

Conference Paper

The Potential of Using the New Species *Monarda Didyma* L. for Introduction in Western Siberia

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Abstract

This article examines the introduction and use of the new species *Monarda didyma* L. in the conditions of Western Siberia. The rhythm of the seasonal development of the longrhizome-taphrhizome life form was investigated. The timing and duration of the basic phenological phases were determined and their temperature thresholds were identified. Based on the phenological development, it was established that *M. didyma* can be classified as a long-growing evergreen plant. According to the identified blossoming period, the species falls into the long-flowering late-summer group. The presented phenological spectrum represents an important comparative and practical tool for Western Siberia and other geographical areas. The new species has a promising outlook for cultivation in Western Siberia and possesses a high adaptive potential, which allows for its use as an essential-oil-bearing, aromatic, decorative and melliferous plant.

Keywords: *M. didyma*, of using, introduction, rhythm of seasonal development

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1. Introduction

Monarda didyma L. is a perennial herbaceous polycarpic plant in the family *Lamiaceae*, native to North America. Its natural habitat ranges from Quebec to North Carolina. It grows in the prairie, on grasslands, preferring sunny open spaces [1]. It is cultivated in many European and Asian countries as a decorative, officinal and aromatic plant [2]. The essential oil contained in the above-ground part of the plants is characterized by a high bactericidal activity as well as anti-inflammatory, immunomodulating and antimicrobial properties thanks to its rich composition and high concentration of thymol, carvacrol and vitamins (B2, B1, C); *M. didyma* can be thus considered a promising officinal plant. The presence of the essential oil allows for its wide application not only in medicine, but also in perfumery and cosmetology. Its long blossoming period allows for the use of *M. didyma* in landscape gardening as well as a melliferous plant. The concept of “plant

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introduction” encompasses the idea of effectual human activity, oriented towards the enrichment of the cultivated flora of a country or area with new plants [3]. Several scholars [4, 5], while dealing with the issues of the sustainable socio-economic development of rural areas, have pointed out the necessity for the formation and development of multifunctional agriculture, the generation of new complex approaches and mechanism which might ensure the growth of economic parameters and significantly increase the life quality of the population. The introduction of new plant species, possessing several economic benefits, is of crucial scientific and practical interest in Western Siberia. The cultivation and processing of the promising oil-essential-bearing species *M. didyma* as a raw material can become one of such new approaches, ensuring the execution, on part of agriculture, not only of its traditional functions, but also of the functions of different industrial sectors (food-processing, microbiological, medical and chemical). In order to unclothe the potential of using *M. didyma* under new natural and climatic conditions, the introduction success rate should be evaluated according to an asset of biological and economic parameters, the main of which are the full accomplishment of ontogenesis, the cycle of seasonal development and the conservation on part of the plant of its inherent habit. The complex research of the ontogenesis and seasonal rhythmic processes in perennial plants allows for the evaluation of the level of sustainability of a species under new natural and climatic conditions, as well as of the promising outlooks of its cultivation [6]. *M. didyma* has been cultivated in Russia as a decorative plant since the XIX century, as an aromatic and officinal species since the XX century, but the peculiarities of its adaptive possibilities under the conditions of Western Siberia have not been studied yet. The introduction of the species *M. didyma* thus represents a current topic.

The aim of the study was to identify the growth potential of *M. didyma*, to research the peculiarities of seasonal rhythm and to evaluate the promising outlooks of the introduction of the new species in Western Siberia.

To achieve the set goal, the following tasks were undertaken:

1. Identifying the life form and describing its habit in the generative period of the ontogenesis occurring under the conditions of introduction;
2. Researching the rhythm of seasonal development, analyzing the phenological spectra over the years while taking into account the weather and climatic conditions, identifying the temperature thresholds (the sums of the effective temperatures at the start of each phenological phase);
3. Determining the quantitative indices of the essential oil contained in *M. didyma* under the conditions of Western Siberia;

4. Evaluating the introduction success rate and promising outlooks of using the species *M. didyma* under the new vegetation conditions.

2. Methods and Equipment

Experimental research started at the Botanical Garden of Omsk State Agrarian University in 2006, when trials were laid down using vegetative material obtained from the Central Siberian Botanical Garden of the Siberian Branch of the Russian Academy of Sciences (Novosibirsk, Russia). In the following years, trials were carried out yearly by means of direct inoculation of locally produced seed, which were sown in early spring on allotments with a declared area of 2.0 m² with fourfold replication. Recording and observations were registered taking into account at least 30 sample plants over a period of nine years (2009-2016). Research on the biological and morphological characteristics of the seeds and on their germination ability was carried out in collaboration with the Centre for Collective Usage “Plant Breeding and Seed Research of Field Crops” (Omsk State Agrarian University, Omsk, Russia) and the Centre for Collective Usage “Equipment for the Microscopic Analysis of Biological Objects” (Central Siberian Botanical Garden of the Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia). Phenological observations on the seasonal development of plants were carried out by applying the methodology of I.N. Beydeman [7]. Particular attention was devoted to the phenological phases: blossoming and fructification, but also the beginning and end of vegetation, in order to outline the characteristics of the habit and subsequently some recommendations for the further use of the plants. The individual development of *M. didyma* individuals was studied according to the conception of the discretional description of ontogenesis by T.A. Rabotnov [8]. The life form was determined following the ecological and morphological classification of life forms using individuals in their middle-aged generative condition [9]. The pertaining phenorhythmtype was identified following the classification by I.V. Borisova [10]. The success rate and promising outlooks of the introduction were evaluated taking into account an asset of biological and economic parameters based on a point scale [11, 12]. The city of Omsk is geographically located in the temperate climatic zone [13]. The climate in Omsk is typically continental, lukewarm (average annual temperature of +2.1 °C) and considerably humid (hydrothermal index of 1.0) with a long-lasting harsh winter, a short hot summer (the temperature in summer months ranges between +16.4 °C and +19.4 °C) and relatively short mid-seasons. The long-term average annual temperature amounts to +2.1 °C. The coldest month is January with an average temperature of -17.7 °C, while the warmest is June with an average

temperature of +19.4 °C. Over the years of research the absolute minimal temperature amounted to -40.0 °C in February and December 2012, while the highest maximal temperature amounted to +36.0 °C in June 2012 and August 2011 and 2012. The area of introduction is characterized by harsh temperature fluctuation over the year in specific days, which leads to climatic instability. The absolute annual amplitude of air temperature is high, reaching 86.0-92.0 °C. The continentality index amounts to 0.90 in the city of Omsk. Average monthly precipitations in summer months range between 5.0 mm and 172.0 mm. Average yearly precipitation amount to 379.0 mm. The frost-free period lasts 130 days. Quantitative data were elaborated using Microsoft Excel and Word.

TABLE 1: Biomorphological characteristics of *Monarda didyma* L. in the generative period

Age condition	Young generative (g1)	Middle aged (g2)	Old generative (g3)
Height of the vegetative shoot, cm	$\frac{38.9 \pm 3.2}{18.0 - 70.0}$	$\frac{36.5 \pm 2.1}{21.0 - 57.0}$	$\frac{59.1 \pm 2.4}{46.0 - 86.0}$
Number of vegetative shoots, pcs	$\frac{2.0 \pm 0.1}{1.0 - 3.0}$	$\frac{3.0 \pm 0.3}{1.0 - 7.0}$	$\frac{3.6 \pm 0.3}{1.0 - 6.0}$
Height of the generative shoot, cm	$\frac{115.5 \pm 2.2}{96.4 - 140.0}$	$\frac{102.3 \pm 0.9}{94.0 - 117.0}$	$\frac{80.1 \pm 1.3}{70.0 - 95.0}$
Number of generative shoots, pcs	$\frac{6.0 \pm 0.4}{3.0 - 12.0}$	$\frac{12.5 \pm 0.6}{8.0 - 19.0}$	$\frac{1.3 \pm 0.1}{1.0 - 2.0}$
Number of metamers on the elongated generative shoots, pcs	$\frac{12.7 \pm 0.2}{11.0 - 14.0}$	$\frac{11.8 \pm 0.2}{10.0 - 14.0}$	$\frac{12.1 \pm 0.2}{10.0 - 15.0}$
Width of the leaf blade, cm	$\frac{3.6 \pm 0.1}{2.5 - 4.2}$	$\frac{3.4 \pm 0.1}{2.6 - 5.0}$	$\frac{2.5 \pm 0.1}{1.8 - 3.4}$
Length of the leaf blade, cm	$\frac{8.1 \pm 0.2}{5.6 - 9.7}$	$\frac{7.5 \pm 0.3}{5.7 - 9.6}$	$\frac{6.2 \pm 0.2}{4.0 - 8.4}$
Length of the leafstalk, cm	$\frac{1.6 \pm 0.1}{1.2 - 2.1}$	$\frac{1.2 \pm 0.1}{1.0 - 1.6}$	$\frac{1.1 \pm 0.1}{0.5 - 1.2}$
Length of the main inflorescence, cm	$\frac{6.4 \pm 0.1}{5.5 - 7.0}$	$\frac{6.8 \pm 0.1}{6.0 - 8.0}$	$\frac{6.9 \pm 0.2}{3.5 - 7.0}$
Number of capitate thyrsi in the synflorescence	$\frac{6.3 \pm 0.4}{3.0 - 9.0}$	$\frac{7.5 \pm 0.7}{3.0 - 17.0}$	$\frac{2.7 \pm 0.2}{1.0 - 5.0}$
Bush diameter*, cm	$\frac{15.7 \pm 0.2}{14.0 - 18.2}$	$\frac{23.6 \pm 0.6}{20.0 - 29.0}$	$\frac{15.6 \pm 0.2}{14.0 - 20.7}$

Notes: above the line, the average amount ± the error is indicated; under the line, the minimum and maximum values *: in young generative individuals (g1), the parameters of the bed diameter are indicated, while in middle aged (g2) and old generative (g3) ones, the parameters of the partial bush are given.

TABLE 2: Evaluation of the promising outlook of the introduction of the species *Monarda didyma* L. in Western Siberia (according to the scale by Karpisonova, 1985)

Species	Seed reproduction	Vegetative reproduction	Habit conservation in the culture	Plant survival rate under unfavourable conditions	Vulnerability to diseases and pests	Total score
<i>Monarda didyma</i> L.	3	3	3	2	2	13



Figure 1: Blossoming phase of *Monarda didyma* L. in Western Siberia

3. Results

Under the natural climatic condition of Western Siberia, *M. didyma* is a sympodially growing perennial herbaceous plant which forms a longrhizome-taprhizome life form [14]; the main structural unit of the individual is represented by a branched dicyclic elongated orthotropic shoot with full and partial development cycle. In the generative

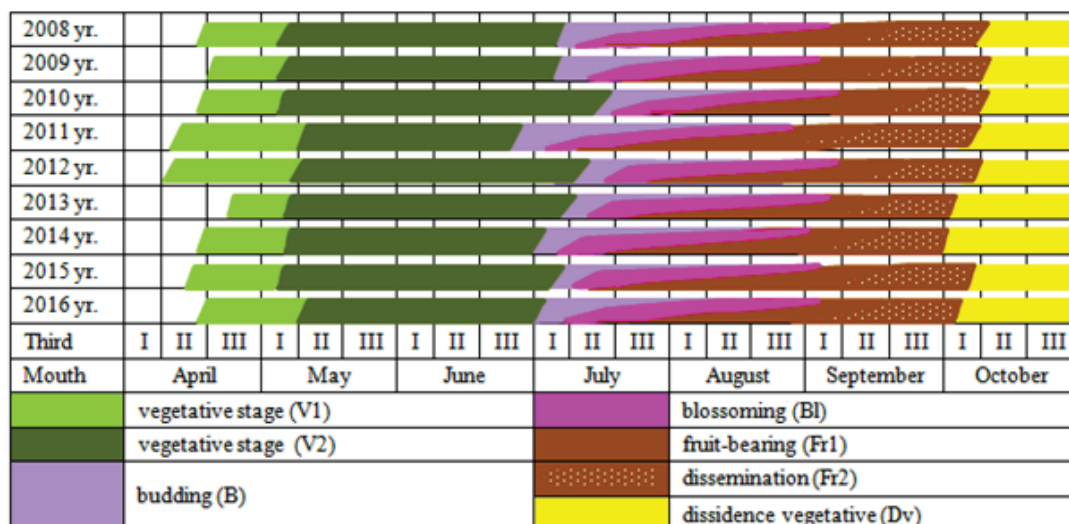


Figure 2: Phenological spectrum of *Monarda didyma* L. after introduction in Western Siberia

period the individual form a bed in Figure 1. The average height of generative shoots amounts to 80.1-115.0 cm in Table 01. The stems are tetrahedral and slightly pubescent. The leaf arrangement is decussate; the leaf blade has an oval-lanceolate shape with jagged margins and green colour. The synflorescence is a closed raceme consisting of 1.0-17.0 frondous-bracteous capitata thyrsi. The leaves of the upper formation are transitional (3 pairs) along the central vein and the margins and have the same colours as the flowers. The cup is tubular, quinque-lobed, between 0.7 and 1.0 cm in length, slightly pubescent; the subulate teeth of the cup are purple-coloured. The corolla is bilabiate, between 2.3 and 3.0 cm in length. Two prominent stamens are present. The flowers are purple or violet with a strong scent of mint and bergamot. The average overall amount of flowers per inflorescence amounts to 83.0-272.0. The vegetative shoots are mesotonically branched above the ground, with a height of 18.0-86.0 cm. 13.0-18.0 elongated metamers are axially distributed, their leaves have the same shape as in the generative shoots. The fruit is a quadrilocular coenobium carrying 1 mericarp with an oval-elongated shape and dark brown colour. During their life cycle, the individuals undergo four ontogenetic periods and ten conditions. The average life span of individuals in the Omsk Region reaches 7-9 years.

Nine years of phenological observations have led to the elaboration of the phenological spectrum of *M. didyma* in Figure 2, in which the peculiarities of the rhythm of seasonal development are graphically represented. The spring aftergrowing of shoots begins as soon as the average daily temperature reaches +5 °C, this period usually starts at the end of the II third of April (on average on April 17th), with a GDD of 30 °C and higher. Deviations were observed in 2011 and 2012, when the beginning of such

phase was registered 5-7 days earlier, and in 2013, when it was registered 8 days later than the average dates. As for the beginning of the phase of active vegetation (B1), the rhythm becomes even over the years, active growth begins and shoots start to branch. Most individuals transition to this phenological state when the GDD exceeds 120 °C in the I third of May (on average on May 7th). As regards the beginning of the phase of active vegetation, slight deviations of ± 3 days can be observed along the years. In the III third of May plants are particularly valuable for decorative use thanks to the variety of shapes of leaf blades (cordate, oval-ovate, oval-lanceolate) and for the light green colour of greenery. The phase of the beginning of budding starts on average in the I third of July (July 7th) when the GDD exceeds 960 °C on average; such phase lasts 35-40 days. The earliest beginning of the budding phase was registered in 2011 (June 27th), the latest were registered in 2010 (July 16th). After 4-9 days the plants transition to the blossoming phase when the GDD exceeds 1000 °C; the beginning of the blossoming phase starts around the July 12th, its end – around September 3rd. The fructification phase starts about 7-9 days after the beginning of the blossoming phase when the GDD exceeds 1400 °C and is long-lasting (38-51 days). According to its blossoming rate, *M. didyma* falls into the long-flowering late-summer group. Fruits mature about 1.5 months after the beginning of blossoming (on average on August 26th), while the dissemination (shedding of metacarps) begins when the GDD exceeds 1800 °C (on average on September 9th), i.e. 10-15 after fruit maturation (most commonly on the 10th day). The shed fruits do not have a rest period and show spontaneous seeding already on the 10th-15th day. After fructification and dissemination the reproductive shoots wither away, under the local conditions this occurs in the beginning of October; in this phase, active growth and development of vegetative innovation shoots can be observed on average until the end of October. According to the characteristics of the phenological development, the species can be classified as a long-growing evergreen plant. The phenorhythmtype varies between 179 and 198 days. This way, *M. didyma* undergoes the full cycle of seasonal development.

In cooperation with the scientists from the Central Siberian Botanical Garden of the Siberian Branch of the Russian Academy of Sciences and the Novosibirsk Institute of Organic Chemistry named after N.N. Vorozhtsov, the composition of the essential oil of *M. didyma* plants after introduction in the forest-steppe area of the Omsk Region was studied and compared with the oil of plants cultivated in other regions of Russia [15]. Over the years of research (2010-2013) the content of essential oil in raw material obtained from *M. didyma* varied between 0.92 and 2.11 %; nonetheless, its composition remained stable. 1.26 % was obtained on average from the whole above-ground part of

the plants. 37 different components were identified in the samples at studies; the main components were thymol (64.9 %) and carvacrol (1.2 %).

The results of the evaluation of introduction are presented in Table 02 using a point scale. The overall result amounts to 13 points, thus *M. didyma* can be considered a promising species.

4. Discussion

In order to unclosethe potential of using *M. didyma* under new natural and climatic conditions, we introduced success rate should be evaluated according to an asset of biological and economic parameters. The complex research of the ontogenesis and seasonal rhythmic processes allowed for the evaluation of the level of sustainability of a species under new natural and climatic conditions. During their individual development, the individuals of *M. didyma* undergo a full ontogenesis. The generative period for economic and decorative use is of crucial interests, under the local weather and climatic conditions it lasts 3-5 years. The analysis of the seasonal development allows stating that *M. didyma* undergoes a full cycle of seasonal development, while the duration of the vegetation and of the phenological phases under introduction conditions depends on the annual weather conditions, varies between 179 and 198 days. The main index of seasonal rhythmic is the duration of blossoming: the period lasts 38-51 days and depends on the age of the plants and on the branching and number of generative shoots. During the blossoming phase, *M. didyma* plants are especially decorative and economically useful. As a rule, valuable essential oil is obtained from plants during the flowering phase. In our research (2010-2013), as for content and composition, the essential oil is not inferior to the one in the traditional cultivation areas of the species. Subsequently, possessing a high adaptive potential *M. didyma* and is a promising oil-essential-bearing species for introduction under the conditions of Western Siberia. The success rate and promising outlooks of the introduction were evaluated taking into account an asset of biological and economic parameters based on a point scale in Table 02. Each parameter shall now be considered separately.

As regards seed reproduction, seed renewal is abundant and occurs annually. The thousand kernel weight amounts to 0.4-0.8 g. In the second and subsequent years, plants form a considerable amount of full seeds with a high laboratory (54-82 %) and field (34-60 %) germinating capacity, which testifies the promising outlooks of reproduction of the species in Western Siberia. The shed fruits do not have a rest

period (spontaneous seeding already on the 10th-15th day), it is therefore necessary to plan the seed harvesting period in advance to avoid losses.

While evaluating the introduction success rate of a new species according to the overall behaviour of plants in the trial and to the asset of economic parameters, its capacity of vegetative reproduction should be taken into account along with the capacity of seed reproduction [16]. As for the vegetative reproduction capacity, plants reproduce well by means of bed division and softwood cutting. When dividing the bed in autumn, the plants flower and produce full seeds in the following year. According to the observations on softwood cutting (2012), the rooting ability was high and amounted to 68-93 % even without treatment with a growth regulator. It has been established that the best options is represented by spring softwood cutting, since plants which are planted in the ground in autumn after rooting flower and produce full seeds in the following year.

As regards the habit conservation in the culture, when introduced under the conditions of Western Siberia, *M. didyma* conserves its natural dimension if compared to American representative species [17, 18].

The plant survival rate under unfavourable conditions is average; the withering away of shoots and loss of individuals occurs in case of particularly harsh autumn-winter and winter-spring periods. According to the observations, such phenomena amounted to 5-10 % per year and depended on the presence of extreme temperatures and snow covering in the transitional cold periods.

The vulnerability to diseases and pests is average. In warm dry years (2008 and 2012, in the period of active vegetation) plants were damaged by green tortoise beetles and spider mites; in July and August after consistent rainfalls singular plants were infected by powdery mildew (up to 72 %) in 2009, 2013 and 2016.

5. Conclusion

The species *M. didyma* is considerably promising for cultivation in Western Siberia (according to the scale by R.A. Karpisonova, it obtained 13 points) and possesses a high adaptive potential. *M. didyma* is a sympodially growing perennial herbaceous plant which forms a longrhizome-taphrhizome life form; the main structural unit of the individuals is represented by a branched dicyclic elongated orthotropic shoot with full and partial development cycle. The individuals form a bed in the generative period. The average life span of individuals in the Omsk Region reaches 7-9 years. The overall life span amounts to 3-5 years. During their individual development, the individuals of *M. didyma* undergo a full ontogenesis, which represents a high index of introduction

success rate. As regards the duration of vegetation, *M. didyma* can be classified as a long-growing evergreen phenorhythmtype, which varies between 179 and 198 days. The most important index of seasonal rhythmic is the duration of blossoming: the period lasts from 38 to 51 days, depending on the age of the individuals, the branching and number of generative shoots. According to the blossoming period, it falls into the long-flowering late-summer group. Thanks to its long vegetation and long-lasting blossoming, *M. didyma* is used as a decorative plant from spring to late autumn and attracts pollinating insects until the end of summer.

The potential of the new species *M. didyma* in Western Siberia allows for its use as an officinal, essential-oil-bearing, aromatic, decorative and melliferous plant, which is of crucial practical and scientific interest

Conflict of Interest

The authors have no conflicts of interest.

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