Research Article

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Characteristic of *Salvia officinalis* L. genotypes in the Steppe of South Ukraine

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In this study gives the characteristic of *Salvia officinalis* L. genotypes (Lamiaceae)grown in the Southern Steppe of Ukraine. *S. officinalis* one of the most well-known plants from *Salvia* L. genus that is used as an aromatic, medicinal, and culinary herb. The plant raw material of this plant is characterized by numerous biological activities that allow use in the pharmacological industry. This plant is characterized by morphological polymorphism and the selection of new genotypes within *S. officinalis* has a polyfunctional meaning. The plant material of this study was the genotypes of *S. officinalis* (108-14, 109-14, 108-14-1, 108-14-2, and 113-16). It investigated 3d years of living plants at the flowering stage from the experimental collections of aromatic and medicinal plants in the Kherson region, v. Plodove (Institute of Climate Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine). The height of plants of investigated genotypes was 65.02–86.37 cm, the diameter of the plant was 89.37–117.03 cm, the leaf length was 8.20–11.06 cm, the leaf width was 2.95–3.79 cm, the inflorescence length was 14.52–26.01 cm, the inflorescence diameter was 4.07–5.57 cm, the number of whorls in inflorescences was 8.12–10.55, and the number of flowers in the whorl was 10.02–12.14. The color of the leaf surface, the character of the leaf surface (wrinkles), and colour of the flowers depended on genotype. The mass of raw from the shrub was determined from 350.11 to 560.27 g and the average mass of essential oil of one plant was from 1.37 to 2.01 g depending on genotype. The essential oil content in the herb, leaves, and inflorescences on dry mass was 1.0–1.5%, 1.09–1.79%, and 0.98–1.28%, respectively. In the herbs and leaves, minimal and maximal content of oil were found in genotypes 113–16 and 109–14, respectively. These results can be useful for further selective work within *S. officinalis* species and including other species of this genus.

Keywords: dalmatian sage, morphometric features, essential oil

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Introduction

The study of plants of the *Salvia* L. genus is still actual due to polyfunctional use in human life. *Salvia* species are widely diverse and used as a culinary herb, spice, medicinal, cosmetic, and ornamental plants in many countries in the world (Hamidpour et al., 2014; Grdiša et al., 2015; Sharopov et al., 2018).

Salvia genus is one of the most groups of Lamiaceae Martinov and includes approximately 1000 species which are distributed in Eurasia, Africa, and America (González-Gallegos et al., 2020). Some species are cultivated widely and among them, *Salvia officinalis* L. (dalmatian sage) is the most well-known and used (Hassiotis, 2018). The ancient Romans cultivated this popular culture as an ornamental and honey-bearing plant. Its homeland is considered to be Asia Minor, from where it spread across the Balkan Peninsula and the Mediterranean (El Euch et al., 2019).

The essential oil of sage leaves contains tannins, ursulic and oleic acids, alkaloids, and flavonoids. The main action of clary sage is antiseptic and anti-inflammatory (Sharopov et al., 2018). The plant also has astringent, emollient, and hemostatic properties, and also reduces sweating. It promotes the secretion of gastric juice and has mild antispasmodic properties (Vosoughi et al., 2018; Hudz et al., 2020). In this regard, the infusion of leaves is used to treat such diseases of the digestive system as gastritis, peptic ulcer disease of the stomach and duodenum with reduced acidity of gastric juice, and spastic colitis. Infusion of leaves is also used for catarrh of the upper respiratory tract, chronic bronchitis, angina, and inflammatory processes of the oral cavity and pharynx (El Eough et al., 2019). Some foreign scientists emphasize the positive effect of sage extracts on human cognitive activity (Wightman et al., 2021). The essential oil demonstrated antibacterial, antifungal (Agrawal et al., 2021), and antiviral (Rashidipour et al., 2022) activities. Due to this fact, sage is suitable for the biological protection of agricultural plants from fungal pathogens, and is also a good repellent (Vosoughi et al., 2018; Harizia et al., 2021; Khaled-Gasmi et al., 2021; Morkeliūnė et al., 2021). The chemical composition of the essential oil of *S. officinalis* can explain the allelopathic potential of this plant (Bouajaj et al., 2013).

The results of these studies suggest the use of the essential oil of both species as an effective natural anti-inflammatory and antiviral agent (Abou Baker et al., 2021). The study of the antioxidant properties, including medicinal sage, grown in the South of Italy, concluded the possibility of using them in functional food products, herbal medicines, or as a source of active biomolecules (Vergine et al., 2019). The well-deserved attention to clary sage is justified by the use of its essential oil as a food preservative and auxiliary agent in bacterial food toxic infections (Selim et al., 2022).

According to literature data, the species *Salvia officinalis* is characterized by a great polymorphism of some morphological and biochemical parameters, which allows carry out the individual selection (Jug-Dujaković et al., 2012; Shakoor et al., 2021). Considering the significance of useful properties of *S. officinalis* raw in human life, it's important to find and select new features of plants during the period of vegetation.

Our work aimed to study some morphological and economically valuable features such as the yield and mass fraction of essential oil in the hybrid forms of *Salvia officinalis* in the conditions of the Steppe zone of Southern Ukraine for further selective work.

Material and methodology

Biological material

The research material was the genotypes of *Salvia officinalis* L. (108-14, 109-14, 108-14-1, 108-14-2, and 113-16) (Figure 1a, b). The research was conducted in the Institute of Climate Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine (experimental collections of aromatic and medicinal plants in the Kherson region, v. Plodove). It investigated 3-year-old plants at the flowering stage during 2020–2021.

Morphometric parameter study and morphological describing

The morphometric parameters of plants were used in this study: height of the plant (in cm), the diameter of the plant (in cm), length and width of leaves (cm), length and diameter of inflorescence (in cm), the number of whorls in the inflorescences, the number of flowers in the whorls. Also, were described leaf surface (colour and wrinkle), and inflorescences (colour).

The essential oil content determination

The essential oil was obtained from the herb (aerial mass of plants), leaves, and inflorescences at the flowering stage; the mass fraction of the essential oil was determined by the hydrodistillation method (Ginsberg's method) on the Clevenger apparatus, based on the absolutely dry mass of the plant material (Elyemni et al., 2019).

Figure 1a Selected genotypes of *Salvia officinalis* L. at the flowering stage with inflorescences
A – 108-14; B – 108-14-1

Figure 1b Selected genotypes of *Salvia officinalis* L. at the flowering stage with inflorescences C – 108-14-2; D – 109 -14; E – 113-16

Statistical analysis

The results are expressed as mean values of three replications ± standard deviation (SD); hierarchical cluster analyses of similarity between samples were computed based on the Euclidean similarity index. Data were analyzed with the ANOVA test and differences between means were compared through the Tukey-Kramer test ($p < 0.05$).

Results and discussion

The conditions of the Kherson region promote the cultivation of promising aromatic plants. Especially those species that can be grown in conditions of insufficient soil and air moisture in the South of Ukraine (Svydenko and Yezhov, 2014; Dudchenko et al., 2020). The most common among them are lavender, lavandin (Fernández-Sestelo and Carriello, 2020; Pokajewicz et al., 2021), lemon wormwood (Korablova et al., 2020), medicinal hyssop, peppermint (Yezerska et al., 2021), thyme (Vergun et al., 2022), monarda (Dudchenko et al., 2020), sage (Korablova et al., 2019), the raw materials of which are used in the pharmaceutical, perfumery and cosmetic, food industry, and medicine (Mňahončaková et al., 2019; Hudz et al., 2020; Frolova et al, 2021; Korablova et al., 2021).

In the first year of life, all *S. officinalis* plants vegetated and no special differences were observed between them except for the color and size of the leaf blade. The vegetation of plants in the second year was noted in April, the budding stage occurred in May, and the

Table 1 Characteristics of genotypes of *Salvia officinalis* L. according to morphometric indicators and signs at the flowering stage

Parameter	Genotype				
	108-14	108-14-1	108-14-2	109-14	113-16
Height of plant, cm	72.21 ±4.02[ab]	67.19 ±2.61[b]	66.94 ±3.21[b]	86.37 ±3.41[a]	65.02 ±2.90[b]
Diameter of plant, cm	115.94 ±6.01[a]	103.04 ±4.81[b]	100.18 ±5.11[b]	117.03 ±5.12[a]	89.37 ±6.71[c]
Length of leaf, cm	11.06 ±1.56[a]	9.96 ±0.14[b]	9.51 ±0.81[b]	10.09 ±1.10[a]	8.20 ±2.11[b]
Width of leaf, cm	3.79 ±0.22[a]	2.95 ±0.18[b]	3.51 ±0.30[a]	3.56 ±0.21[a]	3.22 ±0.31[a]
Colour of the leaf surface	green with grey	light-green with grey	light green	dark green	grey
The character of leaf wrinkle	moderate	moderate	strong	strong	moderate
Length of inflorescence, cm	22.02 ±1.15[b]	21.02 ±1.54[b]	26.01 ±1.54[a]	17.35 ±1.51[c]	14.52 ±0.51[d]
Diameter of inflorescence, cm	4.07 ±0.34[c]	5.54 ±0.31[a]	5.57 ±0.50[a]	4.53 ±0.31[c]	5.08 ±0.41[b]
The number of whorls in the inflorescences	10.55 ±0.23[a]	8.12 ±0.18[c]	9.03 ±0.11[b]	8.45 ±0.16[c]	8.23 ±0.52[c]
The number of flowers in the whorls	11.23 ±0.42[ab]	12.14 ±0.63[a]	10.02 ±0.08[b]	10.28 ±0.21[b]	10.66 ±0.87[b]
Color of inflorescence	light purple	rose	light blue	purple	white

Note: within a row, means without a common superscript differ (p <0.05)

beginning of flowering registered in the third decade of May. The period of mass flowering was observed in June and the fruiting period in July (Lichinkina and Svydenko, 2006).

Plants of investigated genotypes at the flowering period occur almost at the same time with a difference of 1–2 days. Genotype 113-16 was flowered first (18.05), and genotype 109-14 was flowered last (21.05). Genotypes 109-14 and 108-14 stood out among the samples of medicinal sage according to the height of the shrub. Genotype 113-16, which differs from others in the white color of the flower, had the lowest shrub height.

The study of complex features of plants among which morphometrical and morphological peculiarities are an important aspect of the assessment of selective work to highlight new genotypes (Çamlica and Yaldiz, 2019; Vergun et al., 2021).

The morphological and morphometrical characteristics of selected genotypes are represented in Table 1. The height of selected *S. officinalis* genotypes varied from 66.94 to 86.37 cm. The diameter of investigated plants achieved 89.37–117.03 cm. The length and width of leaves were 8.20–11.06 and 2.95–3.79 cm, respectively. We also found differences in the colour of the leaf surface and inflorescences for all genotypes and the character of the leaf wrinkle for 108-14-2 and 109-14 genotypes where this parameter was highlighted stronger. The length and diameter of inflorescences were 14.52–26.01 and 4.07–5.57 cm, respectively.

According to Mossi et al. (2011), S.officinalis plants from different origins and propagation forms had a height of plants 30.5–55.3 cm, a width of leaves of 1–3 cm, a length of leaves 2.5–9.0 cm, a length of inflorescences 11.0–20.5 cm.

It is generally known that the raw material of sage is the entire above-ground mass of plants. The yield of above-ground mass in plants in the third year of vegetation varied from 350 to 560 g. The highest productivity was genotype 109-14, and the smallest was genotype 113-16 (Table 2).

The essential oil in sage is accumulated in glandular scales, glandular hairs, and unicellular and multicellular essential oil glands (Kutko et al., 2002). The mass of essential oil from one plant was from 1.37 to 2.01 g.

Table 2 The yield of selected genotypes of *Salvia officinalis* L. at the end of flowering

Parameters	Genotype				
	108-14	108-14-1	108-14-2	109-14	113-16
The mass of raw from shrub, g	500.13 ±20.1[ab]	420.09 ±19.2[b]	480.45 ±23.3[b]	560.27 ±30.1[a]	350.11 ±16.7[c]
The mass of essential oil from one plant, g	2.01 ±0.33[a]	1.37 ±0.09[c]	1.54 ±0.11[b]	1.62 ±0.12[b]	1.67 ±0.08[b]

Note: within a row, means without a common superscript differ (p <0.05)

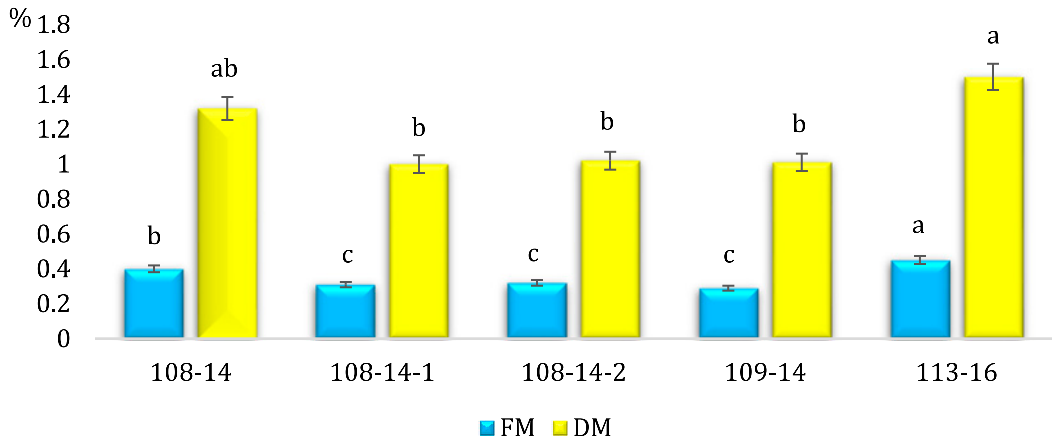

Figure 2 The mass fraction of essential oil of herb of *Salvia officinalis* L. genotypes at the end of flowering
FM – % of fresh mass; DM – % of dry mass. Different superscripts in each column indicate the significant differences in the mean at p <0.05

According to Lichinkina and Svydenko (2006), the yield of leaves from one plant of *S. officinalis* in the Kherson region was 240 g, and the mass of the shrub was 430 g. The fresh weight of conventionally grown plants was 271 g and hydroponically grown 321 g (Traykova et al., 2019).

A significant variation in yield and composition was found among and within *Salvia* species that depend on the origin of raw (Rajabi et al., 2014). Also, some results proved that the use of growth regulators significantly affects essential oil content and components of *Salvia* raw (Rowsan et al., 2010). The period of growth along with other peculiarities is a very important sign, for example, after collection of Turkish *Salvia aramiensis* at the pre-flowering stage, flowering, and post-flowering stages were determined 2.2, 1.0, and 2.1% of essential oil (Demirci et al., 2002). In another study, *S. officinalis* essential oil content was highest during the flowering period (Farhat et al., 2016). It is known that the content of essential oil in clary sage plants depends on the agro-technique of cultivation, season, and the genotype (Pitarević et al., 1984; Vosoughi et al., 2018; Hazrati et al., 2022). All organs of clary sage (*S. sclarea*) are covered with trichomes, but simple and capitate hairs practically do not contain essential oil (Kutko et al., 2002; Svydenko and Lichinkina, 2005). The glandular trichomes of Lamiaceae have important functional and taxonomic meanings but their character differs significantly (Kahraman et al., 2010; Svydenko et al., 2018). The main amount of essential oil is concentrated in essential oil glands, which we also found on leaves, stems, calyxes, and petals.

According to our research, the mass fraction of essential oil in samples in the phase of the end of flowering

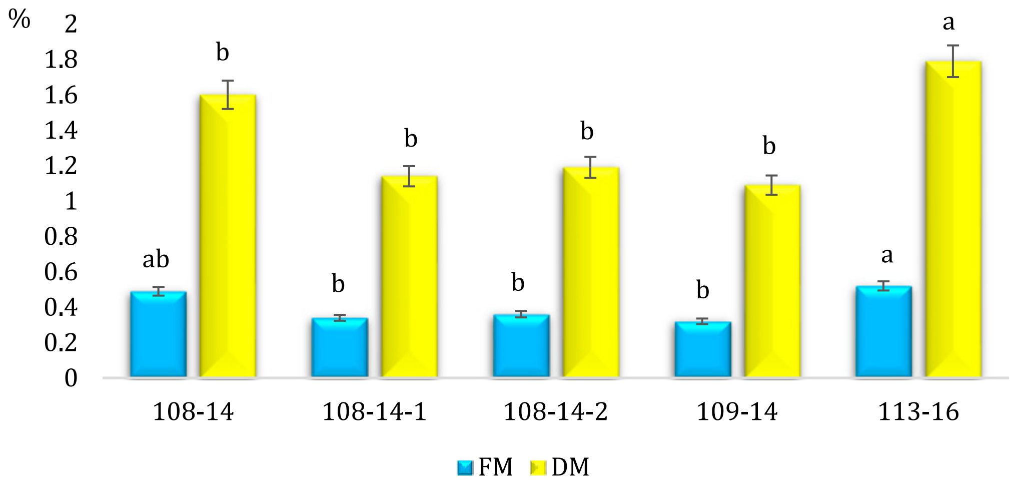

Figure 3 The mass fraction of essential oil of *Salvia officinalis* L. genotypes in the leaves at the end of flowering
FM – % of the fresh mass; DM – % of dry mass. Different superscripts in each column indicate the significant differences in the mean at p <0.05

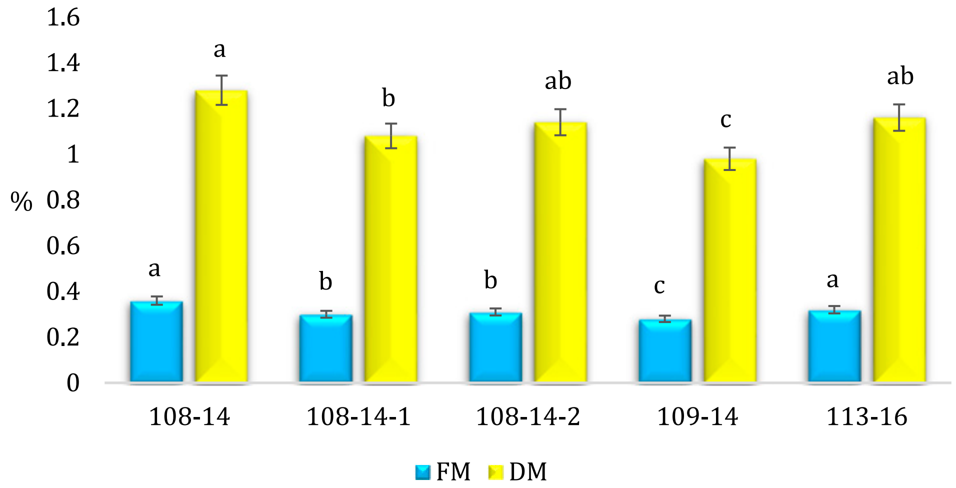

Figure 4 The mass fraction of essential oil of *Salvia officinalis* L. genotypes in the inflorescences at the end of flowering
FM – % of the fresh mass; DM – % of dry mass. Different superscripts in each column indicate the significant differences in the mean at $p < 0.05$

ranged from 0.29 to 0.45% of the fresh mass of plant material or from 1.0 to 1.5% of completely dry (Figure 2). We recorded the largest mass fraction of essential oil in genotype 113-16 and the smallest in genotype 109-14.

The content of *S. officinalis* essential oil from Poland was in May 1.16% and in August 1.35% (Zawiślak, 2014). The essential oil yield of *S. officinalis* fruits, according to Taarit et al. (2009), was 0.39%. As reported Verma et al. (2015), the essential oil yield for these plants from Southern India was 0.22–0.43% for the whole plant and 0.15–0.60% for different parts of the plant.

The content of essential oil depends on many factors among which part of the plant (Sellami et al., 2011). In this study, we determined essential oil mass in the leaves and inflorescences separately. It was determined the content of essential oil of 0.34–0.52% in fresh mass and 1.09–1.79% in dried mass (Figure 3). The highest content of essential oil is determined in leaf raw of the genotype 113-16 and the least in genotype 109-14.

According to Couladis et al. (2002), the interpopulation variation of essential oil content of leaves and flowers of *S. officinalis* from Serbia averaged 1.41 and 1.13%, respectively. The content of essential oil in inflorescences was 0.28–0.36% in fresh mass and 0.98–1.28% in dried mass (Figure 4). The minimal content of essential oil is found in inflorescences raw of genotype 109-14 and maximal in genotype 108-14.

Conclusions

Thus, in conditions of the South Step zone of Ukraine were selected five genotypes of *S. officinalis* and studied for selected morphometrical and morphological peculiarities. Studying the economically valuable features, we established that the mass of the raw per plant, the mass fraction of the essential oil, and the morphometrical parameters of plants depended on the genotypes. All plants differed by inflorescence and leaf surface colour, and character of surface (wrinkle). The minimal mass of the shrub, and essential oil content of the herb and leaves was detected for genotype 113-16. The maximal mass from the shrub, essential oil content of herbs and leaves were determined for genotype 109-14. However, the essential oil content of inflorescences for genotype 109-14 was minimal and for genotype 108-14 maximal. These results can be useful for further selective work within *S. officinalis* species and including other species of this genus. The creation of new varieties will be very useful for pharmaceutical, cosmetic, and food industries and as ornamental plants.

Conflicts of interest

The authors declare no conflict of interest.

Ethical statement

This article doesn't contain any studies that would require an ethical statement.

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References

Abou Baker, D.H., Amarowicz, R., Kandeil, A., Ali, M.A., & Ibrahim, E.A. 2021. Antiviral activity of *Lavandula angustifolia* L. and *Salvia officinalis* L. essential oils against Avian influenza H5N1 virus. In *Journal of Agriculture and Food Research*, *4*, 100135. https://doi.org/10.1016/j.jafr.2021.100135

Agrawal, R., Yusufsaheb, Y.G., Narasimhamurthy, N., Itagi, A.B.H., Kulshrestha, R., & Patil, S.R. 2021. Anti-microbial activity of hempseed oil and sage oil against Streptococcus mutans and *Candida albicans*: an *in vitro* study. In *Pesquisa Brasileira Em Odontopediatria e Clinica Integrada*, *21*, e0251. https://doi.org/10.1590/pboci.2021.115

Bouajaj, S., Benyamna, A., Bouamama, H., Romane, A., Falconieri, D., Piras, A., & Marongiu, B. 2013. Antibacterial, allelopathic and antioxidant activities of essential oil of *Salvia officinalis* L. growing wild in the Atlas Mountains of Marocco. In *Natural Product Research*, *27*(18), 1673–1676. http://doi.org/dx.doi.org/10.1080/14786419.2012.751600

Çamlica, M., & Yaldiz, G. 2019. Characterization of morphological and yield variation of fenugreek (*Trigonella foenum-graecum* L.) genotypes. In *Legume Research*, *444*, 1–5. https://doi.org/10.18805/LP-444

Couladis, M., Tzakou, O., Dukić-Mimica, N., Jančić, R., & Stojanović, D. 2002. Essential oil of *Salvia officinalis* L. from Serbia and Montenegro. In *Flavour and Fragrance Journal*, *17*(2), 119–126. https://doi.org/10.1002/ffj.1065

Demirci, B., Başer, K.H.C., & Tümen, G. 2002. Composition of the essential oil of *Salvia aramiensis* Rech. fil. Growing in Turkey. In *Flavour and Fragrance Journal*, *17*, 23–25. https://doi.org/10.1002/ffj.1027

Dudchenko, V., Svydenko, L., Markovska, O., & Sydiakina, O. 2020. Morphobiological and biochemical characteristics of *Monarda* L. varieties under conditions of the Southern Steppe of Ukraine. In *Journal of Ecological Engineering*, *21*(8), 99–107. https://doi.org/10.12911/22998993/127093

El Euch, S.K., Hassine, D.B., Cazaux, S., Bouzouita, N., & Bouajila, J. 2019. *Salvia officinalis* essential oil: chemical analysis and evaluation of anti-enzymatic and antioxidant bioactivities. In *South African Journal of Botany*, *120*, 253–260. https://doi.org/10.1016/j.sajb.2018.07.010

Elyemni, M., Louaste, B., Nechad, I., Elkamli, T., Bouia, A., Taleb, M., Chaouch, M., & Eloutassi, N. 2019. Extraction of essential oils of *Rosmarinus officinalis* L. by two different methods: hydrodistillation and microwave-assisted hydrodistillation. In *The Scientific World Journal*, *3659432*, 1–6. https://doi.org/10.1155/2019/3659432

Farhat, M.B., Jordan, M.J., Chaouch-Hamada, R., Landousli, A., & Sotomayor, J.A. 2016. Phenophase effect on sage (*Salvia officinalis* L.) yield and composition of essential oil. In *Journal of Applied Research on Medicinal and Aromatic Plants*, *3*(3), 87–93. https://doi.org/10.1016/j.jarmap.2016.02.001

Fernández-Sestelo, M., & Carrillo, J.M. 2020. Environmental effects on yield and composition of essential oil in wild populations of spike lavender (*Lavandula latifolia* Medik.). In *Agriculture*, *10*, 626. https://doi/org/10.3390/agriculture10120626

Frolova N., Ukrainets, A., Korablova, O., & Voitsekhiskyi, V. 2021. Plants of *Nepeta cataria* var. *citriodora* Beck. and essential oils from them for food industry. In *Potravinarstvo Slovak Journal of Food Sciences*, *13*(1), 449–455. https://doi.org/10.5219/1109

González-Gallegos, J.G., Bedolla-García, B.Y., Cornejo-Tenorio, G., Fernandez-Alonso, J.L., Fragoso-Martínez, I., García-Peña, M.R., Harley, R.M., Klitgaard, B., Martínez-Gordillo, M.J., Wood, J.R.I., Zamudio, S., Zona, S., & Xifreda, C.C. 2020. Richness and distribution of *Salvia* subg. Calosphace (Lamiaceae). In *International Journal of Plant Science*, *181*(8), 831–856. https://doi.org/10.1086/709133

Grdiša, M., Jug-Dujaković, M., Lončarić, M., Carović-Stanko, K., Ninčević, T., Liber, Z., Radosavljević, I., & Šatović, Z. 2015. Dalmatian sage (*Salvia officinalis* L.): a review of biochemical contents, medicinal properties and genetic diversity. In *Agriculturae Conspectus Scientificus*, *80*(2), 69–78.

Hamidpour, M., Hamidpour, R., Hamidpour, S., & Shahlari, M. 2014. Chemistry, pharmacology, and medicinal property of sage (*Salvia*) to prevent and cure illnesses such as obesity, diabetes, depression, dementia, lupus, autism, heart disease, and cancer. In *Journal of Traditional and Complementary Medicine*, *4*, 82–88. https://doi.org/10.4103/2225-4110.130373

Harizia, A., Benguerai, A., Elouissi, A., Mahi, T., & Bonal, R. 2021. Chemical composition and biological activity of *Salvia officinalis* L. essential oil against *Aphis fabae scopoli* (hemiptera: Aphididae). In *Journal of Plant Diseases and Protection*, *128*(6), 1547–1556. https://doi.org/10.1007/s41348-021-00525-z

Hassiotis, C. N. 2018. The role of aromatic *Salvia officinalis* L. on the development of two mycorrhizal fungi. In *Biochemical Systematics and Ecology*, *77*, 61–67. https://doi.org/10.1016/j.bse.2018.01.004

Hazrati, S., Beidaghi, P., Beyraghdar Kashkooli, A., Hosseini, S. J., & Nicola, S. 2022. Effect of harvesting time variations on essential oil yield and composition of sage (*Salvia officinalis*). In *Horticulturae*, *8*(2). https://doi/org/10.3390/horticulturae8020149

Hudz, N., Makowicz, E., Shanaida, M., Biało, M., Jasicka-Misiak, I., Yezerska, O., Svydenko L., & Wieczorek, P.P. 2020. Phytochemical evaluation of tinctures and essential oil obtained from *Satureja montana* herb. In *Molecules*, *25*, 4763. https://doi.org/10.3390/molecules 25204763

Jug-Dujaković, M., Ristić, M., Pljevljakušić, D., Dajić-Stevanović, Z., Liber, Z., Hančović, R., Radic, T., & Šatović, Z. 2012.

High diversity of indigenous populations of dalmatian sage (*Salvia officinalis* L.) in essential-oil composition. In *Chemistry and Biodiversity*, *9,* 2309–2323.

Kahraman, A., Celep, F., & Dogan, M. 2010. Anatomy, trichome, morphology and palynology of *Salvia chrysophylla* Stapf (Lamiaceae). In *South African Journal of Botany*, *76*, 187–195. https://doi.org/10.1016/j.sajb.2009.10.003

Khaled-Gasmi, W., Hamouda, A. B., Chaieb, I., Souissi, R., Ascrizzi, R., Flamini, G., & Boukhris-Bouhachem, S. 2021. Natural repellents based on three botanical species essential oils as an eco-friendly approach against aphids. In *South African Journal of Botany*, *141*, 133–141. https://doi.org/10.1016/j.sajb.2021.05.001

Korablova, O., Rakhmetov, D., Frolova, N., Yushchenko, N., Shanaida, M., & Svydenko, L. 2019. Bioecological characteristics plants of *Salvia verticillata* L. under condition Forest-Steppe zone of Ukraine. In *Agrobiodiversity for Improving Nutrition, Health and Life Quality*, *3*, 203–211. https://doi.org/10.15414/agrobiodiversity.2019.2585-8246.203-211

Korablova, O. A., Rakhmetov, D. B., Shanaida, M. I., Vergun, O. M., Bagatska, T. S., Svydenko, L. V., & Ivashchenko, I. V. 2021. The content of macro- and microelements in plants of the genus *Artemisia* under conditions of introduction in the M. M. Gryshko National Botanical Garden of the NAS of Ukraine. In *Plant Varieties Studying and Protection*, *17*(3), 199–209. https://doi.org/10.21498/2518-1017.17.3.2021.242983

Korablova, O., Vergun, O., Fishchenko, V., Haznyuk, M., & Rakhmetov, D. 2020. Evaluation of some biochemical parameters of raw of *Artemisia* spp. (Asteraceae Berchht. & J. Presl.). In *Agrobiodiversity for Improving Nutrition, Health and Life Quality, 4,* 13–22. https://doi.org/10.414/agrobiodiversity.2020.2585-8246.0013-022

Kutko, S.P., Rabotyagov, V.D., & Orel, T.I. 2002. Morpfobiologicheskoe izuchenie *Salvia officinalis* L. v usloviyah Predgornoi zony Kryma [The morphobiological study of *Salvia officinalis* L. in the pre-mountain conditions of Crimea]. *Materialy mezhdunarodnoi nauchnoi konferencii "Sovremennye voprosy sozdaniia I ispolzovaniia sortov I gibridov maslichnyh kultur"* [Proceedings of International Scientific Conference "Modern questions of creation and use of cultivars and hybrids of oil plants"]. Zaporizhzhia, p. 34. [In Russian]

Lichinkina, N., & Svydenko, L. 2006. Peculiarities of biology and biochemistry of *Salvia officinalis* L. in the Southern Steppe zone of Ukraine conditions. In *Plant Introduction*, *30*(2), 79–82. https://doi.org/10.5281/zenodo.2567143

Mňahončaková, E., Vergun, O., Svydenko, L., Horčinová Sedlačková, V., Hrúzová, M., Brindza, J., & Ivanišová, E. 2019. Antioxidant potential of Lamiaceae herbs from Botanical Garden of Slovak University of Agriculture in Nitra. In *Agrobiodiversity for Improving Nutrition, Health and Life Quality, 3*, 462–472. https://doi.org/10.15414/agrobiodiversity.2019.2585-8246.462-472

Morkeliūnė, A., Rasiukevičiūtė, N., Šernaitė, L., & Valiuškaitė, A. 2021. The use of essential oils from thyme, sage and peppermint against Colletotrichum acutatum. In *Plants*, *10*(1), 1–11. https://doi.org/10.3390/plants10010114

Mossi, A.J., Cansian, R.L., Paroul, N., Toniazzo, G., Oliveira, J.V., Pierozan, M.K., Pauletti, G., Rota, L., Santos, A.C.A., & Serafiri, L.A. 2011. Morphological characterization and agronomical parameters of different species of *Salvia* spp. (Lamiaceae). In *Brazilian Journal of Biology*, *71*(1), 121–129.

Pitarević, I., Kuftinec, J., Blažević, N., & Kuštrak, D. 1984. Seasonal variation of essential oil yield and composition of dalmatian sage, *Salvia officinalis*. In *Journal of Natural Products*, *47*(3), 409–412. https://doi.org/10.1021/np50033a002

Pokajewicz, K., Biało, M., Svydenko, L., Fedin, R., & Hudz, N. 2021. Chemical composition of the essential oil of the new cultivars of *Lavandula angustifolia* Mill. bred in Ukraine. In *Molecules*, *26*, 5681. https://doi.org/10.3390/molecules26185681

Rajabi, Z., Ebrahimi, M., Farajpour, M., Mirza, M., & Ramshini, H. 2014. Composition and yield variation of essential oils among and within nine *Salvia* species from Iran. In *Industrial Crops and Products*, *61*, 233–239. https://doi.org/10.1016/j.indcrop.2014.06.038

Rashidipour, M., Shakib, P., Goudarzi, G., Pournia, Y., Karimi, M., & Sarlak, M. 2022. Native Iranian medicinal plants with anti-vaginal infection properties: a systematic review. In *Infectious Disorders – Drug Targets*, *22*(6), 41–47. https://doi.org/10.2174/1871526522666220501171551

Rowsan, V., Khosh Khoi, M., & Javidnia, K. 2010. Effect of salicylic acid on quality and quantity of essential oil components in Salia microsiphon. In *Journal of Biology and Environmental Sciences*, *4*(11), 77–82.

Sellami, H.K., Flamini, G., Cioni, P.L., & Smiti, S. 2011. Composition of the essential oils in various organs at different developmental stages of *Ammi visnagi* (L.) Lam. from Tunisia. In *Chemistry and Biodiversity*, *8*(11), 1990–2004. https://doi.org/10.1002/cbdv.201100128

Selim, S., Almuhayawi, M. S., Alqhtani, H., Al Jaouni, S. K., Saleh, F. M., Warrad, M., & Hagagy, N. 2022. Anti-salmonella and antibiofilm potency of *Salvia officinalis* L. essential oil against antibiotic-resistant *Salmonella enterica*. In *Antibiotics*, *11*(4). https://doi.org/10.3390/antibiotics11040489

Shakoor, A., Zhao, F., Zaib, G., Li, W., Lan, X., & Esfandani-Bozchalayi, S. 2021. Morphometric analysis and sequence-related amplified polymorphism determine genetic diversity in *Salvia* species. In *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *49*(1), 12153. https://doi.org/10.15835/nbha49112153

Sharopov, F., Valiev, A., Sobeh, M., Arnold, E., & Winka, M. 2018. Bioactivity of three *Salvia* species in relation to their total phenolic and flavonoid content.). In *Pharmaceutical Chemistry Journal*, *52*(7), 596–600. https://doi.org/10.1007/s11094-018-1866-6

Svydenko, L.V., Yezhov, V.M. 2014. Perspektyvy vyroschuvannya deyakyh efiroliinyh kultur v Stepu Pivdennomu [Perspectives of cultivation of selected essential-oil plants in the Southern Steppe]. In *Visnyk Agrarnoji nauku* [*Bulletin of Agrarian Science*], *6*, 20–24. [In Ukrainian]

Svydenko, L., & Lichinkina, N. 2005. The biological peculiarities and accumulation of the essential oil by *Salvia sclarea* L. in Kherson region conditions. In *Plant Introduction*, *26*(2), 37–39. https://doi.org/10.5281/zenodo.2584370

Svydenko, L., Grygorieva, O., Vergun, O., Hudz, N., Horčinová Sedlačková, V., Šimková, J., and Brindza, J. 2018. Characteristic of leaf peltate glandular trichomes and their variability of some Lamiaceae Martinov family species. In *Agrobiodiversity for Improving Nutrition, Health and Life Quality, 2*, 124–132. https://doi.org/10.15414/agrobiodiversity.2018.2585-8246.124-132

Taarit, M.B., Msaada, K., Hosni, K., Hammami, M., Kchouk, M.E., & Marzouk, B. 2009. Plant growth, essential yield and composition of sage (*Salvia officinalis* L.) fruits cultivated under salt stress conditions. In *Industrial Crops and Products*, *30*, 333–337. https://doi.org/10.1016/j.indcrop.2009.06.001

Traykova, B., Stanilova, M., Nikolova, M., & Berkov, S. 2019. Growth and essential oils of *Salvia officinalis* L. plants derived from conventional or aeroponic-produced seedlings. In *Agriculturae Conspectus Scientificus*, *84*(1), 77–81.

Vergine, M., Nicoli, F., Negro, C., Luvisi, A., Nutricati, E., Accogli, R.A., Sabella, E., & Micelli, A. 2019. Phytochemical profiles and antioxidant activity of *Salvia* species from Southern Italy. In *Records of Natural Products*, *13*(3), 205–215. https://doi.org/10.25135/mp.96.18.07.119

Vergun, O., Shymanska, O., Rakhmetov, D., Bondarchuk, O., & Rakhmetova, S. 2021. Morphometric parameters of plants of *Crambe* spp. during vegetation. In *Agrobiodiversity for Improving Nutrition, Health and Life Quality, 5*(2), 233–240. https://doi.org/10.15414/ainhlq.2021.0022

Vergun, O., Svydenko, L., Grygorieva, O., Horčinová Sedlačková, V., Fatrcová Šramková, K., Ivanišová, E., & Brindza, J. 2022. Polyphenol content and antioxidant activity of *Thymus* spp. In *Potravinarstvo*, *16*(1), 1–14. https://doi.org/10.5219/1715

Verma, R.S., Padalia, R.C., & Chauhan, A. 2015. Harvesting season and plant part-dependent variations in the essential oil composition of *Salvia officinalis* L. grown in Northern India. In *Journal of Herbal Medicine*, *5*(3), 165–171. https://doi.org/10.1016/j.hermed.2015.04.004

Vosoughi, N., Gomarian, M., Ghasemi Pirbalouti, A., Khaghani, S., & Malekpoor, F. 2018. Essential oil composition and total phenolic, flavonoid contents, and antioxidant activity of sage (*Salvia officinalis* L.) extract under chitosan application and irrigation frequencies. In *Industrial Crops and Products*, *117*, 366–374. https://doi.org/10.1016/j.indcrop.2018.03.021

Wightman, E.L., Jackson, P.A., Spittlehouse, B., Heffernan, T., Guillemet, D., & Kennedy, D. O. 2021. The acute and chronic cognitive effects of a sage extract: a randomized, placebo-controlled study in healthy humans. In *Nutrients*, *13*(1), 1–21. https://doi.org/10.3390/nu13010218

Yezerska, O., Darmograj, R., Hudz, N., & Levon, V. 2021. Prospects of the application of some species of the Lamiaceae family and some features of the development of their tinctures. In *Agrobiodiversity for Improving Nutrition, Health and Life Quality*, *5*(1), 72–79. https://doi.org/10.15414/ainhlq.2021.0008

Zawiślak, G. 2014. Yield and chemical composition of essential oil from *Salvia officinalis* L. in the third year of cultivation. In *Herba Polonica*, *60*(3), 13–22. https://doi.org/10.2478/hepo-2014-0012