



# Initial introduction of selected promising foreign medicinal species for establishing a collection of essential-oil plants

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## Research

### Abstract

**Background:** The article presents the results of the initial introduction of several promising foreign medicinal plants aimed at establishing a collection of essential-oil species at the Tashkent Botanical Garden. The obtained data can be used to expand the assortment of medicinal and essential-oil plants, as well as to develop specialized collections and implement new crops in agricultural practice.

**Methods:** Phenological observations and biometric measurements (Shulz 1981) were carried out throughout the growing season of essential-oil plants in 2025. Following the traditional methodology of phenological observations (Methodology... 1975), the dates of the following phenological phases were recorded: onset of vegetation, beginning of budding, flowering period, fruit ripening, and end of the growing season.

**Results:** Under the agrocenosis conditions of the Botanical Garden, the introduced species (*Agastache scrophulariifolia*, *Dracocephalum moldavica*, *Hyssopus ambiguus*, *Leonurus cardiaca*, *Monarda citriodora*, *Nigella damascena*, *Origanum laevigatum*, *Salvia deserta*, *Scutellaria albida* subsp. *colchica*, *Scutellaria altissima*) reached the flowering and fruiting phases during their first year of vegetation. For *Salvia hispanica*, flowering was observed in the second half of October; however, due to a sharp temperature drop, flowering and seed formation were interrupted, and viable seeds were not obtained. In *Scutellaria albida* subsp. *colchica*, *Scutellaria altissima*, and *Nigella damascena*, self-seeding and rapid transition to generative stages were recorded, indicating their successful adaptation to the introduction conditions. Analysis of flowering times showed a shift compared to their natural habitats, with the introduced species being classified into five groups based on the onset of flowering.

**Conclusion:** The introduced species (*Hyssopus ambiguus*, *Origanum laevigatum*, *Agastache scrophulariifolia*, *Leonurus cardiaca*, *Monarda citriodora*, *Dracocephalum moldavica*, *Scutellaria albida* subsp. *colchica*, *Scutellaria altissima*, *Salvia deserta*, and *Nigella damascena*) of alien flora successfully completed a full ontogenetic cycle and produced viable seeds during their first year of vegetation under the conditions of the Botanical Garden. *Salvia hispanica* is characterized by

genetically determined short-day flowering without photoperiodic variability and, considering the successful seed formation in the subtropical zone of Uzbekistan, can be recommended for cultivation in the Surkhandarya region. *Scutellaria albida* subsp. *colchica*, *Scutellaria altissima*, and *Nigella damascena* successfully regenerate through self-seeding and partially proceed to generative development, indicating their good adaptation to the new growth conditions.

**Keywords:** adaptation, creation of collections, essential oil plants, foreign species, introduction, medicinal plants, phenology.

## Background

Plant introduction is the fastest way to enrich the local flora with species valuable for economic purposes (Malysheva 1973; Bedulenko 2013).

Creating plant collections in botanical gardens or other protected natural areas allows for a comprehensive assessment of the biological and morphological traits of species when transferred to new climatic conditions (Andreev *et al.* 2006; Plugar & Shevchuk 2019; Pshenchikina *et al.* 2024).

Established collections or expositions serve as a basis for breeding programs aimed at developing cultivars with specific traits, such as frost resistance, disease resistance, or drought tolerance. Expanding the range of cultivated plants through foreign species reduces dependence on imported raw materials for the pharmaceutical, food, and perfumery-cosmetic industries (Chasovskikh & Gagiyeva 2011; Marko *et al.* 2018; Morozov 2018; Vysochina 2020; Zamani *et al.* 2025).

Foreign flora, particularly species from the circumboreal, North American, or Mediterranean floristic regions, is rich in taxa that can surpass local analogues in productivity or in the uniqueness of their chemical composition (Pestsov *et al.* 2009; Martynova 2019; Ivoylov & Khapugin 2021). North American species, such as *Monarda fistulosa* L. and *Monarda didyma* L., significantly exceed many local essential-oil plants in thymol and carvacrol content, exhibiting strong antiseptic properties (Melnik *et al.* 2018). Species like *Agastache rugosa* (Fisch. & C.A. Mey.) Kuntze and *A. foeniculum* (Pursh) Kuntze are valued for their unique anise-like aroma and high green biomass productivity, which can be several times higher than that of traditional medicinal herbs of the region (Portnyagina *et al.* 2022; Kolomiets & Shplis 2023; Kravtsova *et al.* 2025). Mediterranean representatives, such as *Hyssopus officinalis* L., are distinguished by high drought tolerance and, due to their broad phytochemical profile, are in demand in the food, canning, and processing industries (Kormosh *et al.* 2018).

In the sharply continental climate of Uzbekistan, characterized by harsh winters and hot, dry summers, the establishment of scientific collections of essential-oil plants should focus on winter hardiness and the preservation of oil quality under temperature stress. The sharply continental climate often induces plants to increase the production of secondary metabolites (essential oils) as a protective response to ultraviolet radiation and drought (Kondratyev *et al.* 2018; Rodríguez-Hernández 2019; Karalija *et al.* 2022; Dyakova *et al.* 2023; Laftouhi *et al.* 2023; Jangpangi *et al.* 2025; Nutfilloyeva & Safarov 2025). Studying the quality and quantity of essential oils under the specific conditions of a region is necessary to identify the most promising forms with high content of biologically active compounds (Oztürk *et al.* 2009; Vidic *et al.* 2010; Biswas *et al.* 2011; Karalija *et al.* 2022).

For establishing a scientific collection of plants under sharply continental climatic conditions, natural stratification (late autumn sowing) is the most reliable method for improving the quality of seed propagation. Plants undergo a natural hardening cycle, which is critically important for foreign introducents that must overwinter under harsh conditions. Stratified seeds produce plants with a more robust root system. In conditions of dry summers and severe winters, this is particularly crucial: the deeper the roots develop in the first year, the higher the chances that the collection will survive the winter (Fakhriddinova & Khamraeva 2024).

Currently, interest in studying essential-oil plants is driven by several factors. First, most of these species are medicinal, and interest in them is growing because widely used synthetic drugs, while having therapeutic effects, can often cause serious side effects, including allergic reactions. It is well known that natural products are generally less harmful, making them widely applicable in the prevention and treatment of various diseases. Second, the use of essential-oil plants in landscape design is attracting increasing attention as an accessible and relatively low-cost means of optimizing the environment. A rational approach to selecting and arranging plants, considering not only their aesthetic but also phytosanitary properties, has become particularly relevant in agro-landscapes. Essential-oil plants in landscape design positively influence the microclimate, reducing the number of pathogenic and conditionally pathogenic microorganisms in the air, enhancing human performance,

and improving psycho-emotional well-being, thereby expanding their use in creating therapeutic and wellness compositions (Gladysheva 2016).

At present, the Tashkent Botanical Garden lacks a raw material base of medicinal essential-oil plants. Only a small number of species are maintained in the medicinal plant collection of the Laboratory of Introduction and Agroecology of Raw Material Plants, which does not allow for the industrial-scale harvesting of medicinal raw materials (Khamraeva *et al.* 2024).

Primary introduction allows for the assessment of plants' adaptive potential under new soil and climatic conditions, their growth and developmental characteristics, progression through ontogenetic stages, and prospects for generative reproduction. The creation of specialized collections in botanical gardens is an important step in the conservation, study, and subsequent implementation of introduced species into cultivation.

In the conditions of the Tashkent Botanical Garden, introduction studies of foreign medicinal and essential-oil plants are particularly relevant, as the continental climate of the region differs significantly from the natural habitats of many introduced species. This necessitates a comprehensive evaluation of their biological and phenological traits, resilience, and adaptive capacity.

Therefore, the aim of this study is the primary introduction of several promising essential-oil plants from foreign flora under the conditions of the Tashkent Botanical Garden, with a view to their further cultivation and practical application in the Republic of Uzbekistan.

## Materials and Methods

Botanical Garden on the modern territory, was founded in 1950. Currently, the area of the Botanical Garden is 66.5 hectares (Fig. 1). The Botanical Garden is located in the northeastern part of Tashkent, 480 m above the sea level. Its territory has a roughly triangular shape, from the south and southeast the border runs along the shore of the Salar River. In the northern part of the garden, near the entrance, the Akkurgan River flows. The total area of the laboratory of introduction of medicinal plants collection is 0.78 hectares, with coordinates 41°20'42.4''N 69°18'44.2''E.

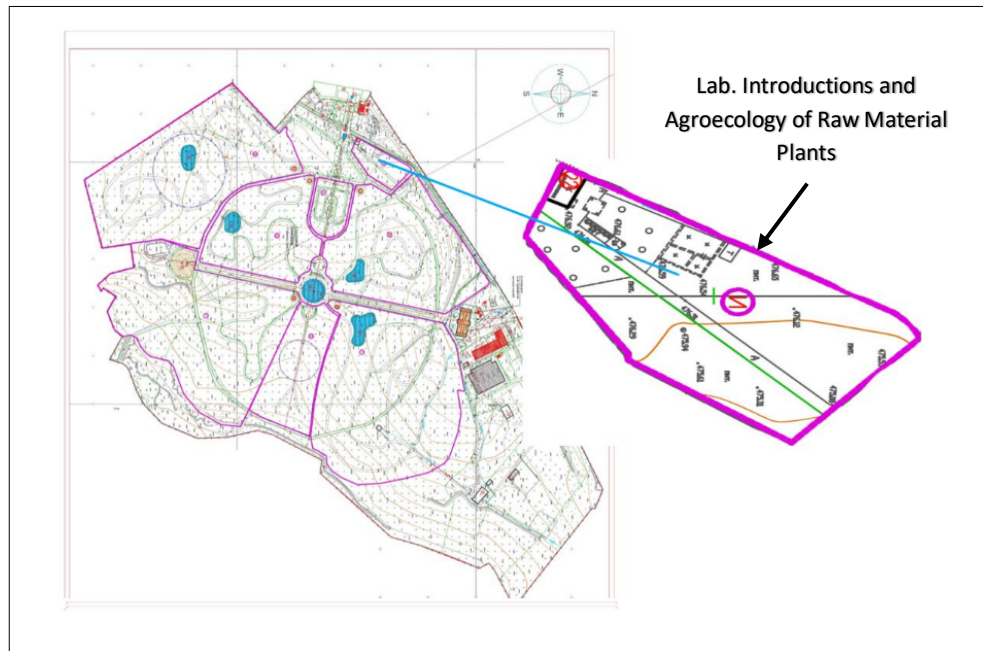


Figure 1. Schematic map of the Tashkent Botanical Garden

The climate of Tashkent is sharply continental and is characterized by high insolation (duration of sunshine 2871 h/year), dryness, significant daily temperature fluctuations, hot summers, dry, warm autumn, and moderately cold winters. The absolute minimum temperature is ...-25,80 °C (very rarely), the absolute maximum is... + 44.6 °C. The main amount of precipitation, according to long-term data, is 380-440 mm, which falls during the autumn-winter-spring periods (Belolipov

1989). The climate of Tashkent according to the Köppen-Geiger system is classified as Csa (hot summer Mediterranean climate). The temperature here averages 14.1 °C. The average annual rainfall is 623 mm (<https://ru.climate-data.org>).

Seeds of 10 plant species from the family Lamiaceae Martinov and 1 species from the family Ranunculaceae Juss. were obtained from botanical gardens of various CIS countries (Russia: N.V. Tsitsin Main Botanical Garden of the Russian Academy of Sciences; Belarus: Central Botanical Garden of the National Academy of Sciences; Kazakhstan: Zhezkazgan Botanical Garden and Almaty Botanical Garden) in 2023-2024 through international cooperation (Table 1). The seeds were sown in small containers with a closed root system at two different times - late autumn (29 November 2024) and early spring (12 February 2025) - using mixtures of different substrates: 100% peat mixture (peat, coconut substrate, biohumus, perlite) and a 50/50 peat-sand mixture for late autumn sowing; 100% peat mixture for early spring sowing.

Photography of plants was carried out by the digital camera Canon EOS 250D. Phenological observations and biometric measurements (Shultz 1981) were carried out during the growing season of essential oil plants during 2025. According to the traditional methodology of phenological observations (Methodology ... 1975), the dates of the following phenophases were recorded: the beginning of vegetation, the beginning of budding, the flowering season, fruit ripening, end of the growing season. The sum of effective temperatures (SET) is defined as the sum of positive mean daily temperatures from the beginning of vegetation up to the onset of a specific phenological phase (flowering) at +5°C and above (Losev 1994).

Between 14 and 23 April 2025, the studied plants at the seedling and juvenile ontogenetic stages, grown in small containers with closed root systems, were transplanted into open ground to monitor their growth and development under full sunlight. However, due to higher-than-average air temperatures in April and May compared to previous years, and a sharp decrease in relative humidity, the monitoring plot was covered with a plastic mesh on 24 May to protect the plants from the harmful effects of solar radiation.

Table 1. Ecogeographical characteristics of the introduced species

<i>Species name</i>	<i>Ecology / Habitat</i>	<i>Geography*</i>
<i>Agastache scrophulariifolia</i> (Willd.) Kuntze	Riparian areas, open sites, and meadows	Eastern Canada, north-central and southern regions of the USA
<i>Dracocephalum moldavica</i> L.	Dry hills, rocky riverbanks, valleys; 200-2700 m above sea level	From Iran to the Russian Far East
<i>Hyssopus ambiguus</i> (Trautv.) Iljin ex Prochorov. & Lebel	Rocky and gravelly slopes, foothills and lower mountain slopes, rocky riverbanks	Altai, Kazakhstan, Mongolia, Western Siberia
<i>Leonurus cardiaca</i> L.	Vacant lots, along railways and roads, pastures, rocks, old quarries, and riverbanks	Mediterranean region, Europe, Iran
<i>Monarda citriodora</i> Cerv. ex Lag.	Steppes, roadsides, and other sunny sites	from Central and South America to Northern and Western Mexico
<i>Origanum laevigatum</i> Boiss.	Subtropical biomes	Southern Turkey, northwestern Syria, Cyprus
<i>Salvia deserta</i> Schangin	Mountain steppe slopes, forest edges, riverbanks, as a weed	From Central Asia to southwestern Siberia and Xinjiang
<i>Salvia hispanica</i> L.	Mountain areas with well-drained sandy or clay soils, at 1800-2600 m above sea level	Mexico, Guatemala
<i>Scutellaria albidia</i> subsp. <i>colchica</i> (Rech.f.) J.R.Edm.	Rocky slopes, forests, shrubs, at 50-1500 m above sea level	Northeastern Turkey, Crimea, Transcaucasia
<i>Scutellaria altissima</i> L.	Forests, shrubs, pasture slopes	From East-Central Europe to the Caucasus
<i>Nigella damascena</i> L.	Dry steppe slopes and as a weed	Macaronesia, from the Mediterranean region to northwestern Iran

\* Natural species distribution worldwide according to POWO (<https://powo.science.kew.org/>).

## Results and Discussion

### *Agastache scrophulariifolia*

The plants were transplanted into open ground on 18 April 2025. By 3 June, the plants had reached the virginal stage of development, with 5-8 metamers formed on the main shoot (Fig. 2). Plant height ranged from 7 to 22 cm. Leaves were simple, opposite, with large serrated margins; the teeth were distinct and rounded. Leaf blade length ranged from 2.2 to 7 cm, width

1.8-5.5 cm, and petiole length 1.5-3.5 cm. By 24 June, plant height had increased to 34-70 cm, with 10-13 metamers on the main stem and first-order lateral shoots developing from the middle part of the plant (Table 2).

Observations on 5 August revealed that racemose inflorescences with white or lilac flowers had formed on the main stem and first- and second-order lateral shoots of generative plants. Plant height reached 110-112 cm, with up to 14 nodes on the main stem. First-order lateral shoots measured 39-49 cm in length, bearing 5-7 opposite inflorescences. Second-order lateral axes measured 7-12 cm, with 4-6 nodes and a total of 1-5 inflorescences arising from the axils of opposite leaves or from a single leaf axil. Seed ripening continued until the first frosts in early November.

Species of the genus *Agastache* J. Clayton ex Gronov. do not naturally occur in Uzbekistan; however, another species of this genus, the perennial herb *Agastache foeniculum* (Pursh) Kuntze, has been cultivated in the Tashkent Botanical Garden since 2014 (Khamraeva *et al.* 2024). Its full life cycle under introduction conditions lasted five years. Ecological, biological, and phytochemical characteristics of *A. foeniculum* under introduction conditions were comparable to those reported from its natural habitat (Fakhriddinova & Khamraeva 2024).

*Agastache scrophulariifolia* is also a perennial herbaceous species, which showed positive results in the first year of vegetation. Historically, this plant was used by Native American tribes such as the Iroquois and Chippewa for respiratory ailments, particularly colds, coughs, and fevers. Over time, especially in the early 1900s, *A. scrophulariifolia* was incorporated into eclectic medicine (a system combining traditional and herbal therapies), where it was described as a carminative, diaphoretic, and mild nervine. With the revival of phytotherapy, it has reappeared in formulations intended for treating seasonal allergies, digestive disorders, and mental lethargy (<https://ask-ayurveda.com/wiki/article/86-agastache-scrophulariifolia>).

Furthermore, results by M.-A. Nechita *et al.* (2025) indicate that *A. scrophulariifolia* represents a promising natural source of polyphenolic compounds with potential therapeutic value for inflammatory and cardiovascular diseases associated with oxidative stress.

#### ***Dracocephalum moldavica***

The plants were transplanted into open ground on 18 April 2025. By 3 June, plant survival at the virginal stage of development was 70-80%. The main stem had 7-10 metamers, and first-order lateral shoots were developing from the middle metamers of the main stem (Fig. 3). Plant height ranged from 16 to 24 cm. Leaves were simple, opposite, slightly widened at the base, lanceolate, with rounded and slightly recurved marginal teeth. Leaf blade length was 3-7 cm, width 1-1.4 cm, and petiole length 0.4-1 cm.

By the end of the second decade of June, second-order lateral branches began forming from the middle portion of first-order lateral shoots. By 24 June, plant height reached 30-50 cm, and the main stem had 12-14 metamers. Budding of the generative period was observed on 29 June, flowering began on 13 July, and full bloom was recorded on 1 August (Table 2).

Observations on 5 August showed that plants had reached a height of 49-80 cm, with 17-25 nodes on the main stem and 10-14 pseudo-whorled inflorescences above it, each bearing three flowers per axil of opposite leaves. First-order lateral shoots measured 42-58 cm in length, and second-order lateral shoots 11-26 cm. Seed ripening continued until 25 September.

*Dracocephalum moldavica* has been traditionally used in folk medicine in Asia and Europe. Its aerial parts have been employed to treat digestive disorders, liver and stomach diseases, as well as to relieve cough and respiratory symptoms. In Chinese medicine, the plant is used to strengthen the heart and reduce "internal heat," while in Mexican traditional medicine it is applied as a calming agent for nervous conditions and anxiety (Zhan *et al.* 2024). Experimental studies have confirmed the anti-inflammatory, antioxidant, and antibacterial effects of the plant's extracts and essential oil, as well as its potential in treating pulmonary disorders by reducing inflammation (Aćimović *et al.* 2022). The plant contains rosmarinic acid, caffeic acid, tilianin, luteolin-7-glucuronide, and other flavonoids and phenolic acids, which possess antioxidant, anti-inflammatory, and cardioprotective properties (Wu *et al.* 2020).

#### ***Hyssopus ambiguus***

The plants were transplanted into open ground at the juvenile stage on April 18, 2025, and by June 3 they had reached the virginal stage of development (Fig. 4). Plant height reached 9-10 cm, with up to 10 metamers formed on the main stem. The leaves were narrow-lanceolate, 2-3.5 cm long, 4-6 mm wide, with petioles 0.4-0.6 cm long. By June 24, plant height increased to 25-30 cm, with 15-17 metamers on the main stem and branching of the first-order lateral shoots of basitonic and/or

Table 2. Phenological stages of the introduced species cultivated in full sun exposition (2025)

Species name	Start of vegetative growth	The beginning of budding	Beginning of flowering	Full bloom	End of flowering	Start of fruiting	End of fruiting	End of the growing season
<i>Agastache scrophulariifolia</i> (Willd.) Kuntze	25.02.2025	26.06.2025	14.07.2025	01.08.2025	31.10.2025	20.07.2025	03.11.2025	06.11.2025
<i>Dracocephalum moldavica</i> L.	19.02.2025	29.06.2025	13.07.2025	01.08.2025	20.09.2025	18.07.2025	25.09.2025	30.09.2025
<i>Hyssopus ambiguus</i> (Trautv.) Iljin ex Prochorov. & Lebel	24.02.2025	04.07.2025	16.07.2025	01.08.2025	03.11.2025	22.07.2025	03.11.2025	06.11.2025
<i>Leonurus cardiaca</i> L.	05.03.2025	07.06.2025	14.06.2025	02.07.2025	03.10.2025	22.06.2025	10.10.2025	06.11.2025
<i>Monarda citriodora</i> Cerv. ex Lag.	15.03.2025	26.05.2025	07.06.2025	25.06.2025	05.10.2025	15.06.2025	12.10.2025	18.10.2025
<i>Origanum laevigatum</i> Boiss.	03.03.2025	04.07.2025	16.07.2025	05.08.2025	05.11.2025	23.07.2025	03.11.2025	06.11.2025
<i>Salvia deserta</i> Scahngin	15.03.2025	02.08.2025	19.08.2025	03.09.2025	05.11.2025	30.08.2025	03.11.2025	06.11.2025
<i>Scutellaria albida</i> subsp. <i>colchica</i> (Rech. f.) J.R. Edm.	19.02.2025	03.06.2025	09.06.2025	27.06.2025	05.11.2025	11.06.2025	03.11.2025	06.11.2025
<i>Scutellaria altissima</i> L.	19.02.2025	30.05.2025	05.06.2025	21.06.2025	05.11.2025	07.06.2025	03.11.2025	06.11.2025
<i>Nigella damascena</i> L.	23.02.2025	10.05.2025	22.05.2025	02.06.2025	14.08.2025	26.05.2025	19.09.2025	23.09.2025

mesotonic types. The onset of the generative phase, marked by the formation of flower buds, was observed on July 4, and flowering began on July 16 (Table 2). However, due to anomalously high temperatures in July 2025, some plants perished at the end of the month. By August 5, the plants in the generative stage reached 57 cm in height, with up to 27 metamers on the main stem, first-order lateral shoots measuring 18-45 cm, and second-order lateral shoots 9-11 cm. Observations showed that 5-12 semi-whorled inflorescences with 3-5 flowers each formed in the axils of opposite leaves at the tops of stems, with seed maturation continuing until the first frosts in early November. As the species has a sub-shrub growth form, part of the shoot system became woody and persisted through the winter.

The Tashkent Botanical Garden has been cultivating the promising medicinal species *Hyssopus officinalis* for several decades (Khamraeva *et al.* 2024).

For *Hyssopus ambiguus*, native to central Kazakhstan, 1,8-cineole is the main component of the essential oil. Its antimicrobial properties have been studied, and based on these findings, methods have been developed to produce essential oil compositions with pleasant aromas for relatively inexpensive therapeutic and prophylactic preparations, capable of effectively combating upper respiratory infections (Atazhanova *et al.* 2024).

#### ***Leonurus cardiaca***

The plants were transplanted into open ground on April 14, 2025, and all individuals survived until the end of the growing season. Observations on June 3 revealed that the plants were at the virginal stage. Up to 6-12 metamers were formed on the main stem (Fig. 5), with plant heights ranging from 24 to 58 cm. First-order lateral shoots emerged from the lower metamers, with some individuals exhibiting larger lateral shoots due to rapid growth. The four-angled stem edges were more pubescent than other parts. Leaves were simple, opposite, with the lower surface and margins covered with short fine hairs. Leaf blade length ranged from 2 to 9 cm, width from 2.2 to 8 cm, and petiole length was 3-5 cm. Flowering began on June 14, 2025 (Table 2).

By June 24, plants in the generative stage had reached 90-110 cm in height, with 9-14 metamers on the main stem. Numerous cyclical inflorescences developed on the upper part of the main stem and at the apices of first-order lateral shoots located in the middle and upper parts of the main stem. Observations on August 5 showed that plants reached 131-145 cm in height, with 14 metamers on the main stem and up to 22-24 cyclical inflorescences above it. First-order lateral shoots measured 34-55 cm, and second-order lateral shoots reached 12 cm. Mature seeds were collected by early October.

*Leonurus cardiaca* has traditionally been used as a medicinal plant with sedative and cardiotonic effects. In phytotherapy, its aerial parts are applied to alleviate conditions associated with cardiac arrhythmias, nervous excitement, anxiety, and hypertension, as well as to support digestion and relieve spasms. Clinical studies and pharmacological data confirm the sedative, hypotensive, antibacterial, antioxidant, and anti-inflammatory effects of motherwort-based preparations. Beyond cardiac and nervine effects, it is also used in gynecological practice to manage menopausal symptoms, menstrual pain, and amenorrhea, and for topical applications in wound healing and skin inflammation (Wojtyniak *et al.* 2013).

#### ***Monarda citriodora***

The plants were transplanted into open ground on April 22. As of June 3, all transplanted individuals had survived and were at the generative stage of development. Up to 7-9 nodes were formed on the main stem, and plant height ranged from 30 to 50 cm (Fig. 6). First-order lateral shoots and pseudo-whorled inflorescences developed from the middle nodes of the main stem, starting from the 7th node. Leaves were simple, opposite, oblong-lanceolate; leaf blade length was 3-7 cm, width 1-1.4 cm, and petiole length 0.4-1 cm. Observations on June 7 indicated the onset of flowering (Table 2).

By June 24, generative plants reached a height of 51-85 cm, and 3-5 pseudo-whorled inflorescences were present on the main stem and first-order lateral shoots, arranged cyclically. Sympodial growth was observed due to elongation of first-order lateral shoots, while second-order lateral shoots with two metamers and pseudo-whorled inflorescences formed at their apical parts. As of August 5, generative individuals reached heights of 73-78 cm; first-order lateral shoots were 22-44 cm long, and second-order lateral shoots measured 18-27 cm. Seed maturation continued until October 12.

The leaves of the plant have a characteristic citrus aroma and are used in folk medicine and phytotherapy. They are most commonly consumed as herbal tea to support the respiratory system, particularly in cases of colds, coughs, and fever; the leaves are also brewed as a calming remedy for respiratory tract disorders. In traditional medicine, the plant is used to

alleviate symptoms of colds and respiratory infections. The main biologically active component of *Monarda citriodora* is the essential oil of the aerial parts, which is rich in terpenes and phenolic compounds (Lawson *et al.* 2021).

#### ***Origanum laevigatum***

The plants were transplanted into open ground on April 22, 2025. On June 3, the plants were in the virginal stage; the main stem was orthotropic, with 6-9 formed metamers (Fig. 7). Plant height ranged from 8 to 17 cm. The branching type was mesotonic, meaning that first-order lateral shoots developed from the middle part of the main stem. Leaves were simple, entire-margined, softly pubescent, triangular in shape; leaf blade length was 1.2-3.0 cm, width 1.1-2.1 cm, and petiole length 0.7-2.0 cm. The stem and leaf petioles were covered with short, erect hairs.

By June 24, plant height increased to 21-42 cm, with up to 9-14 metamers formed on the main stem. Observations on August 5 showed that in generative individuals, the length of the main stem ranged from 34 to 48 cm. At this stage, branching changed to an anisotropic pattern, and the soil surface was almost completely covered due to rapid formation of lateral shoots of different orders and adventitious roots developing from metamer growth points. Small purple-pink flowers were arranged in a panicle inflorescence, with seed maturation continuing until the first frosts in November (Table 2).

Although *Origanum laevigatum* lacks extensive ethnobotanical descriptions in the literature, the genus *Origanum* as a whole has long been used in traditional medicine as a medicinal and aromatic herb, particularly for digestive disorders, respiratory diseases, inflammatory conditions, and as a remedy to improve appetite and sleep. Essential oils and extracts of *Origanum* species are well known for their antiseptic, anti-inflammatory, antioxidant, and antispasmodic properties, largely due to the presence of phenolic compounds such as carvacrol and thymol (Sharifi-Rad *et al.* 2021).

#### ***Salvia deserta***

The plants were transplanted into open ground on April 23, 2025. As of June 3, the survival rate of individuals ranged from 92 to 98%. All plants were in the immature ontogenetic stage, with five pairs of leaves arranged oppositely in a rosette (Fig. 8). Leaves were simple, round to ovate in shape; the upper surface was rough, and the margins were finely and irregularly serrated with rounded teeth. Leaf blade length ranged from 4.0 to 6.5 cm, width from 2.5 to 3.0 cm, and petiole length from 3.0 to 4.0 cm. The petiole margins were covered with small spreading hairs.

By August 2, the formation of an orthotropic main shoot was observed in some plants. Its height ranged from 15 to 49 cm, with 2-5 metamers formed, and the initiation of inflorescence development was noted in the apical part. The inflorescences were densely pubescent false verticillasters, consisting of three flowers in each opposite leaf axil (six flowers in total). At the apex of the main stem, three elongated panicles were formed. Flowering began on August 19, 2025, starting from the lower part of the central inflorescence (Table 2). Below the metamer bearing the inflorescences on the main shoot, first-order lateral shoots developed, which also formed inflorescences.

Observations on September 12 showed that the length of the main stem reached 118-145 cm, and the shoot became prostrate. Seed maturation continued until the first frosts in early November.

In traditional medicine (e.g., among Uyghur practitioners), *Salvia deserta* has been used for the treatment of cough, excessive moisture-related disorders, urethritis, and cardiovascular symptoms. Its medicinal properties are described as heat-clearing, detoxifying, anti-edematous, and diuretic (Ren *et al.* 2023). Modern studies indicate that *S. deserta* extracts may exhibit immunomodulatory effects by influencing cytokine secretion and phagocyte activity, as well as demonstrating biological activity against inflammatory processes in cellular models (Zhussupova *et al.* 2022). Root extracts of *Salvia deserta* show antibacterial and antioxidant activities, making the species a promising source of raw material for the development of phytotherapeutic agents (Kustova *et al.* 2018). The essential oil of *S. deserta* contains numerous compounds, including  $\beta$ -phellandrene as the major component of the floral oil, along with phenolic acids and other terpene fractions typical of the genus *Salvia* (Li *et al.* 2015).

#### ***Salvia hispanica***

The plants were transplanted into open ground on April 22, 2025. Plant survival by the beginning of the summer season (June 3, 2025) was 100%. The plants were in the virginal stage of ontogenesis and had up to nine metamers on the main shoot stem. Branching was of the basitonic type. Plant height ranged from 65 to 70 cm (Fig. 9). Leaves were simple, opposite, broadly triangular, with large sharp teeth along the margins. The length of the leaf blade varied from 3.5 to 15.0 cm, width

from 2.0 to 8.0 cm, and petiole length from 3.5 to 8.5 cm. The leaves were covered with soft felt-like hairs, while the leaf blade and stem were sparsely covered with short hairs.

During observations on June 24, plant height reached 160-165 cm; the main shoot stem had up to 13 metamers, and first-order lateral shoots had up to six metamers. By August 5, plant height increased to 185-204 cm, with 22 nodes on the main shoot and 14 nodes on first-order lateral shoots. Due to rapid growth, the plant apices reached the protective net, which led to a deterioration in plant development from late July onward. Leaves began to curl and turn yellow, metamers on the stems twisted spirally, and the growth of the main shoot was markedly inhibited.

Bud development was observed from October 15, and the first flowers opened on October 28. However, negative air temperatures recorded in early November (-1 to -2 °C) resulted in complete freezing of the plants (Table 2).

The plant has traditionally been used by indigenous peoples of Central and South America as both a food and medicinal species. In modern phytotherapeutic practice, its seeds are distinguished by several valuable properties. They are a rich source of dietary fiber, which improves gastrointestinal function, lowers cholesterol levels, and helps regulate glycemia. The seeds contribute to cardiovascular health due to their high content of polyunsaturated fatty acids, particularly omega-3 fatty acids, which reduce the risk of atherosclerosis and hypertension. They also exhibit anti-inflammatory and antioxidant activity owing to the presence of phenolic compounds and flavonoids.

Polyunsaturated fatty acids constitute approximately 30-35% of the seed composition and include  $\alpha$ -linolenic acid (omega-3), linoleic acid (omega-6), and oleic acid, providing anti-atherogenic and anti-inflammatory effects. Proteins account for 18-23% of the seed content and possess a complete amino acid profile, rich in arginine and glutamine. These proteins are easily digestible and support metabolic processes. In addition, the seeds are rich in calcium, magnesium, phosphorus, potassium, and iron, making them beneficial for bone health and overall metabolism (Grancieri *et al.* 2019).

#### ***Scutellaria albida* subsp. *colchica***

The plants were transplanted into open ground on April 17, 2025, and survival by the beginning of summer ranged from 88 to 94%. Observations conducted on June 2 showed that all individuals were in the virginal stage of ontogenesis. The main shoot was orthotropic; the main stem bore up to 6-12 metamers, while first-order lateral shoots developed from the median metamers (Fig. 10). Plant height ranged from 10 to 40 cm.

Leaves were simple, opposite, cordate, with moderately serrated margins; the teeth were rounded and slightly tuberculate. Leaf blade length ranged from 2.0 to 4.0 cm, width from 1.5 to 3.5 cm, and petiole length from 1.4 to 2.6 cm. The budding phase was recorded on June 3, and flowering began on June 9.

According to observations on June 24, plant height reached 38-65 cm, the main shoot stem had 12-15 metamers, and the formation of an open inflorescence continued in its apical part. On first-order lateral shoots, similar inflorescences began to form from the 2nd to the 5th nodes. By August 5, plant height increased to 67-90 cm. Above the 12th-15th node on the main shoot, 11-29 opposite leaves were formed, each bearing a single flower in the leaf axil. The length of first-order lateral shoots ranged from 29 to 52 cm, second-order shoots from 17 to 39 cm, and third-order shoots from 7 to 19 cm.

Seed maturation continued until the first frosts in early November. Seeds that matured successfully germinated, producing new plants that developed to immature and virginal stages of ontogenesis before the onset of the first autumn frosts (Table 2).

There is no widely documented evidence of direct traditional phytotherapeutic use of *Scutellaria albida* subsp. *colchica* in folk medicine. However, species of the genus *Scutellaria* are generally used in phytotherapy due to the sedative, anti-inflammatory, antioxidant, and antispasmodic effects of their phytochemical constituents, particularly flavonoids and terpenes, which are characteristic of many *Scutellaria* species (Shah *et al.* 2022). Chemical analysis of the essential oil of *S. albida* subsp. *colchica* revealed hexadecanoic (palmitic) acid as the major component (approximately 13%), followed by other volatile compounds such as (E)-nerolidol and hexahydrofarnesyl acetone (Cicek *et al.* 2010).

#### ***Scutellaria altissima***

The plants were transplanted into open ground on April 17, 2025. Observations conducted on June 2 showed that some individuals were in the generative stage, while others remained in the virginal stage. In generative plants, up to nine

metamers were formed on the main shoot stem. First-order lateral shoots developed initially from the upper metamers and subsequently from the median and lower ones (Fig. 11). From the upper metamer of the stem, the formation of an open panicle-type inflorescence began. Plant height at this stage was approximately 24 cm.

Leaves were simple, opposite, triangular in shape, with large, rounded teeth along the margins. Leaf blade length ranged from 3.0 to 5.5 cm, width from 2.2 to 4.3 cm, and petiole length from 1.5 to 2.0 cm.

By June 24, the plants were in the generative stage; their height ranged from 23 to 47 cm. On first-order lateral shoots, 3-5 nodes were formed, while second-order lateral shoots developed up to three nodes. Observations on August 5 showed that plant height reached 33-47 cm; the length of first-order lateral shoots was 30-44 cm, and that of second-order lateral shoots was 15-18 cm. Seed maturation continued until the first frosts in early November.

Seeds produced by the plants germinated successfully, and the resulting seedlings developed to immature, virginal, and generative stages of ontogenesis before the onset of the first autumn frosts (Table 2).

Flavonoids such as baicalin, scutellarin, wogonoside, luteolin, and other phenolic compounds characteristic of the genus *Scutellaria* have been identified in this species. These compounds exhibit antioxidant activity and may inhibit processes associated with cellular aging and damage (Georgieva *et al.* 2021). The essential oil of the aerial parts of *Scutellaria altissima* is dominated by phenylpropanoids, particularly myristicin (~47.8%), linalool (~13.1%), apiol, and 1-octen-3-ol. This distinctive phytochemical profile may explain its specific organoleptic and biological properties and makes the species a promising subject for further pharmacological research and potential phytotherapeutic applications (Badalamenti *et al.* 2025).

#### ***Nigella damascena***

The plants were transplanted into open ground on April 14, 2025. From May 10, the budding stage of the generative period was recorded in the plants. Plant height ranged from 40 to 50 cm. Each plant formed 4-9 vegetative shoots from a single rosette (Fig. 12). The leaves are stiff, twice or thrice pinnately dissected, into narrow linear-bristly lobules and 5-12 cm long.

Flowering of solitary flowers at the tips of the stems was observed on May 22. On June 2, the mass flowering phase was recorded, and up to four first-order lateral shoots, 7-20 cm in length, formed on the main stem. Plant growth and development continued, resulting in the formation of second-order lateral shoots. Each lateral shoot also terminated in a flower, and the flowering process gradually shifted to these shoots. In June, synchrony between flowering and fruiting was observed, leading to lodging of all shoots under the weight of immature fruits. Seed maturation lasted from late July to the end of the second decade of September (Table 2). Seeds that had fallen germinated, and the resulting plants developed to immature, virginal, and generative stages before the onset of the first autumn frosts.

The species possesses valuable biological properties, including antioxidant and anti-inflammatory activity. Seed extracts contain polyphenols and flavonoids that reduce oxidative stress. Traditionally, the seeds have been used as antispasmodic and carminative agents to improve digestion and reduce flatulence; they were applied in cases of dyspepsia, meteorism, and colic. Seed infusions were used to strengthen the heart, relieve dyspnea, and alleviate cough. In folk medicine, the seeds were considered remedies for enhancing immunity, vital energy, and overall body strength. Seeds and seed oil exhibit antimicrobial activity against both Gram-positive and Gram-negative bacteria. Potential applications in cardiometabolic therapy have been suggested due to lipid-lowering effects and the presence of unsaturated fatty acids. In traditional medicine, the seeds are also used as antispasmodic, choleric, and anthelmintic agents, as well as for immune system support (Badalamenti *et al.* 2022).

The main objective of experiments on the introduction of non-native plant species is to assess their cultivation potential under new environmental conditions and to develop appropriate cultivation methods. One of the key aspects of plant adaptation to seasonal climatic conditions is the study of the rhythmic patterns of vital processes. The most evident and general expression of seasonal rhythms is the change in individual phenological phases, which usually represent the external manifestation of seasonal plant development. The timing and duration of phenological phase transitions reflect adaptive responses arising from external and internal structural changes under new conditions. The characterization of plants with short or long vegetation periods is interpreted as a hereditary trait formed during the historical and evolutionary process and aimed at ensuring successful reproduction and the production of viable offspring.

Under the agrocenotic conditions of the Botanical Garden, it was observed that the following adapted species - *Agastache scrophulariifolia*, *Dracocephalum moldavica*, *Hyssopus ambiguus*, *Leonurus cardiaca*, *Monarda citriodora*, *Nigella*

*damascena*, *Origanum laevigatum*, *Salvia deserta*, *Salvia hispanica*, *Scutellaria albida* subsp. *colchica*, and *Scutellaria altissima* - entered the flowering and fruiting phases of the generative period in the first year of vegetation, with the exception of *Salvia hispanica*.

In *Salvia hispanica*, growth was inhibited due to the experimental plot being covered with a polyethylene net; the main shoot contacted the net, became infected with a fungal pathogen, and inflorescence formation was observed only in the second half of October, with flowering occurring at the end of the month. However, as a result of a sharp temperature drop on November 4-5, the processes of flowering and seed maturation were interrupted. A unique biological feature of this species is that *Salvia hispanica* is a short-day flowering plant characterized by photoperiodic sensitivity and the absence of photoperiodic plasticity. In its native range, *S. hispanica* reaches heights of up to 1 m and has an annual herbaceous life form, whereas under the conditions of the present study it reached heights of up to 2 m or more. According to the literature, in the higher latitudes of the United States prior to 2012, sudden cold events occurring before or after flower formation halted seed development, limiting the production of mature seeds; more recently, seed-producing cultivars developed through breeding have been cultivated both in natural habitats and in the USA (Chia 2012; Jamboonsri *et al.* 2012). According to our data for 2024-2025, under the conditions of the Tashkent Botanical Garden, *S. hispanica* entered the flowering phase after mid-October, and fully mature seeds could not be obtained.

In three species - *Scutellaria albida* subsp. *colchica*, *Scutellaria altissima*, and *Nigella damascena* - individuals originating from freshly matured seeds were recorded during the same vegetation period. These individuals were observed at the immature and virginal stages in early October, while in the latter two species they reached the budding phase of the generative period by the middle of the first decade of the month. *Scutellaria altissima* began flowering on October 16, whereas in *Nigella damascena* the buds were damaged by frost during the first freezing events on November 4. Nevertheless, such rapid rates of development during the first year of vegetation indicate successful adaptation of these species to the climatic conditions of Tashkent.

The introduced plant species were divided into **five groups** according to the timing of the onset of flowering:

- species beginning to flower in late spring (May): *Nigella damascena*;
- species flowering in early summer (June): *Leonurus cardiaca*, *Monarda citriodora*, *Scutellaria albida* subsp. *colchica*, *Scutellaria altissima*;
- species flowering in mid-summer (July): *Hyssopus ambiguus*, *Origanum laevigatum*, *Agastache scrophulariifolia*, *Dracocephalum moldavica*;
- species flowering in late summer (August): *Salvia deserta*;
- species flowering in autumn (October): *Salvia hispanica*.

An analysis comparing the duration of the flowering phase of the generative period for the 11 species under introduced conditions with data reported in the literature for flowering in their natural habitats revealed that, in most cases, the flowering periods were slightly shifted relative to those in their native ranges (Table 3).

Table 3. Comparison of flowering duration of the studied species under introduced and natural conditions

Species name	Duration of the flowering phase under introduced conditions	Duration of the flowering phase under natural conditions	Sum of effective temperatures under introduced conditions, °C*
<i>Agastache scrophulariifolia</i>	July-October	July-September	3089,7
<i>Dracocephalum moldavica</i>	July-September	July-August	3014,5
<i>Hyssopus ambiguus</i>	July-November	August	3151
<i>Leonurus cardiaca</i>	June-October	June-August	2113
<i>Monarda citriodora</i>	June-October	June-August	1920,8
<i>Origanum laevigatum</i>	July-November	July-September	3080,7
<i>Salvia deserta</i>	August-November	June-September	4100,7
<i>Salvia hispanica</i>	October-November	July-September	5730,9
<i>Scutellaria albida</i> subsp. <i>colchica</i>	June-November	June-August	2045,2
<i>Scutellaria altissima</i>	June-November	June-July	1938,8
<i>Nigella damascena</i>	May-August	June-August	1597,7

\*Sum of effective temperatures above +5°C from the beginning of the growing season to the day of flowering

Thus, in the species *Nigella damascena* and *Hyssopus ambiguus*, the onset of flowering shifted to earlier dates, while in 11 other species, excluding *Nigella damascena*, the duration of flowering increased under introduction conditions. This phenomenon is often explained by the fact that, unlike in their natural habitats, the onset of flowering in introduced species shifts earlier, its duration may increase or decrease, and fruit formation and maturation are accelerated due to the sum of effective temperatures above +5 °C at the end of winter, in spring, and summer in Uzbekistan being higher than in their native range and accumulating over a shorter period of time.

The later onset of flowering in *Salvia deserta* is explained by the fact that not all individuals were able to enter the generative period in the first year of ontogenesis; only some specimens had accumulated sufficient effective temperatures by the last month of the summer season to initiate this process.

Thus, 10 species of alien flora adapted to the agrocenosis of the Botanical Garden (*Hyssopus ambiguus*, *Origanum laevigatum*, *Agastache scrophulariifolia*, *Leonurus cardiaca*, *Monarda citriodora*, *Dracocephalum moldavica*, *Scutellaria albida* subsp. *colchica*, *Scutellaria altissima*, *Salvia deserta*, *Nigella damascena*) - despite belonging to different life forms - entered the flowering and fruiting stages of the generative period in the first year of vegetation and completed all ontogenetic stages from seed to the formation of new seeds.

Short-day flowering is a unique biological feature of *Salvia hispanica*, as this genetically determined trait is characterized by the absence of photoperiodic sensitivity and photoperiodic variability under introduction conditions. Two years of observations indicate that the plant develops vigorously vegetatively (up to 1 m in height in its native range, 2-2.5 m in our conditions); however, the flowering phase begins after mid-October, making it impossible to obtain fully mature seeds. Therefore, its introduction in Tashkent, as well as in similar soil-climatic conditions, is not recommended. *Stevia rebaudiana* Bertoni is also a short-day tropical perennial herb (Asteraceae Bercht. & J.Presl); its bioecological characteristics were studied in the subtropical zone of Uzbekistan (Surkhandarya region) by A.M. Begmatov (2012), where fully mature seeds were obtained. Based on these data, *Salvia hispanica* can be recommended for cultivation in the Surkhandarya region.

In *Scutellaria albida* subsp. *colchica*, *Scutellaria altissima*, and *Nigella damascena*, reproduction from self-sown seeds matured during the growing season was observed; that is, at the beginning of October, individuals at the immature and virginile stages were present. Some individuals of *Nigella damascena* and *Scutellaria altissima* progressed to the bud formation phase of the generative period, and in the latter species, the flowering phase was also recorded. This indicates a positive adaptive response of these plants to the new habitat.

## Declarations

**Ethics approval and consent to participate:** All participants involved in the interview process gave their prior informed oral consent.

**Consent for publication:** Not applicable.

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**Authors' contributions:** D.T. Khamraeva, Nargiza K. Rakhimova, S.S. Nosirov collected and analyzed the data, drafted, and developed the manuscript. D.T. Khamraeva searched literature and adjusted the manuscript to the journal submission guidelines. R.W. Bussmann critically revised the manuscript. All authors contributed to the research, data collection, and approved the final manuscript.

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