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Introduction to Culture, Reproduction, and Productivity of Aromatic Plants of the *Lamiaceae* Family in the Central Polissia of Ukraine

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Abstract. The introduction of new types of aromatic plants of the *Lamiaceae* family into the culture is relevant for the enrichment of the biological diversity of the flora of the Central Polissia of Ukraine, as well as for the expansion of the raw material base of spicy-aromatic, medicinal, food, decorative, and honey-bearing plants. The purpose of this study is to find methods of propagation of aromatic plants, best sowing times and feeding areas, and to obtain phytoraw and seed materials. Research methods: laboratory, field, statistical. It was established that the best period for sowing plants of the *Lamiaceae* family in the conditions of the botanical garden of the Polissia National University is the third decade of April. The use of various methods of propagation proves the expediency of propagation of all annual and perennial plant species under study by seeds, and for *M. didyma*, *S. officinalis*, *L. vera*, and *O. vulgare* – also by particles, rhizomes, transplanting, and propagule. It is recommended to place *S. hortensis*, *D. moldavica*, *E. cristata*, *H. officinalis* according to the scheme of 30x45 cm, *L. vera*, *L. anisatus*, *N. transcaucasica*, *S. officinalis* – 30x50 cm, and *O. vulgare*, *S. sclarea*, *M. didyma*, – 40x50 cm. Among the annual species, the highest productive potential was found in *D. moldavica*, the above-ground mass productivity of which was 24.7±1.7 t/ha; among perennials – in *H. officinalis* (38.9±0.2 t/ha) and *L. anisatus* (44.1±0.9 t/ha). The highest yield of essential oil in terms of absolutely dry substance was found in *S. officinalis* (1.2%), *L. vera* (1.808%) and *H. angustifolius* (2.054%). The results of research on reproduction methods can be used for growing new species of aromatic plants of the *Lamiaceae* family both on homesteads and in agricultural enterprises. The most productive types of aromatic plants should be introduced into production for further use of phytoraw materials and essential oil in pharmacy, food, and other sectors of the national economy

Keywords: *Lamiaceae*, introduction, methods of reproduction, productive potential

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INTRODUCTION

Presently, special attention is paid to the issue of manufacturing medicines and food additives from vegetable raw materials. As a result of the search and introduction of rare new crops and possible areas of their cultivation, it is possible to expand the raw material base of medicinal and aromatic plants (Zharinov & Ostapenko, 1994; Rakhmetov, 2017). Plants belonging to the *Lamiaceae* family, which are new to the conditions of the Polissia of Ukraine, have a wide range of uses. It is the sixth-largest family of angiosperms (Ahmad *et al.*, 2021; Napoli *et al.*, 2020; Zhao *et al.*, 2021), which includes over 245 genera and 7,886 species, as well as many economically important species distributed in all climatic zones of the planet, with the greatest species diversity found in the Mediterranean (Fedoronchuk, 2022).

Representatives of the genera *Ajuga* L., *Lamium* L., *Dracocephalum* L., *Glechoma* L., *Mentha* L., *Salvia* L., *Thymus* L., *Galeopsis* L., *Leonurus* L., *Origanum* L., *Stachys* L., *Elsholtzia* L., *Betonica* L. are found in the natural ecosystems of the Polissia region of Ukraine; however, their industrial use is impossible due to the limited resource base. Therefore, there was a need to expand domestic production of medicinal, spicy-aromatic plants that were not previously cultivated in Ukraine.

The purpose of this study is to find the best breeding methods, sowing and harvesting periods, figure out productivity indicators of rare plants of the *Lamiaceae* family in the conditions of the Central Polissia of Ukraine. Thanks to the resolution of these issues, it is possible to enrich the phytodiversity of the region due to new species. This will expand the raw material base of medicinal and aromatic plants, increase the ecological and economic effect, and improve the health of the population.

LITERATURE REVIEW

To expand the domestic raw material base for obtaining valuable biologically active substances, some researchers propose to introduce new promising plant species from different botanical and climatic zones into the culture. Thus, T. Ivanova *et al.* (2022) reported the introduction into culture of 27 taxa of the *Lamiaceae* family in Bulgaria, L.A. Kotyuk *et al.* (2022) reported 17 taxa in Ukraine, Sharafzadeh & Zare (2011) – 10 taxa in Iran.

K. Carović-Stanko *et al.* (2019) note that spicy and aromatic crops of the *Lamiaceae* family (*Hyssopus officinalis*, *Lavandula angustifolia*, *Monarda fistulosa*, *Nepeta cataria*, *Origanum vulgare*, *Salvia officinalis*, *Salvia sclarea*, *Satureja hortensis*, etc.) are used for flavouring, preservation of food products. Dry raw materials of *Origanum vulgare* and *Satureja hortensis* plants contain vitamins, proteins, sugars, lipids, amino acids, macro- and microelements, and therefore Skendi *et al.* (2019) suggest adding it to flour when baking bread. Ukrainets & Frolova (2010) established that "obtaining natural flavours by processing essential oils synthesised by aromatic plants and their introduction into production will enable food industry enterprises to produce products that meet global quality standards."

According to R.R. Raja (2012), plants of the Lamiaceae family are described by considerable medicinal potential, and J. Michel *et al.* (2020) recommend the use of phytoraw material and essential oil of *Dracocephalum moldavica*, *Lavandula angustifolia*, *Origanum vulgare*, *Salvia officinalis*, and *Satureja cuneifolia* for the treatment of cardiovascular diseases. E. Napoli *et al.* (2020) note the radioprotective properties of *Origanum*, *Salvia*, and *Lavandula* essential oils.

M. Kozlowska *et al.* (2015) established the bactericidal properties of ethanol extracts of *Origanum vulgare*, *Salvia officinalis* against *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Proteus vulgaris* and *Listeria monocytogenes*, S.I. Dubinin *et al.* (2020) – antihelmintic properties of *Origanum vulgare*, *Hyssopus officinalis* and *Satureja hortensis plants*, and S. Bedini *et al.* (2021) – insecticidal properties.

O.S. Demianiuk *et al.* (2022) suggest the use of aromatic plants *Lavandula angustifolia*, *Origanum vulgare*, *Satureja hortensis* and *Salvia officinalis* for vertical greening of the external and internal walls of premises, and consider it necessary to popularise them.

T.M. Manushkina (2021) noted that "essential oil crops have important agroecological importance. It is advisable to grow biennial or perennial ether-bearing plants on low-productivity, stony soils, since they protect the soil from wind and water erosion, inhibit the germination of weeds, and activate soil microflora. Cultivation of essential oil crops provides an increase in biodiversity in agroecosystems, air purification from pathogenic bacteria due to the release of essential oil with antiseptic properties, aesthetic beauty in the flowering phase; they are valuable honey plants" (Manushkina, 2021).

Industrial areas of rare plants of the *Lamiaceae* family are concentrated mainly in Kherson (Ushkarenko *et al.*, 2020), Poltava (Shatkovskyi *et al.*, 2021), and Dnipropetrovsk oblasts (Baranets & Korshykov, 2020). Skybitska & Mohylyak (2013) report the successful introduction of aromatic plants of the *Lamiaceae* family in the West, and L.A. Kotyuk *et al.* (2021) – in the Polissia of Ukraine.

L.A. Kotyuk (2015, 2017) notes that reproduction by seed is an essential condition for the preservation of plant species, population growth and the ability to adapt to new living conditions, while D.B. Rakhmetov (2011) points to its advantages when introducing new types of plants into culture. The studies of Shatkovskyi *et al.* (2021) proved that when planting seedlings of the *Lamiaceae* family in open ground, watering and additional care is necessary. Therefore, they recommend that perennial species be propagated by a vegetative method, which ensures the rapid distribution of the species and the preservation of genetic traits.

MATERIALS AND METHODS

The study used sparsely distributed annual and perennial plant species: summer savory (*Satureja hortensis* L.),

vietnamese balm (*Elsholtzia cristata* Willd.), Moldavian dragonhead (*Dracocephalum moldavica* L.), lavender (*Lavandula vera* D. C.), narrow-leaved hyssop (*Hyssopus angustifolius* M. Bieb.), hyssop (*Hyssopus officinalis* L.), bee balm (*Monarda didyma* L.), oregano (*Origanum vulgare* L.), cat mint transcaucasica (*Nepeta transcaucasica* Grossh.), anise lofant (*Lophanthus anisatus* Adans), clary sage (*Salvia sclarea* L.), common sage (*Salvia officinalis* L.).

The experiment was established in the botanical garden of the Polissia National University (Zhytomyr) during 2008-2021 in an illuminated area. The soil of the experimental plots was described by the following parameters: *Ph*-saline humus horizon – 6.23±0.051, N_k – 90,543,731 mg/kg soil, K_2O – 84,03±3,859 mg/kg, P_2O_5 – 458,01±4,771 mg/kg, humus content – 2.967±0.082%.

The climate of the Central Polissia of Ukraine is moderately continental. Average long-term air temperatures above 0°C are maintained for 150 to 160 days, so the conditions for the cultivation of spicy and aromatic plants are quite favourable. Average long-term temperature of the coldest month (February): from -1 to -6°C, the warmest (July): from +18.4 to +23°C. The annual amount of precipitation was recorded both below the norm (600 mm) and above the norm: from 550 to 920 mm. The average annual relative humidity was 71-78%. The end of spring frosts was observed during the third decade of April, and the beginning of the first autumn frosts – in late September – early October.

The specific features of plant development were investigated according to the methods (DSTU 7160-2010; Methodology for examination..., 2016; Rakhmetov, 2011). The essential oil content was determined according to the Clevenger method (Raw medicinal plant..., 1988).

The study used seed material from the exchange funds of botanical gardens of Ukraine and the world. Plants were grown by sowing seeds directly into the soil or by seedling method. Sowing was performed during the last decade of April – the first decade of May.

Plants *H. officinalis*, *S. hortensis*, *D. moldavica*, *E. cristata* were placed according to scheme 45×30 cm, *S. sclarea*, *O. vulgare*, *M. didyma*, – 50×40 cm, and *L. vera*, *L. anisatus*, *N. Transcaucasica*, *S. Officinalis* – 50×30 cm, four-fold repetition. Fertilisers, pesticides, and irrigation were not used during plant cultivation. During the growing season of the plants, weeds were removed, the rows were loosened, spring pruning was carried out (*H. officinalis*, *H. angustifolius*, *S. montana*) or dead shoots of perennial plants were removed (*O. vulgare*, *L. anisatus*, *M. didyma*, *S. sclarea* and *S. aethiopis*).

RESULTS AND DISCUSSION

The introduction of new aromatic, medicinal, food, and honey-bearing plants of the *Lamiaceae* family is necessary for the enrichment of the biological diversity of the flora of the Polissia of Ukraine. The main criteria that indicate the perspective of introduction into culture are the establishment of propagation methods, optimal sowing dates and feeding areas, features of plant care during their growing season, methods of obtaining phytoraw materials and seed material.

Introductory research carried out in the Central Polissia of Ukraine used seed material from different botanical and geographical zones of the globe. According to the origin of the plant of the *Lamiacea* family, it is assigned to four genetic centres: the Mediterranean (*S. officinalis*, *H. angustifolius*, *H. officinalis*, *S. hortensis*, *L. vera*, *O. vulgare* and *S. sclarea*), to the North American (*L. anisatus* and *M. didyma*), European-Siberian (*E. cristata* and *D. moldavica*), Western Asian (*N. transcaucasica*) (Kotyuk, 2022).

Studies have established different life expectancy of spicy-aromatic plants in the conditions of the Central Polissia of Ukraine. Thus, under the study conditions, the maximum duration of the life cycle of *S. sclarea* plants was 3 years, *L. anisatus* – 6 years, *N. transcaucasica* – 9 years, *S. officinalis* – 10 years, *M. didyma* – 10 years, *L. vera*, *O. vulgare*, *H angustifolius* – 12 years, *H. officinalis*, *S. montana* – 15 years (Fig. 1).

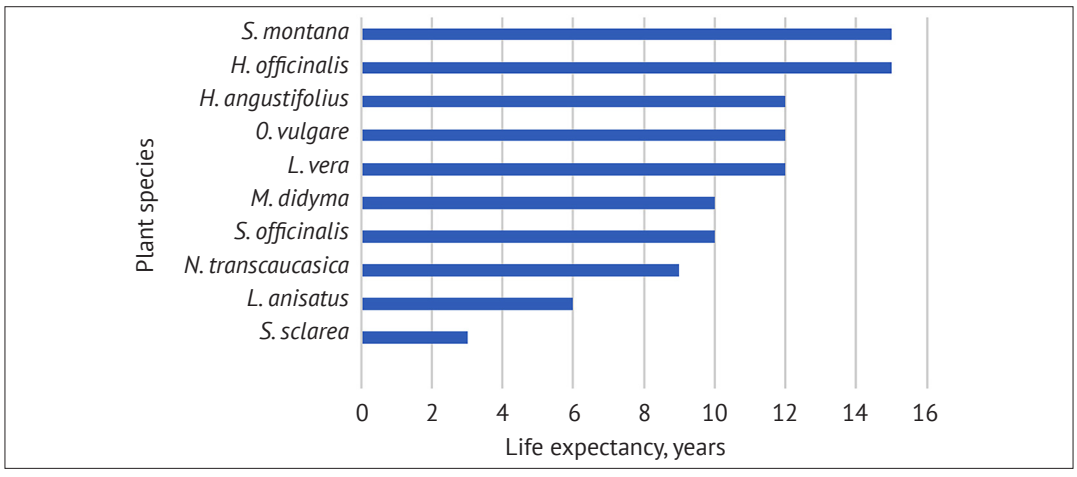

Figure 1. *Life cycle of the Lamiacea family plants under cultivation in the botanical garden of the Polissia National University (2008-2021)*

According to V.O. Ushkarenko *et al.* (2020), during the industrial cultivation of *S. sclarea* plants under drip irrigation conditions in the Southern Forest Steppe of Ukraine (Kherson Oblast), the life cycle of *S. sclarea* plants was four years. T.M. Manushkina (2021) notes that *S. sclarea* is a biennial plant in the conditions of the Mykolaiv Oblast, and a triennial plant in the conditions of the study, which, apparently, is caused by the difference in soil and climatic conditions. As for the life span of other perennial plants, there is no information in the scientific sources of the last decade.

The seed material of representatives of the *Lamiacea* family is formed in the fruits – cenobia, which are located in the calyx of the flower. The fruit develops from a cenocarpous bipartite gynoecium, which, when ruptured, forms four one-seeded fragments – erems (Novikoff & Barabasz-Krasny, 2015). In the new conditions of growth, the erems of aromatic plants matured at different times, which is conditioned upon features of the species, different duration of fruiting and acropetal order of flowering in inflorescences. When the fruits ripened in the lower semi-rings of the inflorescences, the buds in the upper ones had not yet opened. Therefore, to obtain seed material, the plants were cut during the period when most of the inflorescence was in the fruiting phase, they were maturated for 7-10 days, after which they were threshed.

Erems from the calyx of the flower can release themselves and form self-sown plants. In the conditions of the growth of aromatic plants in the botanical garden of the Polissia National University, their ability to self-renew, forming self-sown plants, was found, which is evidence of their adaptation. Observations showed that under the conditions of culture, the vast majority of plants formed self-sown plants, which overwintered or died due to the effects of negative temperatures. Annual plants *S. hortensis*, *D. moldavica*, *E. cristata* formed abundant or moderate self-sowing plants in autumn, after the fall of erems, but the seedlings died during the winter, so their sub-winter sowing is not advisable. In some places, self-sowing plants' shoots appeared in the spring, which formed viable seedlings. Abundant self-seeding and frost-resistant seedlings were formed by *H. angustifolius*, *H. officinalis*, *S. sclarea*, *L. anisatus*, *O. vulgare* and *N. transcaucasica*. *N. transcaucasica* bore fruit 2-3 times during the season and were resistant to low temperatures during the growing season. Self-seeding was not found in *S. officinalis*, *M. didyma*, *L. vera* (Table 1).

Table 1. *Characterisation of the viability of self-sowing plants of the Lamiaceae family in the conditions of the Central Polissia of Ukraine*

Evaluation criteria	Abundant	Moderate	Thinned	Missing
Species	*N. transcaucasica** *S. sclarea** *H. officinalis** *D. moldavica***	*E. cristata*** *S. hortensis***	*O. vulgare** *L. anisatus** *H. angustifolius**	*S. officinalis* *M. didyma* *L. vera*

Note: * *– self-sowing plant is resistant to negative temperatures,* ** *– unstable*
Source: *compiled by the authors*

Studies have shown that in the conditions of the Central Polissia of Ukraine, the most optimal time for sowing aromatic plants is the last decade of April. Depending on features of the species, soil moisture and temperature conditions, plant seedlings appeared after 8-20 days (*H. officinalis*, *N. transcaucasica*, *D. moldavica*, *S. sclarea*) or 14-30 days (*E. cristata*, *S. hortensis*, *L. vera*, *H. angustifolius*, *O. vulgare*, *M. didyma*). Sowing in the early spring period (the first decade of April) caused very sparse shoots and a delay in their emergence.

When sowing in the first decade of June (summer sowing), there was a delay in germination and a slowdown in plant development due to insufficient moisture supply in the soil. In this case, flowering of plants was observed during September-October; during autumn frosts, inflorescences were often damaged, so seed material was not formed.

The authors' research found that sowing for winter can be successful for *H. angustifolius*, *H. officinalis*, *N. transcaucasica*, *L. anisatus*, *S. sclarea*.

V.O. Ushkarenko *et al.* (2020) believe that under the conditions of the Kherson Oblast, the best sowing time for *S. sclarea* is in the winter, in the first decade of December. This information does not contradict the results obtained.

S. hortensis, *E. cristata*, and *D. moldavica*, whose life cycle is one year, were propagated by the seed method. The depth of seed wrapping is recommended to be 10-15 mm, after which the soil must be compacted. Seedlings of *E. cristata* and *S. hortensis* appeared in an average of 18 days, *D. moldavica* – in 12 days.

Annual species are described by a long pre-emergence period and slowed plant growth at the first stages of ontogenesis; therefore, during this period, it is necessary to remove weeds that develop more intensively. Due to the signs of xerophilic of the plants, added watering was not performed. With the beginning of the generative period, plants did not need added care.

The aerial part (shoots with leaves and inflorescences) of annual plants for the food industry and pharmacy was collected during the flowering phase (July-August) at a height of 10 to 25 cm relative to the soil surface.

The productive potential of plants is evidence of their adaptation to new living conditions. Among the aromatic plants whose life cycle ends in one year, the

highest productivity was noted in *D. moldavica*. Productivity of the aerial part of *D. moldavica* was 24.7±1.7 t/ha, seeds – 0.073±0.028 t/ha, weight of 1000 erems – 2.29±0.39 g (Table 2).

***Table 2**. Productive potential of annual and perennial plants of the Lamiaceae family in the conditions of the botanical garden of the Polissia National University*

Plant type	Year of life	Productivity, t/ha		Weight of 1000 erems, g
		Green mass	Erems	
Annual plants				
E. cristata	**I**	16.2±0.57	0.267± 0.013	0.22±0.01
S. hortensis	**I**	14.0±0.63	0.387± 0.024	0.49±0.04
D. moldavica	**I**	**24.7±1.7**	**0.733± 0.028**	**2.29±0.39**
Perennials				
S. sclarea	**I**	4.3± 0.2	–	–
	II	37.1±6.5	**0.58±0.053**	3.42±0.15
S. officinalis	**I**	0.9±0.1	–	–
	IV	26.0±1.3	0.40±0.038	**7.15±0.27**
H. officinalis	**I**	2.8± 0.2	0.06±0.008	1.17±0.03
	IV	38.9±0.2	0.54±0.052	1.08±0.13
H. angustifolius	**I**	0.72±0.07	–	–
	IV	8.91±0.11	0.27±0.02	0.57±0.02
M. didyma	**I**	1.1± 0.1	–	–
	IV	28.6±3.4	0.38±0.027	0.46±0.02
O. vulgare	**I**	0.9± 0.1	–	–
	IV	33.0±2.0	0.18±0.024	0.10±0.01
L. vera	**I**	0.7± 0.1	–	–
	IV	19.6±1.1	0.45±0.029	1.05±0.11
L. anisatus	**I**	6.8±0.2	0.03±0.006	0.42±0.03
	III	**44.1±0.9**	0.33±0.064	0.41±0.02
N. transcaucasica	**I**	0.65±0.04	0.045±0.004	0.65±0.04
	III	13.2±0.3	0.33±0.058	0.67±0.059

***Note:** "–" seed material is absent*
***Source:** compiled by the authors*

Perennial species of aromatic plants were propagated both by seeds and vegetatively. It was found that the best coverage depth for *O. vulgare* and *L. anisatus* is 10 mm, and for *H. angustifolius*, *L. vera*, *N. transcaucasica*, *H. officinalis*, *M. didyma*, *S. sclarea* and *S. officinalis* – 15 mm. Advantages of vegetative reproduction were found in *M. didyma*, *L. vera*, *S. officinalis* and *O. vulgare*.

H. officinalis plants were propagated by the seed method. At the first stages of ontogenesis, seedlings developed slowly, but during the first year of life they bloomed and bore fruit. The best sowing time: the third decade of April. Friendly seedlings were obtained during summer sowing, but the seedlings did not always form generative organs. During winter sowing, *H. officinalis* plants were overwintered in case of the formation of mature immature individuals even before the onset of persistent frosts. During the first year of vegetation, *H. officinalis* formed one vegetative-generative shoot with second- and third-order shoots. In the second and subsequent years of life, the number of vegetatively generative shoots increased, the maximum indicators of productivity were found in the fourth year of life. In the collection plots, seedlings of *H. officinalis* grow for 15 years, bloom and bear fruit every year, regardless of the appearance of signs of ageing.

It was found that the vegetative reproduction of *H. officinalis* plants of the third and subsequent years of life by particles in April or October is quite effective.

The raw material of *H. officinalis* is green, non-woody leafy shoots with inflorescences. With age, the area of lignification of the shoots increases, the lignified part of the shoots of hyssop becomes unusable. Therefore, during the harvesting of raw materials, the above-ground part of the plants of 1-3 years of life was cut at a height of 10-15 cm, and the 4-year and subsequent ones were cut at a height of 20-30 cm above the soil surface.

The highest indicators of productivity of *H. officinalis* were recorded in the fourth year of life. Thus, the productivity of above-ground mass was 38.9±0.2 t/ha, seeds – 0.54±0.052 t/ha, weight of 1000 erems – 1.08± ±0.13 g. At the end of the first year of life, these indicators were, respectively, 2.8±0.2 t/ha, 0.06±0.008 t/ha, weight of 1000 erems – 1.17±0.03 g (see Table 2).

H. angustifolius plants were propagated by the seed method and vegetatively. Plant seeds were sown in the soil in April, after sowing plant seedlings appeared within 14-17 days. In the first year of life, individuals of *H. angustifolius* formed one vegetative branched shoot, the seedlings did not flower and did not form seeds. Flowering

was observed in the second year of life. During the following years of vegetation, the spring growth of plants began in the first decade of April, when the temperature reached above +10°C, flowering in July (during the 2nd and 3rd year of life) –August (during the 4-12 years of life). The growth processes of *H. angustifolius* plants were completed in October-November. Plants of *H. angustifolius* grow under the conditions of introduction for 12 years.

Plants of *H. angustifolius* were propagated vegetatively, which was simplified by the particulation of individuals. During the third year of life in culture conditions, the number of particles was from 3 to 4, in the fifth and subsequent years – from 10 to 12 pieces. The phytoraw material of *H. angustifolius* (green shoots with inflorescences) was harvested by cutting them at a height of 10-15 cm relative to the soil surface.

Observations have shown that *H. angustifolius* plants are described by lower performance indicators compared to *H. officinalis*. In the first year of life, plant productivity was 0.72±0.07 t/ha, seeds were not formed. The highest productivity was found in plants of the fourth year of life. Thus, the yield of above-ground mass was 8.91±0.11 t/ha, erems – 0.27±0.02 t/ha, weight of 1000 erems – 0.57±0.02 g (see Table 2).

L. anisatus plants were propagated by seed and vegetative methods. When sowing erems in the third decade of April, seedlings appeared after 18-23 days. During the first year of life, seedlings formed one vegetative-generative shoot with shoots of the second order. Growth of *L. anisatus* plants of the second and subsequent years of life after overwintering in the absence of snow cover and air temperature exceeding +10°C was observed in April. In the second and subsequent years of life, plants formed several generative shoots that branched, flowered, and bore fruit.

L. anisatus plants of the second and subsequent years of life were propagated by division into parts. The seedlings took root well, bloomed and bore fruit.

Compared to other species, *L. anisatus* plants were less winter-hardy. The death of 5% of three-year-old individuals in winter and more than 60% of plants in the fifth year of life was noted. Observations showed that the maximum lifespan of *L. anisatus* plants under the conditions of introduction was 6 years.

The raw material of *L. anisatus* – aerial leafy shoots and inflorescences, was cut at a height of 15-20 cm relative to the soil surface. The highest productivity of aboveground raw materials of *L. anisatus* was noted in the third year of life – 44.1±0.9 t/ha, seed material – 0.33±0.064, weight of 1000 erems – 0.41±0.02 g (see Table 2).

L. vera plants were propagated by seeds and vegetatively. During seed propagation of *L. vera* plants without stratification, low field germination was noted (5-10%), seedlings appeared after 25-30 days. During cold stratification for 30 days at a temperature of +5-7°C, the similarity of *L. vera* erems increased to 43%. During the first year of life, plants formed one vegetative shoot, on which shoots of the second order were laid, in the second year of life – shoots of the third order. Flowering and fruiting were observed in the third and subsequent years of life, when plants created a significant number of vegetative-generative shoots. Flowering of plants was observed in June, fruiting in August. When peduncles were cut in the flowering phase, re-formation of inflorescences of *L. vera* plants was observed in August-September.

It is known that *L. vera* plants are propagated by cuttings or seedlings, but these methods require additional care and watering. *L. vera* plants of the third and subsequent years of life took root well when divided into parts, which indicates the advantages of vegetative propagation.

For the economic needs of industries, inflorescences are mainly used, which is about 30% of the above-ground part of plants. However, green shoots with leaves, which are cut at a height of 20-25 cm above the soil surface, are no less valuable phytoraw material and a source of biologically active compounds. The maximum productivity of L. vera was noted in the fourth year of life. Productivity of above-ground plant material was 19.6±1.1 t/ha, erems – 0.45±0.029 t/ha, weight of 1000 erems – 1.05± ±0.11 g (see Table 2).

M. didyma plants were propagated by seeds, seedlings, and vegetatively. The best results were obtained during the spring reproduction of individuals of the third and subsequent years of life by dividing the rhizome with recovery buds into parts. The cuttings took root well, formed generative organs.

Reproduction of *M. didyma* plants by the seed method was accompanied by some difficulties – seedlings appeared 18-21 days after sowing, field germination of seeds was 40 to 50%, seedlings developed very slowly during the first year of life. In addition, the results of the splitting of parental traits were observed and seedlings with different leaf colours (dark green and light green), with different stem lengths (short and tall), variable flower colours (dark purple, pink, or light pink) were obtained. Different resistance to damage by powdery mildew (relatively resistant and unstable). One-year seedlings of *M. didyma* formed one unbranched vegetative shoot, the number of shoots increased in the second and following years (from 8-10 to 20-50 pcs.). Generative organs formed some plants in the second year of life, in the third and subsequent years of vegetation – all plants.

When propagated by the seedling method, 30% of *M. didyma* individuals took root, the plants turned out to be unstable to drought, and summer thunderstorms caused lodging and damage to the stem, which led to their death. Under the conditions of introduction today, individuals of *M. didyma* grow for 10 years, the death of 40% of individuals was found.

The raw material of *M. didyma* – the aerial part of plants with leaves and inflorescences, was cut at a height of 10-15 cm relative to the soil surface. The

maximum productivity of *M. didyma* plants was observed in the fourth year of life. Phytomass productivity was 28.6±3.4 t/ha, erems – 0.38±0.027 t/ha, weight of 1000 erems – 0.46±0.02 g (see Table 2).

Erems of *O. vulgare* plants are petite, have low laboratory similarity (about 20%). Seedlings of *O. vulgare* in the first year of life formed one vegetative shoot, in the second and subsequent years of life, the number of vegetative-generative shoots increased. *O. vulgare* plants flowered and bore fruit from the third year of life.

It has been established that the best method of reproduction for *O. vulgare* plants is vegetative, by dividing the rhizome with regeneration buds into parts. The mentioned method of reproduction made it possible to quickly increase the number of plants of this species since they took root well and grew to the size of the parent in 1-2 years.

Twelve-year-old plants currently grow in the collection of aromatic plants and are quite productive. The raw material of *O. vulgare* is shoots with leaves and inflorescences, cutting them at a height of 10 cm from the soil surface. The highest productivity of above-ground mass of *O. vulgare* (33.0±2.0 t/ha) was recorded in the fourth year of life. Among all studied species, *O. vulgare* plants have the lowest seed productivity (0.18±0.024 t/ha) and weight of 1000 seeds (0.10±0.01 g).

According to the results of research by Shatkovskyi *et al*. (2021) when planting seedlings in open ground according to the scheme of 60x10 cm, the dry mass productivity of *O. vulgare* under drip irrigation conditions was 3.16 t/ha (in terms of raw mass – 26.3 t/ha). The yield of plants in the conditions of the Polish region is higher, in addition, their cultivation does not require added costs for irrigation.

Plants of *N. transcaucasica* were propagated both by seeds and vegetatively, by division into parts. The plants formed viable self-seeding throughout the growing season, sprouts appeared after 8-20 days, depending on moisture conditions. During the first year of life, the seedlings developed one vegetative-generative shoot, flowering and fruiting were observed during August-September. In the second and subsequent years of life, *N. transcaucasica* plants flowered and bore fruit 3 times during the growing season.

The maximum productivity of *N. transcaucasica* plants was observed in the third year of life. Plant phytomass productivity during this period was 13.2±0.3 t/ha, seed material – 0.33±0.058 t/ha, weight of 1000 erems – 0.67±0.059 g (see Table 2).

S. officinalis plants were propagated by seeds, seedlings, green cuttings, and division into parts. During the first year of life, seedlings of *S. officinalis* formed a rosette of leaves, later one vegetative shoot. In one-year individuals, generative shoots were not formed. Plants of the second year of life developed several branched shoots, on which shoots of the 2nd, 3rd and 4th orders were formed. Flowering was observed in the last decade of June, ripening of erems – in the third decade of August.

In the third and fourth year of life, the plants exceeded quantitative indicators of growth and productivity in comparison with plants of the first and second years of life. Flowering was observed during the first-second decade of June, ripening of erems – at the beginning of August. Re-flowering of some *S. officinalis* plants in September was noted. At this time, individuals of *S. officinalis* have been growing under the conditions of introduction for ten years, a decrease in productivity indicators and signs of plant death have been detected.

The raw material of *S. officinalis*, mainly leaves, was collected by cutting them together with green shoots at a height of 14-18 cm relative to the soil surface. The highest indicators of productivity of *S. officinalis* were observed in the fourth year of life: productivity of phytomass was 26.0±1.3 t/ha, erems – 0.40±0.038 t/ha, weight of 1000 erems – 7.15±0.27 g (see Table 2).

S. sclarea plants were propagated by the seed method and division into particles. When propagating by seeds during the first year of vegetation, seedlings formed a rosette of leaves, in the second and subsequent years of life – generative shoots. Flowering of *S. sclarea* plants was observed in July, fruiting in August.

S. sclarea plants of the second or third year of life were propagated by division into parts, which was facilitated by the particulation of the root system. In the conditions of introduction, abundant self-sowing of *S. sclarea* and high frost resistance of seedlings were found, so we believe that the vegetative method of plant propagation is not appropriate. The raw material of *S. sclarea* – leaves and vegetatively generative shoots (including inflorescences, which make up to 40% of the entire phytomass) was cut 10-15 cm above the soil surface. The maximum productivity of *S. sclarea* plants was established during the second year of life: above-ground mass – 37.1±6.5 t/ha, erems – 0.58±0.053 t/ha, weight of 1000 erems – 3.42±0.15 g (see Table 2).

In the conditions of the Central Polissia of Ukraine, the productivity *of S. sclarea* inflorescences was 14.84 t/ha, which does not contradict the information about other researchers. Thus, according to the report of Ushkarenko *et al*. (2020), under the conditions of the Kherson region, when *S. sclarea* was sown in the first decade of December with a row width of 45 cm, a yield of inflorescences was obtained at the level of 15.01-14.61 t/ha. At the same time, additional costs for irrigation affect the profitability of production, and in the conditions of the Polish region, plants do not need watering.

An important indicator of the adaptation of rare plant species to new living conditions is not only phytomass productivity, but also the possibility of synthesis of biologically active compounds by the plant organism. It is common knowledge that glandular structures are formed on the vegetative and generative organs of plants of the *Lamiaceae* family: trichomes, peltate

glands, in which aromatic substances in the form of essential oils accumulate. Thanks to this, biologically active compounds are obtained from the above-ground mass of plants, which are used as natural flavourings of food products, medicinal, and perfumery and cosmetic products. The essential oil of each studied plant has a wide range of effects on the body, as it is a multi-component mixture of chemical compounds, mainly terpenoids and aromatic components (Shanayda & Pokryshko, 2015). In Ukraine, natural essential oils are imported from abroad, and they are costly. Therefore, the cultivation of aromatic essential oil crops on the territory of the state can provide industries with ecologically safe raw materials.

Research has established that the natural and climatic conditions of the Central Polissia of Ukraine are quite suitable for growing crops that are a source of obtaining essential oils. The highest yield of essential oil in terms of dry mass during flowering was found in plants: *Hyssopus angustifolius* (2.054%), *Lavandula vera* (1.808%), *Salvia officinalis* (1.2%) and *Monarda didyma* (1.07%), the lowest – in *Origanum vulgare* (0.197%) (Fig. 2).

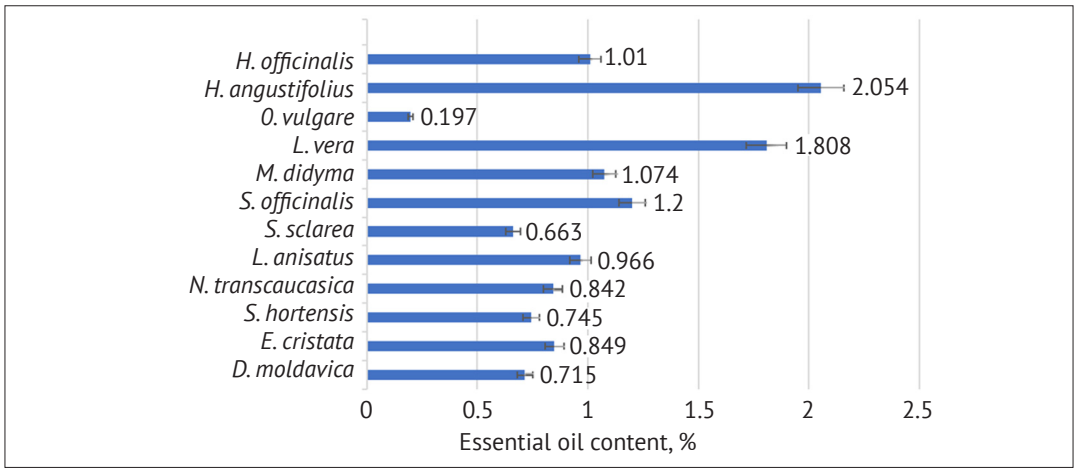

***Figure 2**. Essential oil content of phytoraw materials of aromatic plants in the conditions of the botanical garden of the Polish National University, % by absolute dry weight*

Considering the different timing of the beginning of flowering and the considerable duration of this period, all species of plants of the *Lamiaceae* family turned out to be quite promising for use in landscape design (Fig. 3). It is advisable to use compositions of aromatic plants in diverse types of flower design – aroma beds, landscape slides, flowerbeds, mono- and multi-species compositions, mix borders with decorative species of bushes and trees, to improve the condition of administrative premises, recreation, and health areas. Plants *D. moldavica*, *S. sclarea*, *H. angustifolius*, *H. officinalis*, *N. transcaucasica*, *L. anisatus*, *O. vulgare* are summer-blooming plants, the flowering of which began in July. Flowering of the mentioned species is long-lasting – from 30 to 50 days. The shortest flowering period (20-30 days) was observed in the early summer flowering species *M. didyma* (Table 3).

***Table 3**. Groups of aromatic plants depending on the timing of flowering in the botanical garden of the Polissia National University*

Group	Phase start time		Species
	Decade	Month	
Spring blooming	II-III	May	*N. transcaucasica*
Early summer blooming	I-IV	June	*L. vera, M. didyma, S. officinalis*
Summer blooming	I-IV	July	*D. moldavica, S. sclarea, H. angustifolius, H. officinalis, O. vulgare, L. anisatus, N. transcaucasica*
Late summer blooming	I-IV	August	*S. hortensis, E. cristata*
Autumn blooming	I-IV I-II	September-October	*N. transcaucasica, L. vera* (2nd and subsequent years of life), *H. officinalis* (1st year of life)

***Source:** compiled by the authors*

Figure 3. *Aromatic plants of the Lamiaceae family in the flowering phase in the botanical garden of the Polissia National University: 1 – Satureja hortensis; 2 – Dracocephalum moldavica; 3 – Elsholtzia cristata; 4 – Monarda didyma; 5 – Hyssopus officinalis; 6 – Lavandula vera; 7 – Hyssopus angustifolius; 8 – Salvia sclarea; 9 – Nepeta transcaucasica; 10 – Lophanthus anisatus ; 11 – Salvia officinalis ; 12 – Origanum vulgare*
Source: *photographed by the authors*

Plants *S. hortensis* and *E. cristata*, which began to bloom in August, are classified as late-summer blooming plants.

H. officinalis plants of the first year of life began to bloom in September-October. In the case of cutting the above-ground mass of plants at the beginning of the flowering phase, the re-formation of inflorescences was observed in the autumn period. This method allows adjusting the timing of repeated flowering of species during the growing season. These species with remontant properties are classified as autumn-blooming.

The research of Skybitska & Mohylyak (2013) confirms the repeated flowering of *H. officinalis*, *L. vera* and *N. transcaucasica* plants in the conditions of the Western Forest Steppe of Ukraine and notes the special decorativeness during the flowering of *Hyssopus officinalis*, *Origanum vulgare*, *Salvia officinalis*, *Salvia sclarea*, *Satureja hortensis*.

The obtained research results are marked by the fact that in the conditions of the Central Polissia of Ukraine, 12 uncommon plant species were analysed regarding the peculiarities of their introduction into culture and methods of reproduction. Similar research was carried out in the Polish region for the first time, and therefore there is almost no information on the cultivation of new species of aromatic plants in the scientific literature. Garden centres that sell some types of plants (*Lavandula vera*, *Origanum vulgare*) in the retail network do not share information about their cultivation and propagation technology. Seeds of aromatic plants offered by domestic and foreign enterprises do not always germinate due to ignorance of cultivation technology. Therefore, the information presented in this paper can be useful not only for farmers, but also for owners of homesteads.

CONCLUSIONS

The third decade of April turned out to be the best period for sowing plants of the Lamiaceae family in the conditions of the botanical garden of the Polish National University. Sowing before winter gives the best result for plants L. anisatus, H. angustifolius, H. officinalis, N. transcaucasica, S. sclarea. The optimal seed sowing depth is 10-15 mm, after which the soil is compacted.

It is advisable to propagate annual and perennial species of plants by seed, and *M. didyma*, *S. officinalis*, *L. vera* and *O. vulgare* by vegetative method (cuttings, particles, cuttings, rhizomes). For *L. vera* seed germination, it is necessary to stratify the erems in a moist substrate at a temperature of +5-7°C for 30 days.

Plants *H. officinalis*, *H. angustifolius*, *S. sclarea*, *N. transcaucasica*, *L. anisatus*, and *O. vulgare* can spread through self-sowing and the formation of seedlings resistant to winter temperatures. However, under culture conditions, *M. didyma*, *L. vera*, and *S. officinalis* plants did not reproduce by self-sowing.

It is advisable to harvest phytoraw materials for further use in the food industry and pharmacy during the flowering phase, cutting annual plants above 10-20 cm above the ground, perennial plants above 10-30 cm.

The productive potential of plants is evidence of their adaptation to new living conditions. Among the annual species, the highest productive potential was found in D. moldavica plants, the productivity of aboveground mass was 24.7±1.7 t/ha, seeds – 0.733±0.03 t/ha; among perennials, plants of *H. officinalis* (38.9±0.2 t/ha) and *L. anisatus* (44.1±0.9 t/ha), and seeds of *L. vera* (0.45±0.029 t/ha) and *S. sclarea* (0.58±0.053 t/ha). The highest yield of essential oil in terms of absolute dry matter was found in plants of *S. officinalis* (1.2%), *L. vera* (1.808%) and *H. angustifolius* (2.054%).

Depending on the features of flowering, plants of the *Lamiaceae* family are divided into groups: spring-blooming (1 species), early summer-blooming (3 species), summer-blooming (7 species), late summer-blooming (2 species) and autumn-blooming (3 species with remontant properties).

Aromatic plants are characterised by different periods of flowering, a significant duration of the named period, and therefore it is advisable to use them in landscape design, to improve the condition of recreational areas and administrative premises.

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Введення в культуру, розмноження та продуктивність ароматичних рослин родини *lamiaceae* у Центральному Поліссі України

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Анотація. Впровадження в культуру нових видів ароматичних рослин родини *Lamiaceae* є актуальним для збагачення біологічного різноманіття флори Центрального Полісся України, а також для розширення сировинної бази пряно-ароматичних, лікарських, харчових, декоративних та медоносних рослин. Мета дослідження – встановлення методів розмноження ароматичних рослин, оптимальних строків посіву й площ живлення, отримання фітосировини і насіннєвого матеріалу. Методи дослідження: лабораторні, польові, статистичні. Було встановлено, що найкращий період сівби рослин родини *Lamiaceae* в умовах ботанічного саду Поліського національного університету – третя декада квітня. Використання різних методів розмноження свідчить про доцільність насіннєвого розмноження усіх досліджуваних одно- та багаторічних видів рослин, а рослин *M. didyma*, *S. officinalis*, *L. vera* і *O. vulgare* – також партикулами, кореневищами, відсадками, живцями. Рослини *S. hortensis*, *D. moldavica*, *E. cristata*, *H. officinalis* рекомендовано розміщувати за схемою 30х45 см, *L. vera*, *L. anisatus*, *N. transcaucasica*, *S. officinalis*, – 30х50 см, а *O. vulgare*, *S. sclarea*, *M. didyma*, – 40х50 см. Серед однорічних видів найбільший продуктивний потенціал виявлено у рослин *D. moldavica*, продуктивність надземної маси яких становила 24,7±1,7 т/га; серед багаторічних – у рослин *H. officinalis* (38,9±0,2 т/га) та *L. anisatus* (44,1±0,9т/га). Найбільший вихід ефірної олії у перерахунку на абсолютно суху речовину встановлено у рослин *S. officinalis* (1,2 %), *L. vera* (1,808 %) та *H. angustifolius* (2,054 %). Отримані результати досліджень щодо способів розмноження можуть бути використані для вирощування нових видів ароматичних рослин родини *Lamiaceae* як на присадибних ділянках, так і в аграрних підприємствах. Найбільш продуктивні види ароматичних рослин доцільно впроваджувати у виробництво з метою подальшого використання фітосировини й ефірної олії у фармації, харчовій та інших галузях народного господарства

Ключові слова: *Lamiaceae*, інтродукція, методи розмноження, продуктивний потенціал