVITY MODELS

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Problem statement. There is a growing public interest in plant-based products for pharmaceuticals, perfumery, cosmetics, and dietary supplements. Essential oil plants play a key role in providing these industries with biologically active substances, and their processed products are strategically important commodities in global trade. Due to the high market value of certain types of essential oils, the production of these goods ensures significant export potential and high profitability for agricultural production. Essential oil-bearing crops are economically beneficial for farmers as niche crops, particularly on lands where other crops may be less productive due to climate change and soil conditions [1, 2].

With the continuing trend of rising temperatures, it is not only the south of Ukraine that may be promising for their cultivation [2]. Ukraine's natural and climatic conditions allow for the cultivation of a wide range of agricultural crops; however, Ukrainian farmers are predominantly focused on the production of traditional crops [3]. Naturally, niche crops will not be able to replace traditional oilseeds or cereals, but the gradual expansion of their production will allow for the diversification of income sources for small businesses. The adoption of innovative technologies for growing essential oil plants contributes to the increased competitiveness of small and medium-sized agribusinesses. At the same time, the integration of niche crops into the structure of sown areas serves as an effective tool for optimizing crop rotations. This helps to mitigate the negative consequences of soil degradation and depletion caused by the excessive concentration of tradiional agricultural crops in the crop rotation [1].

Among promising niche crops are annual essential oil plants such as moldavian dragonhead (*Dracocephalum moldavica* L.) and summer savory (*Satureja hortensis* L.). The herb and essential oil of these species are widely used in various sectors of the national economy.

Analysis of recent research and publications. South Siberia and China are considered the homeland of Dracocephalum moldavica, although it grows in the wild in the countries of Central Asia and Eastern Europe. This plant is cultivated in Europe and Asia as an essential oil-bearing crop and a valuable honey plant [4, 5]. The homeland of Satureja hortensis is the eastern regions of the Mediterranean and the Black Sea. It is widespread in the countries of Western and Eastern Europe, North America, Canada, as well as in small areas in Uzbekistan, Turkmenistan, and Moldova [6].

Biochemical characteristics and utilization of moldavian dragonhead and summer savory. Essential oil, flavonoids, phenols, phenylpropanoids, lignans, terpenoids, vitamins, lipids, proteins, sugars, tannins, macro- and microelements, and other chemical components have been identified in the plant raw materials of moldavian dragonhead [5]. Plants of this species possess high antioxidant and antimicrobial effects [7]. The aerial part of moldavian dragonhead is used for medicinal purposes in folk medicine as an anti-inflammatory and sedative agent, and as a seasoning in the food industry [8]. It has been found that *D. moldavica* extracts act as an effective and biologically safe insect repellent [9]. The essential oil of *Dracocephalum moldavica* is used in the food industry, pharmaceuticals, perfumery, and cosmetology [10].

Satureja hortensis has been used as a spice since ancient times. The dried aerial parts of the plant are added to commercial spice blends for many food products to provide a pleasant aroma and flavor [11, 12]. The composition of the aerial mass of summer savory is dominated by essential oil, polyphenols, and flavonoids, and natural products supplemented with the plant possess medicinal properties [11, 12, 13]. *Satureja hortensis* is used as a folk remedy for treating various diseases [12-15]. The leaves and stems of summer savory are used as animal feed [14]. The essential oil obtained from summer savory plants can be used in the perfumery and cosmetics industry [11].

The impact of agrotechnical measures on development and economically valuable traits. Due to climate change trends toward global warming and atypical lack of precipitation, a decline in biological and valuable economic indicators of agricultural plants is observed [16]. Consequently, the need for artificial irrigation arises even in regions where it was previously provided exclusively by natural means. At the same time, excess moisture is also hazardous. Everything depends on the biological characteristics of the plant species and the soil and climatic conditions of the region where they are grown.

One of the problems of plant adaptation to local agroclimatic conditions is establishing the optimal level of heat and moisture [17].

Moldavian dragonhead and summer savory are annual herbaceous plants of the *Lamiaceae Martynov* family (Fig. 1). The root system of the plants is thin and tap-rooted, located primarily in the upper soil horizon. The stem is erect, tetrahedral, and branched. Both species have essential oil glands located on the leaves and flowers [4, 6, 18].

Moldavian dragonhead and summer savory reproduce by sowing seeds directly into the soil. Researchers working with moldavian dragonhead assert that this species is resistant to low temperatures and is moisture-loving [4]. Studies on the biological characteristics of summer savory have established that this species belongs to the thermophilic group of plants. Although it is capable of withstanding short-term temperature drops, even minor frosts lead to its destruction [2, 6].

Through studies of the ecological and biological characteristics of summer savory introduced under the conditions of the Polissya region, Ukrainian researchers assert that this species is well-adapted and promising for the agricultural sector in this region. Under introduction via seed reproduction, summer savory plants developed normally, flowered, and bore fruit, proving to be drought-resistant [19].

According to scientific research, the height of moldavian dragonhead and its aerial mass are significantly influenced by climate and agrotechnical measures during cultivation [20]. Under the conditions of the Kherson region, the plant height of moldavian dragonhead during the mass flowering phase ranges from 75.8 to 85.6 cm. The yield of floral raw materials varies from 1783 to 2093 g/m² [21].

According to the results of studies conducted in Turkey, climatic factors also have a significant impact on the yield and biochemical parameters of summer savory [22]. The influence of agrotechnical measures, including sowing dates and irrigation, on the essential oil content in plants has been confirmed by research in the Southern Steppe conditions, where the height of summer savory plants in the mass flowering phase ranges from 27.9 to 51.2 cm. The yield of floral raw materials varies from 2.2 to 7.7 t/ha. The mass fraction of essential oil ranges from 0.4 to 0.9% [6].

Research objective. To conduct preliminary research on the economically valuable traits of moldavian dragonhead and summer savory under the conditions of the Central Forest-Steppe and compare them with literature data.

Research results. Seeds of moldavian dragonhead and summer savory, sown under the conditions of the Central Forest-Steppe of Ukraine with a row spacing of 60 cm at three sowing dates (the second and third ten-day periods of April and the first ten-day period of May), produced full seedlings. Within the sowing periods, the onset of the initial development phases (emergence and tillering) in moldavian dragonhead and summer savory under intensive irrigation (80% of field capacity), moderate irrigation (60% of field capacity), and natural moisture conditions was recorded at nearly the same time, which was facilitated by the weather conditions in spring and early summer. In general, the duration of vegetation in both plant species depended on the sowing date and moisture regimes. Within the same sowing date, the vegetation period under irrigation was longer than under natural moisture. At later sowing dates, the vegetation period decreased [2]. The studies are consistent with data obtained by scientists under the conditions of Polissia, who state that there is a high correlation between the duration of development phases of moldavian dragonhead and temperature, and a somewhat weaker correlation with moisture [4, 18].

Biometric measurements of moldavian dragonhead and summer savory showed that under different moisture regimes, plants at the early stages of development (emergence and tillering) differ little in height and diameter. Active plant growth in height in both species is observed during the tillering, budding, and early flowering stages. At the stage of mass flowering, growth rates decrease and terminal growth of plants virtually ceases [23]. However, in summer savory, plants of the first and second sowing dates under intensive irrigation continue to show a slight increase in height. This occurs due to the elongation of shoots at the top of the plants. The plants become less compact.

A ***B***

Fig. 1. Annual aromatic plants at the stage of mass flowering: a – moldavian dragonhead, b – summer savory (author's photo)

Within a single sowing date, the highest height values in both species were recorded in plants under intensive irrigation; slightly lower values (by only 1–2 cm) were observed in plants under moderate irrigation, and significantly lower values were found under natural moisture conditions [2].

Comparing plant height across all sowing dates, it was established that in moldavian dragonhead the maximum height was observed in plants of the first sowing date under intensive irrigation, ranging from 65 to 93 cm, while the minimum was recorded in plants of the third sowing date under natural moisture conditions, averaging 68 cm. Considering all sowing dates in summer savory, the highest values were observed in plants of the second sowing date under intensive irrigation, averaging 55 cm, while the lowest were recorded in plants of the third sowing date under natural moisture conditions, averaging 39 cm.

According to the literature, the economically valuable traits of moldavian dragonhead and summer savory include the yield of aboveground biomass and the essential oil content in it [24].

During growth and development, plants of both species form aboveground biomass that gradually increases across developmental stages, reaching a maximum at the flowering stage and decreasing at the fruiting stage due to lignification of shoots and a reduction in leaf moisture, which is characteristic of this phase.

It was established that within a given sowing date, plants of moldavian dragonhead and summer savory exhibited the highest aboveground biomass under intensive irrigation, somewhat lower under moderate irrigation, and the lowest under natural moisture conditions. The maximum aboveground biomass in moldavian dragonhead was recorded in plants of the first sowing date under intensive irrigation (from 240 g per plant at the beginning of flowering to 525 g at the stage of mass flowering), while the lowest values were observed in plants of the third sowing date under natural moisture conditions (from 105 g per plant at the beginning of flowering to 258 g at the stage of mass flowering).

In summer savory, the highest aboveground biomass values were observed in plants of the second sowing date under intensive irrigation (from 167 g per plant at the beginning of flowering to 232 g at the end of flowering), while the lowest were recorded in plants of the third sowing date under natural moisture conditions (from 36 g per plant at the beginning of flowering to 86 g at the end of flowering).

Determination of essential oil content in moldavian dragonhead and summer savory at different developmental stages showed that the mass fraction of essential oil in plant material gradually increases, reaching a maximum in the middle of the mass flowering stage. At the end of flowering – the beginning of fruiting, this indicator slightly decreases. A similar pattern was established by scientists studying the essential oil content of moldavian dragonhead under the conditions of the Southern Steppe: during plant development, the mass fraction of essential oil increases from the vegetative growth stage (0.05%) and reaches a maximum during full flowering (0.17%), while the end of flowering is accompanied by a decrease to 0.13% [21].

Under the conditions of the Central Forest-Steppe, within the analyzed sowing dates, the maximum essential oil content was recorded in plants receiving natural moisture, while the minimum values were observed in plants under intensive irrigation. The mass fraction of essential oil in moldavian dragonhead plants throughout the entire flowering phase ranged from 0.02% to 0.15% of the fresh weight. The maximum indicators of essential oil mass fraction in moldavian dragonhead were noted in the natural moisture variants, which were practically identical for the first and second sowing dates (0.14% and 0.15% of the fresh weight). High essential oil biosynthesis under insufficient moisture conditions can be explained as a plant defense mechanism against drought. However, the highest essential oil yield per plant was recorded in plants from the second sowing date under moderate irrigation (0.50 g per plant during the mass flowering phase). Slightly lower indicators were obtained from plants of the third sowing date under intensive irrigation (0.47 g per plant during the mass flowering phase).

The essential oil content in summer savory throughout the entire flowering phase ranges from 0.21% to 0.50% of the fresh weight. Comparing the mass fraction indicators of essential oil across all sowing dates for summer savory, the maximum values were recorded in plants from the second sowing date under natural moisture conditions (0.50% of the fresh weight during the mass flowering phase), while the minimum values were observed in plants from the first and third sowing dates under intensive irrigation (0.25% of the fresh weight during the mass flowering phase). The essential oil yield per summer savory plant during the mass flowering period ranged from 0.40 to 0.78 g. The maximum indicators were recorded in plants from the second sowing date under moderate irrigation (0.78 g per plant), and the minimum in plants from the third sowing date under natural moisture conditions (0.38 g per plant).

The low productivity indicators of plants for both studied species in the natural moisture variant are explained by the lowest aerial mass indicators; however, the application of intensive irrigation leads to a decrease in the mass fraction of essential oil in the plant raw material. Sowing dates have an equally significant impact on the productivity of both plant species, as essential oil biosynthesis also depends on the temperature regime. The data obtained under the conditions of the Central Forest-Steppe are partially consistent with data obtained in other regions [18, 21, 25].

Findings. Thus, moldavian dragonhead and summer savory are valuable essential oil plants that can be successfully cultivated in various climatic zones of Ukraine. The yield and essential oil output of the studied species are significantly influenced by sowing dates, the availability of irrigation, and the biological characteristics of the crop. It was established that during the initial stages of development in both moldavian dragonhead and summer savory, the onset of early phenological phases and biometric indicators are practically identical across all moisture variants within the same sowing dates. However, at later stages of development, when precipitation is absent and plants require moisture, a clear trend is observed in both species: within a given sowing date, plants receiving irrigation show superior height and aerial mass indicators, while the minimum values are found in plants receiving natural moisture.

Conversely, the mass fraction of essential oil is maximal in both species under natural moisture conditions. Ultimately, the essential oil yield per plant is maximal in plants from the intermediate sowing date under moderate irrigation. The results obtained can be utilized to construct plant productivity models.

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Svydenko A.V., Stepanova M.M. Research of valuable economic indicators in some species of essential oil plants for building productivity models

Purpose. To conduct preliminary studies of valuable economic indicators of the moldavian dragonhead and summer savory in the conditions of the Central Forest-Steppe and compare them with literature data. **Results.** Moldavian dragonhead (*Dracocephalum moldavica L.*) and summer savory (*Satureja hortensis L.*) are promising essential oil crops. Scientists in different regions of Ukraine and abroad have been studying the biological features and economically valuable indicators of these crops. According to literature data, agrotechnical measures affect crop yield, essential oil content and plant productivity. In the conditions of the Central Forest-Steppe, the yield and mass fraction of essential oil in *Dracocephalum moldavica* and *Satureja hortensis* depended on both the sowing dates and the level of moisture within one term. Plants that received intensive irrigation had the highest yield but lower essential oil content. The maximum mass fraction of essential oil in plant raw materials in *Dracocephalum moldavica* was obtained in the variants of natural moisture in the first and second sowing dates (0.15 and 0.14% of freshly harvested raw materials, respectively), and in *Satureja hortensis* – in the second sowing date in the variant of natural moisture (0.50%). The highest yield of essential oil from one plant in *Dracocephalum moldavica* and *Satureja hortensis* was recorded in plants of the second sowing date in the variant of moderate irrigation (0.50 g and 0.78 g, respectively). **Conclusion.** The yield and mass fraction of essential oil in moldavian dragonhead and summer savory depend on both the sowing dates and the level of moisture within one term. Irrigation has a positive effect on plant yield. The highest yield of essential oil from one plant in both species was recorded in plants of the second sowing date in the moderate irrigation variant. The data obtained in the conditions of the Central Forest-Steppe partially agree with the data obtained in other regions and can be used to build productivity models of the studied crops.

Key words: Dracocephalum moldavica, Satureja hortensis, irrigation, sowing dates, yield, essential oil.

Свиденко А.В., Степанова М.М. Дослідження цінних господарських показників у деяких видів ефіроолійних рослин для побудови моделей продуктивності

Мета. Провести попередні дослідження цінних господарських показників у змієголовника молдавського та чабера садового в умовах Центрального Лісостепу та порівняти їх з літературними даними. **Результати.** Змієголовник молдавський (*Dracocephalum moldavica* L.) та чабер садовий (*Satureja hortensis* L.) – перспективні ефіроолійні культури. Вивченням біологічних особливостей та господарсько-цінних показників цих культур займались вчені в різних регіонах України так і за її межами. Згідно літературних даних на урожайність, вміст ефірної олії та продуктивність рослин впливають агротехнічні заходи. В умовах Центрального Лісостепу урожайність та масова частка ефірної олії у *Dracocephalum moldavica і Satureja hortensis* залежали як від строків сівби так і від рівня зволоження в межах одного строку. Рослини, які отримували інтенсивне зрошення мали найвищу урожайність але нижчі показники вмісту ефірної олії. Максимальні показники масової частки ефірної олії в рослинній сировині у *Dracocephalum moldavica* отримано у варіантах природного зволоження за першого та другого строків сівби (0,15 і 0,14% від свіжозібраної сировини, відповідно), а у *Satureja hortensis* – за другого строку сівби у варіанті природного зволоження (0,50%). Найбільший вихід ефірної олії з однієї рослини у *Dracocephalum moldavica* та *Satureja hortensis* зафіксовано у рослин другого строку сівби у варіанті помірного зрошення (0,50 г та 0,78 г, відповідно). **Висновок.** Урожайність та масова частка ефірної олії у змієголовника молдавського та чабера садового залежать як від строків сівби так і від рівня зволоження в межах одного строку. Зрошення позитивно впливає на урожайність рослин. Найбільший вихід ефірної олії з однієї рослини в обох видів зафіксовано у рослин другого строку сівби у варіанті помірного зрошення. Дані, отримані в умовах Центрального Лісостепу частково узгоджуються з даними, отриманими в інших регіонах і можуть використовуватись для побудови моделей продуктивності досліджуваних культур.

Ключові слова: змієголовник молдавський, чабер садовий, зрошення, строки сівби, урожайність, ефірна олія.

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