УДК 63
DOI https://doi.org/10.32848/agrar.innov.2025.30.21

INTRODUCTION AND USE OF *MONARDA FISTULOSA* L. IN THE WORLD AND IN UKRAINE

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Problem setting. Essential oil plants occupy a narrow segment among agricultural crops in terms of the area occupied by them and the volume of raw material production, however, they are of great value for a number of industries. Thanks to the essential oil contained in them, these plants have multifunctional use in medicine, the food industry, perfumery, cosmetics, in jewelry and decorations, in agriculture and beekeeping [1, 2]. The perfume industry alone uses 30% of the world's cultivation of essential oil plants. Although a significant part of essential oil raw materials is replaced by products of chemical synthesis and is cheaper, it is less valued compared to natural raw materials [3].

Herbal medicines made from plant-based raw materials currently create a market worth $60 billion. They are widely used in Germany, France, the USA, Italy, and India [4]. The world's largest producers of essential oils are China and India. On the African continent, the leaders in essential oil production are Morocco, Tunisia, Egypt, and Algeria. In North America, the largest producers are the USA, Canada, and Mexico [5].

Today, the need for essential oil products in Ukraine is met mainly through imports. The rapid growth of the food, perfumery, cosmetic, pharmaceutical and medical industries require a sharp increase in the production of phytoraw materials, the bulk of which has long been supplied across the border, while medicinal and essential oil raw materials are widely used in Ukraine. 45% of domestic medicines are made from plant raw materials by many companies and enterprises in Ukraine [6]. Today, the need for essential oil products in Ukraine is met mainly through imports. The rapid pace of development of the food, perfumery and cosmetic, pharmaceutical and medical industries requires a significant increase in the production of phytoraw materials. 45% of domestic medicines are produced from plant raw materials by many companies and enterprises of Ukraine [6].

Cultivation of plants with significant biological and economic potential in new growing conditions contributes to the expansion of the range of medicinal, spicy, aromatic and essential oil species [7]. The introduction of promising species suitable for cultivation in Ukraine will reduce the volume of imported products. The significant interest of agricultural producers in the cultivation of essential oil crops is due to the economic feasibility of their production [4]. *Monarda fistulosa* L. is quite valuable in this regard.

Purpose. The purpose of the work was to review and summarize the scientific achievements of domestic and foreign researchers regarding the morphobiological characteristics, economic importance, and cultivation technology of *Monarda fistulosa* L.

Analysis of recent research and publications. The *Lamiaceae* family is the richest in aromatic plants and includes up to 210 genera and over 3,500 species. One of the promising aromatic plants of this family are species of the genus *Monarda* L. [8]. The homeland of monarda is North America. The plant was brought to Spain by Columbus, after the discovery of the continent. And three centuries later it was included by Carl Linnaeus in the classification ("Plant Species" 1753). The genus was named after the Spanish physician and botanist Nicolás Batista Monardes, who first described the plant [9].

According to various authors, the genus Monarda L. has from 16 to 100 species [10, 11], distributed in natural conditions only in North America. Among them are annual and perennial species. In the wild, plants grow in dry areas, on mountain slopes, and moisture-loving species occupy wet meadows and forest glades. Among the many species, the following are well known: *Monarda fistulosa* L., *Monarda didyma* L., *Monarda bradburiana* L.C. Beck., *Monarda citriodora* Cerv.ex Lag, *Monarda clinopodia* L., *Monarda punctata* L. and others. According to domestic and foreign authors, the most common are three species that are grown in different climatic zones: *M. fistulosa*, *M. citriodora* and *M. didyma*. *M. fistulosa* and *M. didyma* are perennial herbaceous plants that are common in the lower 48 states of the USA and occur in the regions of Mexico and Canada adjacent to the USA. *M. citriodora* is an annual plant that is common in northern Mexico and in the southern states of the USA [9, 12].

Morphobiological features.

M.fistulosa is a perennial herbaceous plant of the *Lamiaceae* family. The height of the plants varies from 60 to 120 cm depending on the variety and year of development (Fig. 1).

During the first year, the plant forms one well-leafed stem. In winter, the above-ground organs of the monarda die off. In the spring of the second year of life, from 2 to 6 new shoots grow from the renewal buds. During the third year of life, the plants reach 70-80 cm in diameter. They have 13-18 flowering shoots. The stems are straight and

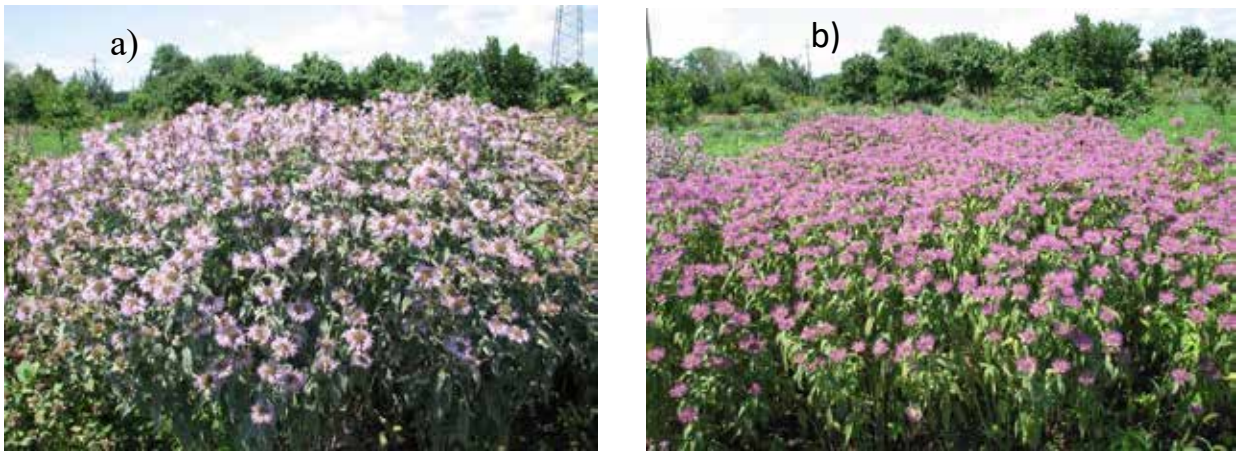

Fig. 1. Appearance of M. fistulosa plants in the flowering phase: a – variety Premiere, b – variety Fortuna

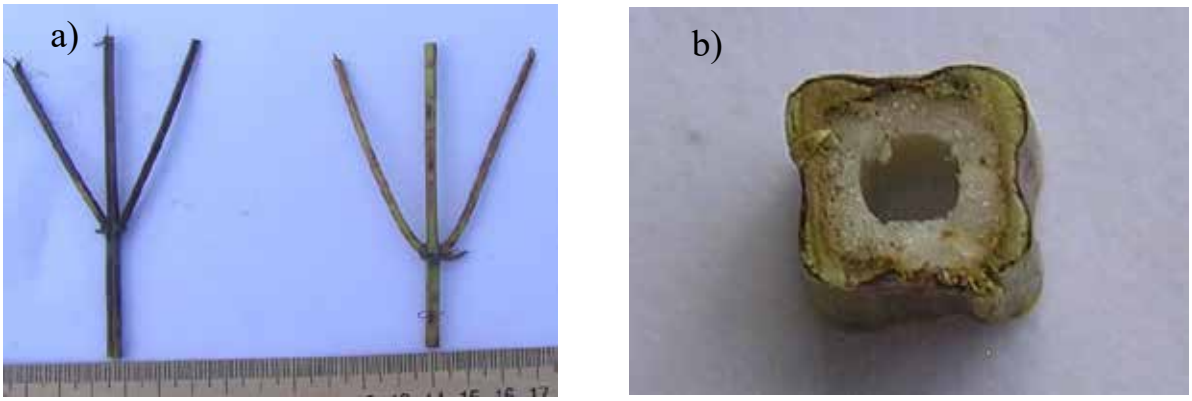

Fig. 2. Stem of M. fistulosa: a – external view of the stem with shoots; b – cross-section of the stem

tetrahedral (Fig. 2). The stems in cross section have 4 ribs and notched or flattened intercostal areas. In the lower part of the stems, the ribs gradually smooth out and become almost rounded. The core of the stem is wide, usually destroyed in the central part.

Up to 35 first-order shoots are formed on the stems, the length of which reaches 20-30 cm. These shoots have a noticeable light or partial anthocyanin color.

The leaves are simple, slightly corrugated, serrate, light green, pubescent, up to 7.5 cm long (Fig. 3). When they are enlarged, trichomes are clearly visible on the upper and lower epidermis of the leaf blade, represented by simple unicellular or multicellular hairs and densely located essential oily peltate glandules, which are immersed in the mesophyll of the leaf. Each gland has a head, which consists of 14-18 narrow cells, arranged radially (Fig. 4).

The flowers are small, collected in axillary false rings, which are located at the ends of the main and lateral shoots. The corolla is lilac-violet in color (Fig. 5).

The flower petals are covered with capitate elongated hairs that contain essential oil and essential oil glands. The calyx of each flower forms a narrow green, toothed tube 1.0-1.5 cm long. Essential oil glands and short simple hairs are located on it. The teeth of the calyx are densely covered with trichomes: simple short unicellular hairs, less often very long, as well as multicellular living ones with thin cellulose membranes (Fig. 6).

Glandular hairs have a 2-3-celled cylindrical stem, a neck and a rounded unicellular head with a dark secret. The essential oil glands of the tube are not immersed in a layer of cells, but sit on a raised multicellular rosette.

The diameter of the inflorescence (Fig. 7) of the Monarda varies from 6.0 to 7.5 cm.

The fruits are small brown nutlet (Fig. 8, 9).

In the second and subsequent years, the plants develop a powerful, branched rhizome.

Vegetation begins in mid-March – early April, depending on the weather conditions of the year. The most active growth is observed in late May-June. During mass flowering, it practically stops. Budding occurs in the second decade of June. Flowering begins in the third decade of June. Mass flowering occurs in the first or second decade of July, fruiting occurs in August. The essential oil raw material of monarda is the above-ground part, collected in the flowering phase. The essential oil is localized in the essential oily glandule, which, especially in large quantities, are found on the surface of a sheet plate (Fig. 10), the calyx of the flower and the petals.

Features of biochemical composition. Monarda is a plant newly introduced into crop cultivation and is

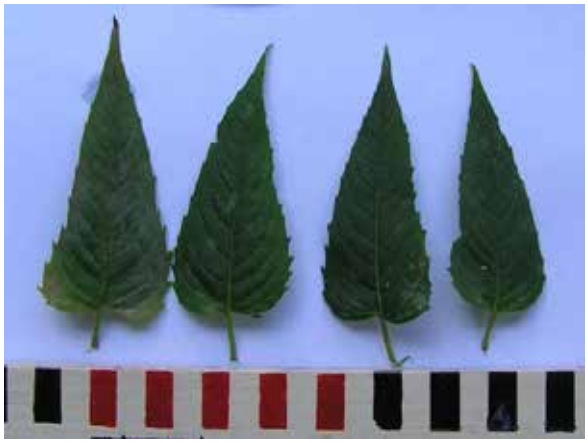

Fig. 3. Leaves of M. fistulosa

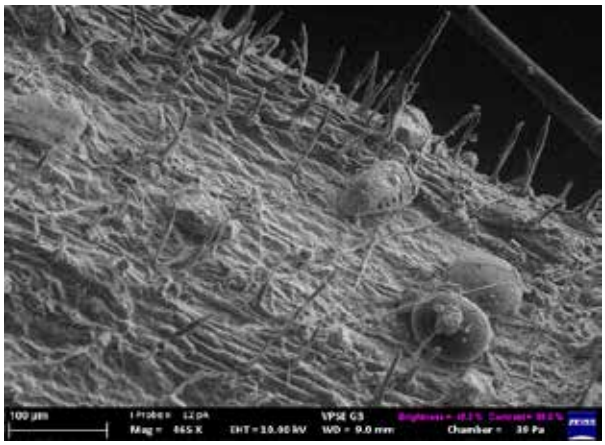

Fig. 4. Scanning electron microscopy of a sheet plate surface of M. fistulosa

Fig. 5. Flower of M. fistulosa

Fig. 6. Scanning electron microscopy of M. fistulosa flower calyx

considered promising for study and practical use by scientists from many countries. In terms of its bactericidal properties, it ranks first among essential oil plants. Interest in this plant is growing due to the content of essential oil in it, the mass fraction of which ranges from 0.5 to 2.8% in terms of absolutely dry raw materials [13]. To date, more than 40 components have been identified that are part of its composition. The main ones are thymol (from 1.4 to 56.3%) and carvacrol, as well as 1,8-cineole, geraniol, terpinene, limonene, linalool, myrcene and other components [14].

In the essential oil of *Monarda fistulosa*, grown in the experimental farm "Novokakhovske", 20 components have been identified. The dominant component of the oil is thymol, the mass fraction of which varies from 46.44 to 81.18%. In addition to phenols, the composition of the essential oil of *Monarda fistulosa* also includes mono- and bicyclic terpenes, acyclic terpenes and their oxygen derivatives.

Studying the content and composition of essential oil in three species of Monarda, including *M. fistulosa*, which grow in southern Alabama, scientists found that the content and its component composition are not the same and depend on the place of cultivation. They isolated many chemotypes. However, in all isolated samples, the phenolic monoterpenoids thymol or carvacrol mainly dominate [15].

According to scientists from the Nicolae Testemitanu State University of Medicine and Pharmacy (Chisinau, Moldova), the ratio of components and the yield of essential oil from different parts of *M. fistulosa* plants can vary depending on both geographical origin and genotype. They found that the maximum content of essential oil is in the leaves and inflorescences, and the lowest in the stems. As a result of multiple analyses, they identified a genotype characterized by an increased content of active substances [16].

In addition to essential oil, the above-ground part of *M. fistulosa* contains vitamins C, B_1, B_2, anthocyanins, flavonoids, and other biologically active substances [17, 18]. Thus, Shanaida M.I.'s studies established that *M. fistulosa* contains 0.07% rutin, 0.05% hyperoside, 1.89% luteolin-7-*O*-glucoside, 0.18% apigenin-7-*O*-glucoside, 0.31% acacetin-7-*O*-glucoside, 0.28% luteolin, and 0.14% apigenin.

18 free sugars (rhamnose, arabinose, fucose, mannose, glucose, galactose, fructose, sucrose, and others) were found in *M. fistulosa* herb. The dominant component is fructose [19].

The above-ground part of the genus *Monarda* plants contains micro- and macroelements that play an extremely

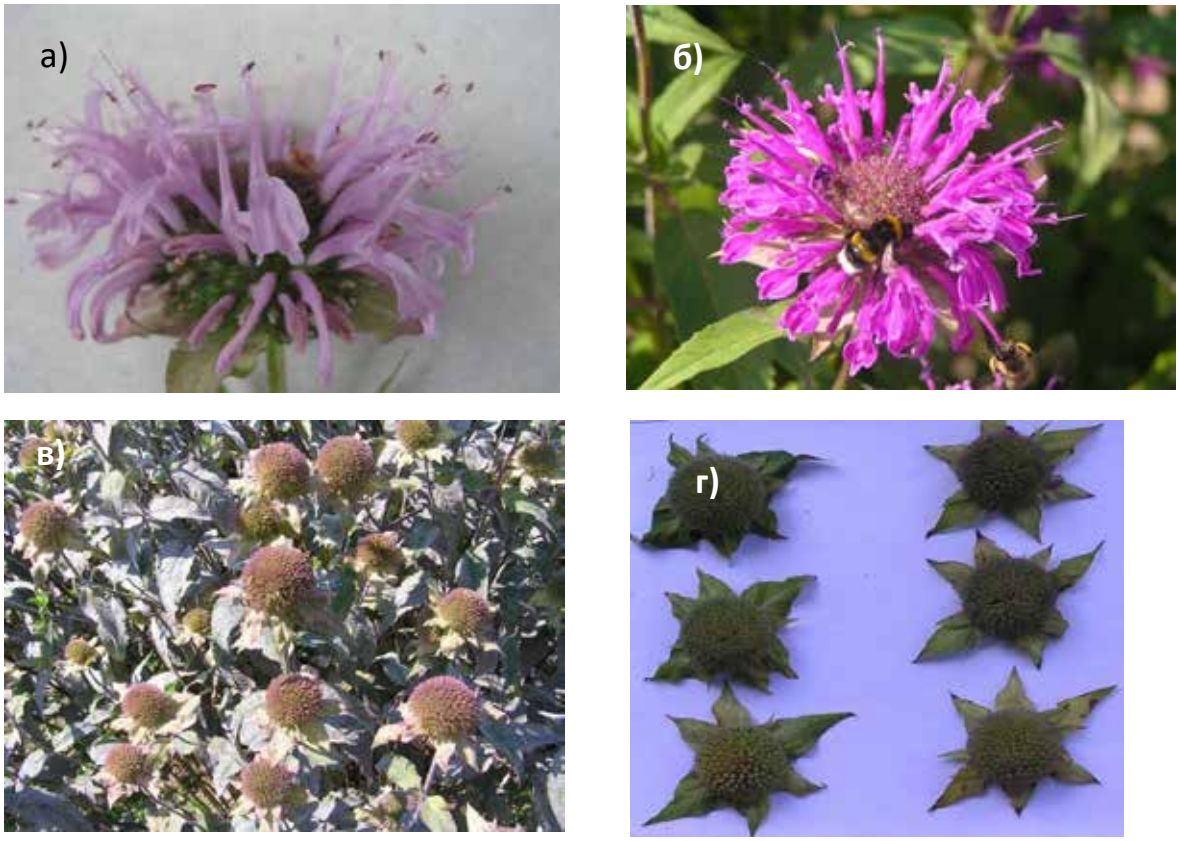

Fig. 7. Inflorescences of M. fistulosa: a – variety Premiere, b – variety Fortuna, c, d – end of flowering-beginning of fruiting

Fig. 8. Fruit of M. fistulosa

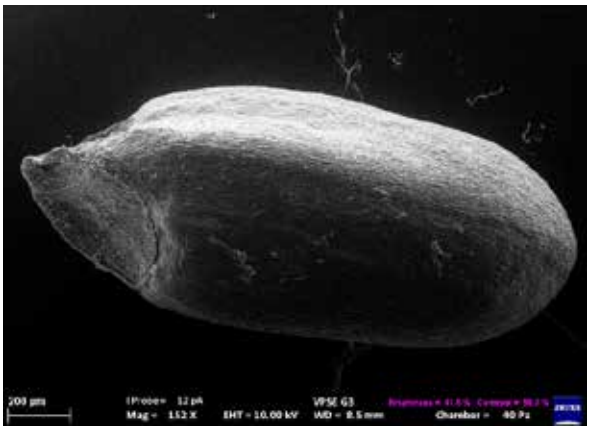

Fig. 9. Scanning electron microscopy of M. fistulosa seed

important role in human life. They are necessary for the normal course of many biochemical reactions in the body, contribute to the synthesis of hormones and enzymes. Scientists of the National Botanical Garden named after M.M. Grishko determined the elemental composition of the above-ground phytomass of plants of the genus *Monarda*. It revealed a fairly large number of elements important in plant life (K, Fe, Cu, Zn, Mn). The first place in the species of the genus *Monarda* among the valuable elements in terms of content belongs to potassium. Potentially harmful elements Sr, Zr are within the permissible norms [18]. Among the 42 species of plants grown in Western India and whose flowers are used for food, *M. fistulosa* ranks first in terms of phosphorus content in flowers (912 μg/100 g) and fourth in terms of calcium content (1760 μg/100 g) [20].

Economic importance. Due to the peculiarities of the composition of the above-ground part, plants of the genus Monarda have a wide range of uses.

Use in medicine. Since ancient times, species of the genus *Monarda*, and especially *M. fistulosa*, have been used by Native Americans (Indian tribes) as medicinal plants for cuts, burns, and colds [15]. Having a high

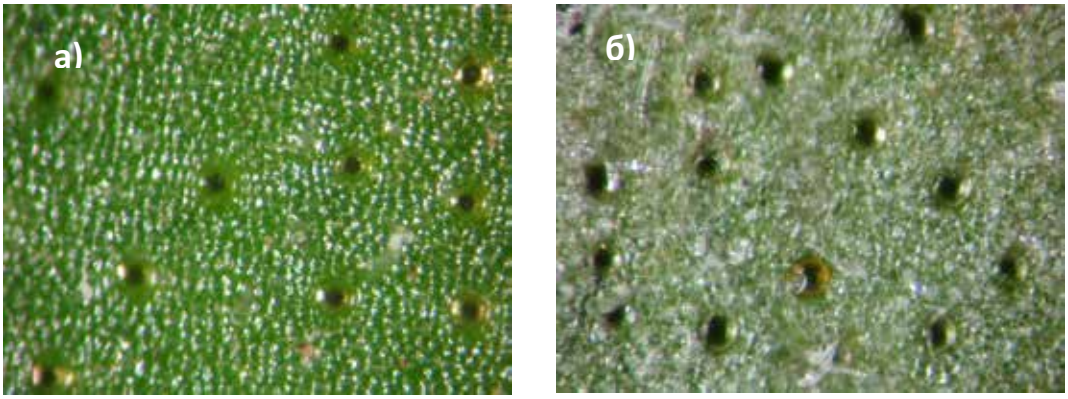

Fig. 10. Essential oily glandula on a surface of a sheet plate Monarda fistulosa of a variety a Premiere: a – upper party, at increase 1,5× 53,0 4.0 -44,78; b – underside, at increase 1,5× 53,0 4.0 -45,18

biological activity, which is higher than lavender, eucalyptus, mint, thyme, and others, the essential oil of monarda has found its application in medicine for the prevention of many diseases [21]. Due to the wide pharmacological spectrum of action of monarda, it is used for inhalations for infectious diseases of the upper respiratory tract and lungs [22].

Monarda extracts and essential oil have high bactericidal, antiviral, antifungal, antimycoplasma and anthelmintic activity, antioxidant, radioprotective, antisclerotic, desensitizing, anti-cancer, anti-inflammatory and analgesic effects [23]. They correct the activity of enzymes, i.e. restore impaired redox processes in the body, have a sedative effect on the central nervous system, enhance the effect of antibiotics that stimulate the regeneration of damaged skin, and reduce elevated lipid metabolism to normal [16].

The plant is also in demand in cosmetology. It is included in creams for mature skin and in preparations for the care of oily and acne-prone skin. Due to its antibacterial properties, the oil serves as an effective means for cleaning and disinfecting indoor air during epidemics. Monarda essential oil is also used in such branches of medicine as balneology and massage [24].

Use in food industry. Some species of the genus have long been grown in monastery gardens in Europe and used to make teas. The above-ground part of the plants has a floral-spicy smell with a thyme and lemony tinge [25]. Monarda (both fresh and dried) is used as a component in the preparation of marinades, canning vegetables, and as a seasoning for meat and meat products. Essential oil and extract of monarda are used as an antiseptic ingredient in the flavoring of soft drinks, in the production of vermouth and cheeses [24]. Due to its bitter taste, monarda can be used as a substitute for imported black pepper in dry spice mixtures [25].

In many countries of the world, this plant is included in the product catalog. Its pleasant taste and unusual aroma make it an indispensable ingredient in the preparation of various dishes [21]. Fresh greens are added to soups, salads, borscht, helping to increase appetite and improve digestion. Crushed leaves of monarda are also used in the food industry in baking [26]. The literature contains recommendations for the practical use of monarda essential oil as a food additive to improve the sensory quality of minced meat, as well as against pathogenic bacteria and bacteria that spoil products, such as *Escherichia coli*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Salmonella typhimurium* and others [27]. The higher activity of *M. fistulosa* essential oil compared to other species was noted. As a result of the study of antifungal activity, a negative effect of *M. fistulosa* essential oil on the development of fungi of the genera *Alternaria spp.*, *Aspergillus spp.*, *Fusarium spp.* was revealed [28]. Monarda essential oil is a promising potential antifungal agent that can be used for the development of biofungicides as alternative to synthetic fungicides against *Botrytis cinerea Pers*. [29].

Monarda essential oil has good inhibitory properties against the germination of weed seeds *Papaver rhoeas* L., *Taraxacum officinale* FH Wigg., *Avena fatua* L., *Raphanus sativus* L. and *Lepidium sativum* L. [30].

Italian scientists have proven the presence of ovicidal, insecticidal and anti-eating properties of *M. fistulosa* essential oil against the Colorado potato beetle. The essential oil completely suppressed the hatching of *L. decemlineata* larvae, and in the variant with potato leaves treated with it, it was observed that the larvae did not feed on it [31].

Alternative solutions to synthetic antibiotics in animal nutrition are being sought. Studies by Canadian scientists show that adding *M. didyma* essential oil to the diet of broilers can potentially replace antibiotics that are added to the diet of animals and stimulate their growth. By exhibiting antibacterial, antioxidant and anti-inflammatory effects, the essential oil significantly improved their live weight gain [32].

Use in ornamental gardening. Due to its decorative properties and due to the grows habit, the variety of colors of inflorescences and the pleasant aroma of monarda, it has found its application in ornamental gardening. The originality and unpretentiousness of the plant contributed to its popularity. It has now become a fashionable idea to use monarda in landscape design. It is usually grown in the second or background of flower beds. It looks good in monogroups. Monarda is used both for forming decorative compositions and as cut flowers [10, 20, 25, 28].

World and domestic practices of growing monarda. It was brought to Europe in Spain at the beginning of the 16th century from North America and Canada. At the

beginning of the 19th century, it began to be cultivated here as an essential oil and spicy-flavor plant. In Portugal, Spain, France, Great Britain it was used under the names “wild bergamot”, “bee or fragrant balm”, “Oswego tea”, “American lemon balm” and others. In 1916, it was grown to obtain thymol for export to India and Europe [34].

The cultivation of Monarda as an ornamental, medicinal, essential oil and aromatic plant is gradually gaining popularity, as a result of which species of the genus Monarda have been introduced into cultivation in many countries of Europe and America [28]. The species *M. didyma*, *M. fistulosa*, *M. punctata* and *M. citriodora* are mainly cultivated [18]. *M. fistulosa* has a wider distribution area compared to *M. didyma*, which is explained by a higher yield of essential oil and a brighter aroma [21]. In addition, there are many varieties and forms of Monarda hybrid (M.×hybrida hort.), created with the participation of the species *M. didyma* and *M. fistulosa* [10].

A great deal of work of the Monarda introduction was carried out in the 1980s by scientists from Ukraine, Moldova, Uzbekistan, Azerbaijan, etc. There are many works on the study of the biological characteristics of the species of the genus [10, 14, 25].

In Moldova, a number of scientists have studied various methods of propagation and cultivation of *M. fistulosa.* According to their recommendations, monarda should be grown separately from crop rotation with annual plants. It is propagated by sowing seeds directly in the field or by planting seedlings obtained in a greenhouse, or vegetatively (by dividing plants into parts). In seed propagation, the efficiency of the seedling method has been proven, since the plants had a larger grows habit and higher yield indicators [34]. Other Moldovan scientists have developed a micropropagation procedure for effective and stable conservation of the species [35].

Scientists from Cairo University (Egypt) studied the effect of Monarda plant density and fertilization on the content and composition of essential oil. They noted a positive effect of nitrogen fertilization on the yield of essential oil. Nitrogen fertilization did not significantly affect the composition of essential oil [11].

During the vegetation season, *M. fistulosa* plants can be affected by fungal diseases such as powdery mildew and rust. The causative agent of rust is the fungus *Puccinia menthae Pers.* Affected plants have brown spots, mainly on the leaves, with a decrease in the quality of the leaves and premature decay of the stem [34]. Rust infection can be avoided by strictly observing crop rotation, using only healthy planting material for propagation. It has been established that another pathogen is powdery mildew fungus, which leads to a change in the quantitative composition and mass fraction of the components of the essential oil of *M. fistulosa*. Researchers from Italy noted that the disease can develop both with the manifestation of symptoms of infection in the form of a white coating on the leaves, and asymptomatically [36].

In Ukraine, *M. fistulosa* and the related species *M. didyma* are grown and studied in the Steppe, Forest-Steppe and Polissya [7, 8, 10]. For a number of years, monarda has shown itself as a cold-resistant crop, withstanding low temperatures in winter (up to -35 °C) without damage. According to the criteria of cold and winter hardiness, it was rated 9 points. It has an average drought resistance (5 points).

Findings. Thus, *Monarda fistulosa* is a valuable medicinal, essential oil and ornamental plant. The content of essential oil in the plant ranges from 0.5 to 2.8% (converted to absolutely dry raw materials). The maximum proportion of essential oil is synthesized in leaves and inflorescences, and the smallest in stems. More than 40 components have been identified in the essential oil of *M. fistulosa*. The main components are thymol and carvacrol. In addition to essential oil, the above-ground part of monarda contains vitamins C, B_1, B_2, anthocyanins, flavonoids, sugars and other biologically active substances. Cultivation of monarda as an ornamental, medicinal, essential oil and aromatic plant is gaining increasing popularity, so it has been introduced into culture in many countries of the world.

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Svydenko S.V., Valentiuk N.O. Introduction and use of Monarda Fistulosa L. in the world and in Ukraine

Purpose. The purpose of the work was to review and summarize the scientific achievements of domestic and foreign researchers regarding the morphobiological characteristics, economic importance, and cultivation technology of Monarda fistulosa L. **Results.** Analysis of the literature showed that Monarda fistulosa is considered promising for study and practical use by scientists from many countries. In terms of its bactericidal properties, it ranks first among essential oil plants. The essential oil of the plant has antagonistic activity against various

pathogenic organisms. It has found wide application in various sectors of the national economy: in medicine, food industry, agriculture. The content of essential oil in the plant ranges from 0.5 to 2.8% when calculated on absolutely dry raw materials. More than 40 components have been identified in the essential oil of Monarda fistulosa. The main components are thymol and carvacrol. The yield of essential oil and the ratio of components from different organs of M. fistulosa plants can vary depending on both geographical origin and genotype. In addition to essential oil, the above-ground part of Monarda contains vitamins C, B_1, B_2, anthocyanins, flavonoids and other biologically active substances. In the herb M. fistulosa 18 free sugars were found. The flowers of the plant are a source of phosphorus (912 μg/100 g) and calcium (1760 μg/100 g). Monarda is propagated by sowing seeds directly in the field or by planting seedlings obtained in a greenhouse, as well as vegetatively – by dividing the plants into parts. The application of nitrogen fertilizers when growing monarda increases the yield of essential oil, but does not affect the component composition. M. fistulosa and its hybrids, due to their inflorescences of various colors, are also used in ornamental gardening. **Findings.** Monarda fistulosa has significant biological and economic potential. It contains essential oil, which has found a wide range of uses in various sectors of the national economy and is a promising plant for cultivation for the production of raw materials for the essential oil industry.

Key words: Monarda fistulosa, essential oil, introduction, cultivation, reproduction, use.

Свиденко С.В., Валентюк Н.О. Інтродукція та використання Monarda fistulosa L. в світі та в Україні

Мета. Узагальнити наукові досягнення вітчизняних та іноземних дослідників стосовно морфобіологічної характеристики, господарського значення та технології вирощування монарди трубчастої. **Результати.** Аналіз літературного матеріалу показав, що Monarda fistulosa науковцями багатьох країн вважається перспективною для вивчення та практичного використання. За своїми бактерицидними властивостями вона займає одне з перших місць серед ефіроолійних рослин. Ефірна олія рослини має антагоністичну активність проти різних патогенних організмів. Вона знайшла широке застосування в різних галузях народного господарства: в медицині, харчовій промисловості, сільському господарстві. Вміст ефірної олії в рослині коливається від 0,5 до 2,8 % при перерахунку на абсолютно суху сировину. В ефірній олії монарди трубчастої індентифіковано більше 40 компонентів. Основними компонентами є тимол і карвакрол. Вихід ефірної олії та співвідношення компонентів з різних органів рослин M. fistulosa може змінюватися залежно як від географічного походження так і від генотипу. Окрім ефірної олії надземна частина монарди містить вітаміни С, B_1, B_2, антоціани, флаваноїди та інші біологічно активні речовини. У траві M. fistulosa виявлено 18 вільних цукрів. Квітки рослини являються джерелом фосфору (912 мкг/100 г) та кальцію (1760 мкг/ 100г). Розмножують монарду посівом насіння безпосередньо в полі або шляхом висадки розсади, отриманої в теплиці, а також вегетативно – поділом рослин на частки. Внесення азотних добрив при вирощуванні монарди підвищує вихід ефірної олії, проте на компонентний склад не впливає. M. fistulosa та її гібриди завдяки своїм суцвіттям різної гами кольорів використовуються також в декоративному садівництві. **Висновки.** Monarda fistulosa має значний біологічний та господарський потенціал. Вона містить ефірну олію, яка знайшла широкий спектр використання в різних галузях народного господарства і є перспективною рослиною для вирощування з метою виробництва сировини для ефіроолійної промисловості.

Ключові слова: Monarda fistulosa, ефірна олія, інтродукція, вирощування, розмноження, використання.