

## Morphobiological and Biochemical Characteristics of *Monarda L.* Varieties under Conditions of the Southern Steppe of Ukraine

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### ABSTRACT

Promising essential oil plants from the *Lamiaceae* family, the raw materials of which are a source of valuable essential oil for pharmaceutical, perfume, cosmetic and food industries, pertain to the *Monarda L.* genus. The *Monarda didyma L.* and *Monarda fistulosa L.* species were first imported to Ukraine from Europe and America in the middle of the twentieth century, and today they are successfully cultivated as decorative, spicy-aromatic and medicinal plants. The purpose of this study was to determine the morphobiological features, valuable economic and selective traits of *Monarda didyma*, *Monarda fistulosa* and *Monarda × hybrida hort.*, developed for the arid conditions of the southern steppe of Ukraine at the Institute of Rice of the NAAS. The experimental part of the study was performed in 2016–2018 on southern sandy and medium loam black soils (chernozem) in the state enterprise (SE) “Research farm “Novokakhovske”. The experiment was conducted using field, laboratory, mathematical and statistical methods in accordance with the generally accepted methods and guidelines in Ukraine. The plants of developed varieties undergo a full cycle of development under arid conditions of the southern steppe of Ukraine and are characterised by an increased decorativeness, goodeconomic value, high drought and winter tolerance as well as the resistance to pest damage. Yield, mass fraction and content of essential oil in the aboveground mass of plants were determined. Maximal plant height (120 cm), yield of aboveground mass (18 t/ha), concentration of essential oil (0.8% of crude mass) and thymol content (78.3%) are typical of the variety of *Monarda fistulosa*, Premiera. The variety of *Monarda fistulosa*, Fortuna, and variety of *Monarda × hybrida hort.*, Tonya, were inferior to Premiera in all of the above-mentioned indicators but demonstrated increased decorativeness and greater resistance to the fungi causing powdery mildew (*Erysiphe monardae*, *Golovinomyces biocellatus*). Therefore, they can be recommended for region-wide cultivation in the agricultural enterprises of the southern steppe of Ukraine as promising essential oil, spice-aromatic and decorative crops. The yield of essential oil from raw materials of *Monarda didyma* variety, Nizhnist, was lower by 32.9% and 26.8%, while its concentration was lower by 37.5% and 28.6%, compared to the *Monarda fistulosa* varieties Premiera and Fortuna, respectively.

**Keywords:** *Monarda*, variety, yield of aboveground mass, essential oil, thymol, carvacrol

### INTRODUCTION

Global pharmaceutical, perfume, cosmetic and food industries experience a constantly growing demand for natural essential oils due to their content, which, in contrast to that of the chemically synthesized oils, is rich in natural aromatic compounds, organic acids, phenols, alcohols, aldehydes and more. This renders essential oils expensive on the world market and underscores

the relevance of the introduction and study of the agricultural techniques for growing essential oil plants in different soil and climatic zones.

Until 2014, essential oil crops were cultivated on the territory of the Autonomous Republic of Crimea. For comparison, the total arable area of essential oil plants in Ukraine was 18.5 thousand hectares in 2013 but decreased nearly 4 times, to 4.9 thousand hectares, in 2018 [Statistical bulletins 2010–2018]. Thus, the current agro-industrial

complex of Ukraine is facing two challenges: the introduction of valuable essential oil crops in other regions of the country, since it is known that the soil and climatic conditions do not significantly affect the content of essential oils and are less important than species and varietal features, as well as the development of new varieties and hybrids of own selection with high economic value [Svidenko et al. 2015, Makukha et al. 2018, Markovska et al. 2020].

Promising essential oil plants of the *Lamiaceae* family, the raw material of which is a source of valuable essential oil, are members of the *Monarda* L. genus, which entails 20 species and originates from North America. After becoming the most widespread in Europe and America, the *Monarda didyma* L. and *Monarda fistulosa* L. species were first imported to Ukraine in the middle of the 20th century. *Monarda fistulosa* L. has a wider distribution area than *Monarda didyma* L. due to the higher yield of essential oil and more sophisticated aroma [Fedotov 2015]. However, there are many varieties and forms of hybrid *Monarda* (*M. × hybrida hort.*), developed using the *M. didyma* L. and *M. fistulosa* L. species [Collicutt et al. 1999]. Scientists note the extraordinary versatility of the essential oil from this plant in medicine (greater than that of lavender, eucalyptus, mint, thyme etc.) owing to its potent biological activity (prevention of bronchitis and acute respiratory diseases; increase in body's resistance to infectious diseases etc.) [Kharchenko et al. 2015]. The high phenol content, with thymol and carvacrol constituting 67–89%, makes the *Monarda* essential oil bactericidal, antiseptic, deodorizing, antihelminthic, antibiotic, antispasmodic, cytotoxic, fungicidal and microbe-repelling. Furthermore, it was found that bacteria develop the resistance to the *Monarda* oil more slowly than to antibiotics and for instance, *Staphylococcus* spp. do not develop the resistance to this essential oil at all. Higher content of thymol and carvacrol in fresh plant materials allows obtaining more thymoquinone and thymohydroquinone from the dry mass of *M. fistulosa* plants, the analgesic, anticonvulsant and cytotoxic properties of which have been proven in numerous studies [Rohlfesen 2017].

Thymol is of greater medical value than carvacrol, its isomer. The latter is commonly used as a food additive during canning owing to its spiciness. The *Monarda* essential oil also contains *n*-cymene and  $\gamma$ -terpinene, high content of which negatively affects the odour and biological

activity of essential oil, rendering it unusable in the perfume and cosmetic industries [Mastelic et al. 2008, Mehdi et al. 2011]. From the perspective of aromatherapy, the *Monarda* essential oil should predominantly contain thymol, with minimal amounts of  $\gamma$ -terpene. However, even in such case, its uncontrolled use can induce allergic reactions and have an irritating effect [Fedotov 2015].

High biological activity of the *Monarda* essential oil against pathogenic microorganisms such as *Escherichia coli*, *Erwinia amylovora*, *Candida albicans*, *Rhizoctonia solani* and *Botrytis cinerea* has been experimentally validated, thereby confirming the fungicidal action of its components [Fraternale et al. 2006, Gwinn et al. 2010, Mattarelli et al. 2015]. The phytotoxic activity of components of *Monarda didyma* L. essential oil (thymol, *n*-cymene and terpinolene) on germinating seeds of *Papaver rhoeas* L., *Taraxacum officinale* FH Wigg., *Avena fatua* L., *Raphanus sativus* L. and *Lepidium sativum* L. was tested in the *in vitro* experiments in central Italy, which is relevant due to the need for the development of bioherbicides capable of controlling the growth of weeds without posing risks to the environment [Ricci et al. 2017]. The essential oils from Italian ecotypes *M. didyma* L., *M. fistulosa* L. and their main compounds (carvacrol, thymol,  $\gamma$ -terpinene, *n*-cymene) exhibit strong nematocidal activity against phytoparasitic nematodes *Meloidogone incognita* and *Pratylenchus vulnus* [Laquale et al. 2018].

The aforementioned data corroborate the relevance and necessity of developing new varieties and hybrids of *Monarda* plants with high indicators from both ecological and economic perspectives.

## MATERIALS AND METHODS

The purpose of this study was to determine the morphobiological features, valuable economic and selective traits of *Monarda didyma*, *Monarda fistulosa* and *Monarda × hybrida hort.*, which were developed in the sector of mobilization and conservation of plant resources at the Institute of Rice of NAAS in accordance with the task GDR24.01.01 .32. P. "Formation of collections of aromatic plants for the development of varieties adapted to the steppe zone of southern Ukraine". The experimental part of the work was performed on the experimental fields of the state enterprise

(SE) “Research farm “Novokakhovske” of the Institute of Rice” of National Academy of Agrarian Sciences (NAAS) of Ukraine, located in the first northern agroclimatic zone of Kherson region. Experimental plots for *Monarda didyma*, *Monarda fistulosa* and *Monarda × hybrida hort.* were also established at the Kherson Region Agrarian University.

The climate of the subzone is moderately continental with short springs; long hot and dry summers; mild winters with frequent thaws. The sum of active temperatures over 10°C is 3200–3400°C. The amount of precipitation during this period is 215–220 mm, often in the form of showers accompanied by hailstorms, at the annual rate of 340–400 mm. The hydrothermal coefficient is 0.5–0.7. There are rainless periods of variable duration almost every year, including ones lasting for more than 40 days once in 2 years. The largest number of the days with dry winds is observed in the Black Sea steppe – on average, from 15 to 24 per year, 40% of which are very intense.

The soil in the established plots was southern sandy and medium loam chernozem. The humus content in the arable layer was 2.25%. The reaction of the soil solution was neutral (pH 6.6–6.8). The density of the arable soil layer was 1.14–1.24 g/cm<sup>3</sup>, the porosity was 53.5–57.0%, and the lowest moisture content was 24.3–28.8%. The supply of the arable layer with nitrates, mobile phosphorus and exchangeable potassium was average.

The objects of study were morphobiological indicators, valuable economic and selective traits of *Monarda fistulosa*, *Monarda didyma*, *Monarda × hybrida hort.* The research was performed on varieties of *Monarda fistulosa*, Premiere and Fortuna, variety of *Monarda didyma*, Nizhnist, and variety of *Monarda × hybrid hort.*, Tonya. The experiments were conducted using field, laboratory, mathematical and statistical methods according to the generally accepted methods and guidelines in Ukraine [Beydeman 1974, Yeshchenko et al. 2014].

The assessment of main biological and decorative indicators, flowering strength, infections with pathogens, pest damage, winter and drought tolerance, yield, economic and biological qualities and properties as well as phenological observations and biometric measurements of the *Monarda* L. plant varieties were carried out according to the current methods and provisions in Ukraine [Regulations... 2012, Methods... 2015,

Methods... 2016, Methods... 2017]. The essential oil was extracted from the freshly harvested raw materials. Afterwards, the mass fraction of essential oil was determined by means of the Ginsberg method on a Clevenger apparatus based on the absolute dry weight of plant raw materials [DSTU 7109: 2009]. The content of the essential oil was determined on an Agilent Technology 6890 N chromatograph with a 5973 N mass spectrometric detector [Jennings 1980].

## RESULTS AND DISCUSSION

The *Monarda fistulosa* L. plants have been cultivated at the SE “Research farm “Novokakhovske” of the Institute of Rice” of NAAS since 1998.

Following many years of research, the Premiere variety, the first of *Monarda* varieties registered in Ukraine, was developed in 2006 using individual- and family-based selection from seed offspring of the biotype №108. Under the conditions of southern steppe of Ukraine, the plants can reach 120 cm in height and 60 cm in diameter. In the second or third year of vegetation, the plants form 10–20 flowering stems. The stem is slightly pubescent and has a strong anthocyanin colour. The leaves are simple, serrated, pubescent, dark green, 6.5–8.0 cm long and 3.0–3.8 cm wide. The flowers are small, collected in compact head inflorescences. Corolla is dark pink.

The vegetation of Premiere variety begins in the second or third ten-day period of March, depending on the weather conditions of the year. Mass flowering occurs in the early third ten-day period of June. Fruiting lasts from the third ten-day period of July to the third ten-day period of August. This variety is winter- and drought-tolerant, very decorative during flowering and grows well in sunny areas and in the partial shade. It has a sophisticated aroma and a long flowering period. It propagates vegetatively, because the seed offspring does not inherit the parental traits (Fig. 1).

The variety of *Monarda fistulosa* L., Fortuna, was developed in 2008 using individual- and family-based selection from the seed offspring of the biotype № 2–08. In the Kherson region, the plants reach a height of 110–120 cm and a diameter of 70–80 cm as well as have 15–18 flowering stems, on which 30–35 first-order shoots, 25–30 cm in length, are formed. The leaves are simple, slightly corrugated, serrated, light green, 8.5–9.0 cm long



**Figure 1.** *Monarda fistulosa* variety Premiera



**Figure 2.** *Monarda fistulosa* variety Fortuna

and 3.0–3.5 cm wide. Central shoots end in inflorescence. The flowers are small, gathered in compact spherical heads at the ends of the stems. Corolla is purple. The diameter of the inflorescence is 6.5–7.5 cm. The fruits are small brown nuts (Fig. 2).

Vegetation occurs from mid-March to early April, with the most active growth observed in late May-June. During mass flowering, vegetation almost stops. Budding occurs in the second ten-day period of June. The flowering begins in the third ten-day period of June. Mass flowering occurs during the first or second ten-day period of July, and fruiting – in August. Plants propagate with seeds and vegetatively. In order to preserve the varietal traits, the vegetative method is preferred. When propagated vegetatively, plants flower in the first year of life.

*Monarda fistulosa* L. Fortuna variety has a longer leaf blade, lighter green leaves (more tender and slightly folded inwards along the central vein) and a bright purple flower, compared to plants of *Monarda fistulosa* L. Premiera variety. The underside of the leaf of the Fortuna plants is not anthocyanin in colour. The central shoots do not always end in inflorescences, especially during the first years of life. The Fortuna plants flower 7–10 days later than the Premiera plants.

They are less or almost not affected by powdery mildew. The plants of this variety have a highly decorative appearance and can be used in landscaping as well as in singular plantings.

Cultivation of *Monarda didyma* in SE “Research Farm “Novokakhovske” of the Institute of Rice” of NAAS began in 2007. The seeds of *Monarda didyma* L. were obtained from the National Botanical Garden. M. M. Grishka. From the seed generation of the biotype №8207, the Nizhnist variety was developed using individual selection in 2015.

This variety has high economic value, is more tolerant to summer droughts and propagates vegetatively. When sowed, the plants flower in the second year of life, and when vegetatively propagated – in the first. The vegetation of the Nizhnist plants begins in the second or third ten-day period of March, depending on weather conditions of the year. Budding occurs in the first ten-day period of June, mass flowering – in the first ten-day period of July and the beginning of fruiting – in the third ten-day period of July.

During the phase of mass flowering, plants reach 70 cm in height and 60–70 cm in diameter as well as have from 10 to 13 flowering stems, on which 25–35 shoots of the first order and 18 shoots of the second order are formed. The leaves are

simple, serrated, dark green, 5.5–6.5 cm long and 3.0–3.5 cm wide. The central shoots end in an inflorescence. The flowers are small, gathered in a dense terminal, capitate inflorescence with a diameter of 4.5–6.0 cm. Corolla is pale pink.

A distinctive feature of this variety is a dense, smooth leaf of dark green colour and a gentle, pale pink colour of the flower. The plants of this variety can be grown as decoration for landscaping and sale (Fig. 3).

The variety of *Monarda* × *hybrida hort.*, Tonya, is a hybrid of the first generation, found among seedlings obtained via free pollination of a group of varieties of *Monarda fistulosa* and *Monarda didyma*. During the phase of mass flowering, the plants of this variety have a height of 90 cm, a diameter of 60–70 cm and a compact shape of the bush. The leaves are simple, serrated, strongly corrugated, light green with anthocyanin colour, 6.5 cm long and 3.5 cm wide. The corolla is purple. The diameter of the inflorescence is 6.0 cm (Fig. 4).

The vegetation of Tonya plants begins in the second or third ten-day period of March. Budding occurs in the first or second ten-day period of June, mass flowering – in the first ten-day period of July and beginning of fruiting – at the end of the third ten-day period of July. This variety is characterized by good decorative qualities due to corrugated leaves, purple colour of the flower and the resistance to fungal diseases

Having analysed the average morphometric parameters of the studied varieties in 2016–2018, it was determined that the plants of *Monarda*

*fistulosa* L. Variety Premiera were 9.0–33.3% higher than those of the Fortuna, Nizhnist and Tonya varieties. The aboveground part of *Monarda* during mass flowering was used as the raw material. Its yield ranged from 14 t/ha to 18 t/ha, with maximal recorded yield of the Premiera variety exceeding the Fortuna variety by 14.3%, Nizhnist variety – by 21.4 and Tonya variety – by 28.6%, respectively ( $LSD_{0.05}$ , t/ha – 0.84) (Table 1).

The *Monarda* essential oil is a light-yellow liquid with a pleasant floral-spicy aroma, containing thyme and lemon scents. It is found in stems, inflorescence and leaves. The feasibility and viability of using the entire aboveground mass of plants as a raw material for the production of essential oil, mass fraction of which depends on the species, variety and sample, were validated in many scientific works.

The authors determined that during the phase of abundant flowering, the mass fraction of essential oil in the aboveground mass of plants of the studied varieties of *Monarda fistulosa* L. ranged from 0.7% to 0.8% of the total raw mass, exceeding the minimum values of *M. × hybrida hort.* Tonya variety by 55.6–77.8%. The concentration of essential oil in the aboveground mass of plants of *Monarda didyma* L. Nizhnist variety was lower by 37.5% and 28.6%, compared to the varieties of *Monarda fistulosa* L. Premiera and Fortuna correspondingly, constituting 0.5% of total the raw mass. The obtained data confirm the findings of studies conducted in the traditional area of *Monarda* cultivation, Crimea, in which the content of essential oil in the aboveground



Figure 3. *Monarda didyma* variety Nizhnist



Figure 4. *Monarda* × *hybrida hort.* variety Tonya

**Table 1.** Comparison of economically valuable characteristics of the *Monarda* varieties (average for 2016–2018)

Economically valuable characteristics	<i>Monarda fistulosa</i> L.		<i>Monarda didyma</i> L.	<i>M. × hybrida hort.</i>
	Variety Premiera	Variety Fortuna	Variety Nizhnist	Variety Tonya
Duration from start of vegetation to flowering, days	90±5	100±7	97±4	95±4
Plant height, cm	120±4.6	110±4.1	90±3.4	90±3.2
Yield of aboveground mass, t/ha	18	17	16	14
Concentration of essential oil, % of raw mass	0.8±0.01	0.7±0.01	0.50±0.01	0.45±0.01
Yield, kg/ha	120±10	110±9	80,5±7	73±7
Weight of 1000 seeds, g	0.301±0.0003	0.350±0.0006	0.375±0.0006	0.362±0.0005
Duration of flowering	30	30	30	30
Resistance to pest damage (aphids), score	9	9	9	9
Disease tolerance (powdery mildew), score	7	8	6	8
Drought tolerance, score	9	8	9	9
Winter tolerance, score	9	9	9	9
Decorativeness, score	60	80	70	80

mass of *Monarda fistulosa* L. was in the range of 0.66–0.80% of the total raw mass, in *Monarda didyma* L. – 0.56–1.12% and in *M. × hybrida hort.* – 0.45–0.50% [Shevchuk et al. 2017].

In our experiment, the yield of essential oil from plants of *Monarda fistulosa* L. the Premiera variety was maximal – 120 kg/ha, exceeding that of *M. × hybrida hort.* Tonya variety by 64.4% or 1.6 times. The yield of the Fortuna variety was 8.3% lower than that of the Premiera variety. The yield of essential oil from the plants of *Monarda didyma* L. Nizhnist variety was lower by 32.9% and 26.8%, compared to the varieties of *Monarda fistulosa* L. Premiera and Fortuna, respectively, and amounted to 80.5 kg/ha. In the experiments conducted in the Nikolaev region (under conditions of southern steppe of Ukraine), the yield of essential oil ranged from 45.1 kg/ha to 115.2 kg/ha in the second year of cultivation of the *Monarda didyma* L. varieties (Slava, Serpanok, Snizhana).

All studied varieties of *Monarda* exhibited strong resistance to aphid damage, strong and moderate resistance to powdery mildew (*Erysiphe monardae*, *Golovinomyces biocellatus*), and were characterized by high drought and winter tolerance.

The essential oil of developed varieties of *Monarda fistulosa* L. and *Monarda didyma* L. contained 23 substances, the main of which are thymol, methylcarvacrol, carvacrol,  $\gamma$ -terpinene, *n*-cymene and octenol-3. Thymol, a predominant component, is a natural monoterpene phenol, which determines the medicinal value of *Monarda* essential oil. Its mass fraction ranged from 70.44% to 78.28%. In addition to phenols, the

essential oil also contains mono- and bicyclic terpenes, acyclic terpenes and their oxygen derivatives (Table 2).

The maximal mass fraction of thymol, 78.28%, was found in the essential oil of the Premiera variety, which exceeded the minimal values of this indicator in *Monarda didyma* L. variety Nizhnist by 11.1%. The Fortuna variety was only slightly inferior to Premiera in terms of the thymol content. However, the largest amount of the second most valuable substance in the *Monarda* essential oil, carvacrol, was detected in Fortuna – 3.84%, which is by 7.4% greater than the in Premiera and by 58.7% greater than in *Monarda didyma* L. Nizhnist variety (Fig. 5).

The content of methylcarvacrol, ether of thymol and carvacrol, in the studied varieties was 4.60–4.89%. Regardless of the ratio of thymol to carvacrol, the mass fraction of methylcarvacrol in essential oils was always greater than that of carvacrol. The maximal content of *n*-cymene, 3.68%, and  $\gamma$ -terpinene, 7.24%, was detected in *Monarda didyma* L. Nizhnist variety, exceeding the contents *n*-cymene and  $\gamma$ -terpinene of *Monarda fistulosa* L. Premiera and Fortuna varieties by 1.7 and 21; 1.8 and 80 times, respectively (Fig. 6).

Having compared the essential oils of *Monarda didyma* L. Nizhnist variety, *Monarda fistulosa* L. Premiera and Fortuna varieties, all of which were developed in SE “Research farm “Novokakhovske” of the Institute of Rice” of NAAS, the chemical diversity of their content was determined quantitatively and by calculating ratios of individual substances. Discrepancy in the composition of the essential oil from raw

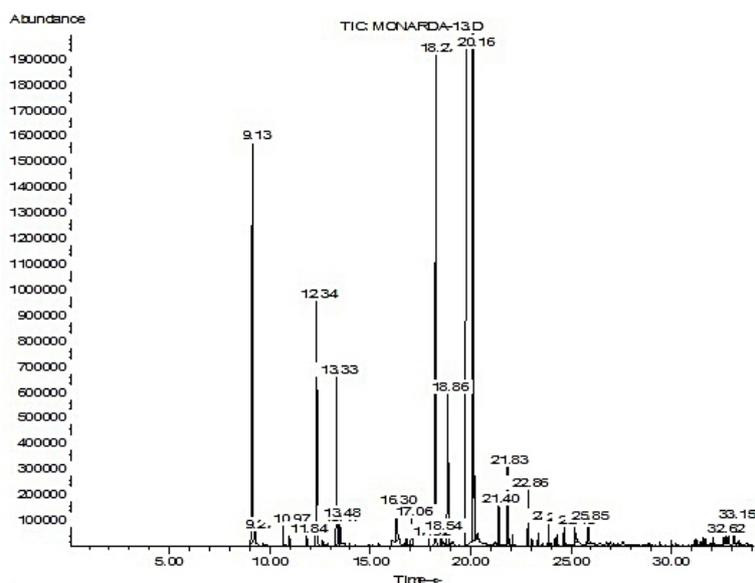
**Table 2.** Content of the essential oil of the *Monarda fistulosa* L. and *Monarda didyma* L. varieties

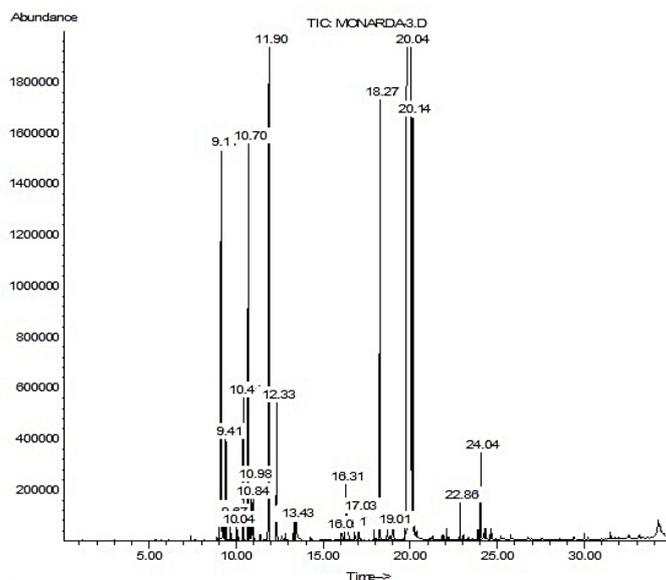
Substance	Proportion of essential oil, %		
	<i>Monarda fistulosa</i> L.		<i>Monarda didyma</i> L.
	Variety Premiera	Variety Fortuna	Variety Nizhnist
$\alpha$ -thuyene	0	0	0
$\alpha$ -cymene	0	0	0
octenol-3	2.11	4.32	4.54
octanol-3	0.58	0.07	0.15
$\alpha$ -terpinene	0.52	0.31	1.21
para-cymene	2.10	0.17	3.68
1,8-cyneol	0.44	0.17	0.40
$\gamma$ -terpinene	3.98	0.09	7.24
trans-sabinene hydrate	1.22	2.36	1.30
cis-sabinene hydrate	0.24	0.22	0.10
terpinene-4-ol	0.52	0.43	0.98
methylcarvacrol	4.80	4.89	4.60
thymol	78.28	77.3	70.44
carvacrol	3.58	3.84	2.42
$\beta$ -caryophyllene	0.30	0.39	0.22

plant materials within one species of *Monarda* is attributed by scientists to the varietal characteristics, region of the plant origin and other factors [Myadelets et al. 2014].

The conducted studies confirmed the maximal thymol content (77.30–78.28%) in the essential oil of developed *Monarda fistulosa* L. varieties, which is 8.9–10% higher than that of *Monarda didyma* L. In sharply continental climate of Western Siberia, these two species of *Monarda* yield 40–70% more essential oil

than in Crimea and up to 4.16% more than in the North Caucasus. However, the thymol content in the essential oil of *Monarda fistulosa* L. was lower, 60–72%, while thymol constituted 50–60% of the essential oil of *M. didyma* [Oparin et al. 2000]. The essential oil of *Monarda fistulosa* L. of the European origin contained up to 61% of thymol, up to 55% of carvacrol, 20–43% n-cymene, 3–20% of carvacrol methyl ether, 31% of  $\gamma$ -terpinene and 3-octanon [Tucker et al. 2009]. The phenol content (thymol and

**Figure 5.** Chromatogram of the essential oil from the aboveground part (raw plant material) of the *Monarda fistulosa* L. Fortuna variety in 2018



**Figure 6.** Chromatogram of essential oil from aboveground part (raw plant material) of the *Monarda didyma* L. Nizhnist variety

carvacrol) in the essential oil of Crimean origin ranged from 67 to 86% [Rabotyagov et al. 2011].

## CONCLUSIONS

Many years of research conducted at SE “Research farm “Novokakhovske” of the Institute of Rice” of NAAS led to the development of the *Monarda fistulosa* varieties, Premiera and Fortuna, *Monarda didyma* Nizhnist variety and *Monarda* × *hybrida hort* variety Tonya. The maximal plant height (120 cm), yield of aboveground mass (18 t/ha), concentration of essential oil (0.8% of raw mass) and its thymol content (78.3%) are characteristic of the *Monarda fistulosa* Premiera variety. *Monarda fistulosa* Fortuna variety and *Monarda* × *hybrida hort*. Tonya variety were inferior to Premiera in terms of all abovementioned indicators but had greater resistance to powdery mildew pathogens (*Erysiphe monardae*, *Golovinomyces biocellatus*) and exhibited increased decorativeness. The yield of essential oil from plant raw materials of the *Monarda didyma* L. Nizhnist variety was lower by 32.9% and 26.8%, while its concentration – by 37.5 and 28.6%, compared to *Monarda fistulosa* L. Premiera and Fortuna varieties, respectively.

The plants of the developed varieties undergo a full cycle of development and produce seeds in the arid climate of the southern steppe of Ukraine. They are characterized by high drought and winter tolerance, as well as the resistance to pest

damage. Therefore, they can be recommended for region-wide cultivation in agricultural enterprises of the southern steppe of Ukraine as promising essential oil, spice-aromatic and decorative crops.

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