MORPHOBIOLOGICAL FEATURES AND THE SIGNIFICANCE OF THE SPECIES *PHACELIA TANACETIFOLIA* BENTH. AS HONEY PLANT

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Abstract

Phacelia tanacetifolia Benth. is a species native to North America and the Andean Mountains in South America. The climatic conditions of the Republic of Moldova are favorable for the growth and development of this species, where it is known as a valuable honey, ornamental and forage species. It is an herbaceous annual, which ends the growing season by producing seeds. The germination capacity of seeds is 77.5±6.18% and the germination energy is 1-3 days. The weight of 1000 seeds is 1.96±0.03 g. The researched species is of interest to beekeepers, being a source of food for honey producing and pollinating insects, available for about 55 days, ensuring high productivity of honey, with long growing season. Insects visit the plants the most frequently between 11:30 and 12:30, since at this time nectar is abundantly produced. It provides food for a wide range of honeybees and pollinators. The entomological monitoring carried out at the "Alexandru Ciubotaru" National Botanical Garden (Institute) revealed the presence of 27 species of insects present on the organs of *P. tanacetifolia* plants, representing 6 orders, 20 families and 24 genera, insects with a diverse trophic spectrum. According to diversity and frequency, species of the genus *Apis* and *Bombus*, the main honey-making and pollinating insects, were more abundantly present.

Key words: *Phacelia tanacetifolia*, honey production potential, development.

Phacelia tanacetifolia Benth. – annual herbaceous plant, native to North America, which was brought to Europe initially as an ornamental plant, and later was used as a honey plant with nectariferous and polleniferous significance (Williams I., Christian D., 1991). It was subsequently researched by many botanists who highlighted the value of this species as honey plant, which can be also used as fodder with high nutritive value (Hickman J., Wratten S., 1996; Sengonca C., Frings B., 1988; Williams I., Christian D., 1991). In the last decades it has been intensively cultivated as a source of nectar to obtain honey production, for the regeneration processes of degradable land, as green manure and as food supplement in the livestock sector. It can also play the role of a natural remedy in controlling the number of harmful insect species, for the maintenance of natural and anthropogenic coenoses (Hickman J., Wratten S., 1996; Sengonca C., Frings B., 1988; Williams I., Christian D., 1991). In Europe, lacy phacelia, in addition to mustard, oilseed radish, oats, buckwheat and dill, is used for pest control in peach orchards (Brown M., 2002).

From morpho-taxonomic point of view, the species belongs to the order *Solonales*, family Hydrophylaceae Lindl. (Boraginaceae Juss.), genus *Phacelia* Juss., where it includes about 200 species of annuals and perennials (Lakic Z. *et al*, 2018). It grows abundantly regardless of the environmental factors, about 60-96 cm tall, forming main stems on which up to 20-25 lateral shoots develop, which also branch out (Țîței V., Roșca I., 2021). At the top of the shoots, 15-20 compact scorpioid cyme inflorescences are produced, consisting of 4-6 coils (whorls). A coil can have 18-22 flowers (Cîrlig N., Iurcu-Străistaru E., Țîței V., 2021), forming a fan-shaped inflorescence with flowers that open in sequence, facilitating the formation of nectaries – a source of nutrition for honeybees and other species of insects from the useful fauna. The calyx has subequal lobes, linear, 5.0-7.5 mm long and 0.4-0.7 mm wide, consisting of 5 stamens, with 5 blue-violet petals and sepals with bristles. The anthers and style protrude out of the flower (Țîței V., Roșca I., 2021).

In bioecological terms, the flowering period is long. The first flowers appear 40-55 days after sowing, and flowering lasts up to 55-60 days (Cîrlig N. *et al*, 2021), except for the cases of

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abnormally high temperatures and pedological drought during the flowering period. It is a species with high productivity, from which purple pollen is obtained. As for the fruit, it is a small dehiscent capsule with 4 dark brown seeds (granules) reaching 3.5-4.2 mm long and 2.2-3.0 mm wide. The weight of 1000 seeds is 1.9–2.0 g. (Țîței V., Roșca I., 2021).

P. tanacetifolia plants develop an extensive and very strong tap root system. This honey plant has a potential productivity of 400-600 kg/ha of honey, in ecological terms, it is an anti-pollution remedy and regulates the number of invasive nematode complexes in the soil, acting as a biological repellent (Țîței V., Roșca I., 2021).

According to the bibliographic data, *P. tanacetifolia* was introduced to Europe in the second half of the 19th century, initially as honey and ornamental plant, and then it was widely explored by beekeepers from the former USSR. Later it has spread to practically all the countries of Eastern and Western Europe. According to Crane et al. 1984, lacy lacy phacelia is among the top twenty honey plant species of major significance worldwide, but mostly in the countries with well-developed beekeeping industry.

Lacy phacelia attracts both honeybees and other complexes of insects feeding on nectar and pollen, the maximum share being attributed to the trophic group - phytophages, followed by omnivorous and zoophagous species (Cîrlig N., Iurcu-Străistaru E., Țîței V., 2021), most of the adult forms feed on the nectar and pollen of flowers, being also the main pollinators of lacy phacelia flowers.

The nectariferous potential of lacy phacelia flowers varies widely depending on the impact of favorable and stressful environmental factors that occur in some vulnerable phases, such as: sowing, the formation of plants, flower buds, affecting the quality of flowers during nectar formation, the maturation of fruits and seeds. The amount of nectar can be in the range of 1.0-4.5 mg/flower, with an average sugar concentration of 28% and honey production – between 500 and 1200 kg/ honey/ ha (Popovic C. *et al*, 2019). For 24 hours in the nectar of a flower, 0.25-0.5 mg of sugar is produced, sometimes up to 2-5 mg (Culacov V., 2007). The honey obtained from lacy phacelia flowers is light beige to cream-white in color, glassy, translucent, with a specific smell and lemony taste, slow crystallization, with an optimal fructose to glucose ratio as compared with honey obtained from the white acacia species (Popovic C. *et al*, 2020).

A special aspect during the growing season of the lacy phacelia is its impact with nectarivorous, pollinophagous, phytophagous insects etc., dependent practically on all nectar-pollinating species, where as a result of the activity of honey producing insects, they are necessary to maintain vitality as well as to obtain bee products, as a biological source with melliferous, curative and fodder potential. Resulting from these significant facts and motivations, we created, for research purposes, a collection of plant species with mainly melliferous potential, but also with other valuable bioecological qualities, within the "Alexandru Ciubotaru" National Botanical Garden (Institute). The collection consists of various native and introduced species from various geographical regions, with different taxonomic affiliations.

The purpose of the research has been to study some morphobiological, ecological and melliferous peculiarities of plants of the species *Lacy phacelia tanacetifolia* and their response to the impact of the climatic conditions of the Republic of Moldova.

MATERIAL AND METHOD

The research was done on the experimental sector located on the territory of the "Alexandru Ciubotaru" National Botanical Garden (Institute) (NBGI), “Plant Resources” Laboratory. The seeds and plants of the species *Lacy phacelia tanacetifolia* Benth. served as research subjects. The seeds of the autochthonous cultivar 'Melifera' created at the "Alexandru Ciubotaru" National Botanical Garden (Institute) and seed samples of the investigated taxons, obtained by international exchange (France, Russia), including plants available in the collection of honey plants, where there are multiple forms already known for their utility as fodder and energy crops. The research was carried out during the 2020-2022 growing seasons, characterized by temperatures above the norm, periods of insufficient precipitation followed by heavy rains, alternations of diurnal and seasonal temperatures, recorded in the critical spring-summer phases. Sowing was carried out in spring at different dates (19.03; 14.04; 22.04; 11.05), depending on the recorded weather conditions, in well-prepared soil, at a depth of 2 cm. The phenological study carried out according to the appropriate guidelines (Beideman I., 1974). Surveys were done at different phenological stages of plants, from seed germination to maturity. At the same time, comparative observations were made on the emergence of floral shoots, their formation, full flowering, in correlation with the abundance and frequency of honey-making insect species, detected in the same periods, establishing the diversity and trophic spectrum of insects, taxonomic classification, degree of impact, melliferous potential. All the data obtained were recorded in field notes, documented

according to the development stages, substantiated by photos, analyses and visual observations of the collected samples, which were later examined under laboratory conditions and compared with botanical and entomological determination guidelines and other specialized literature (Plavilschikov N., 1997; Bei-Bienco G., 1966).

RESULTS AND DISCUSSIONS

In the flora of the Republic of Moldova, there are already several species of honey plants that stand out due to their high productivity, but in order to support the integrity and improvement of the resources of honey plants, in certain areas and micro-zones of the country, these species have been cultivated in various sectors, alone or in association with other plants, in meadows, hayfields, with the aim of maximizing honey production, maintenance of the fauna of honey-producing insects, the ecological balance of the soil and the natural environment. Internationally, as well as in the Republic of Moldova, such valuable honey plants are known and largely cultivated: *Helianthus annuus* L.; *Brassica napus oleifera* L.; *Onobrychis viciifolia*; *Melilotus albus* Medik.; *Mellissa officinalis* L., *Echium vulgare* L.; *Nepeta cataria* L. etc., and in the last decade, the species *Lacy phacelia tanacetifolia* Benth. has gained a lot of popularity.

According to the results of the conducted research, this species possesses melliferous, fodder, curative qualities, which are applied in the formation of new honey plant sectors, in agricultural and fodder crop rotation. These reasons lie at the basis of conducting research on this species, which is quite resistant to most environmental stressors and has high estimated productive potential.

This species is attractive to honeybees and other pollinating insects, being visited by them from early morning to late evening, in spring and summer months. Insects visit the plants the most frequently between 11:30 a.m. and 12:30 p.m., since at this time nectar is abundantly produced, besides, the period after light rain is also preferred by pollinating insects.

In morphobiological aspect, the above-mentioned species was researched in terms of its response to the impact of the climatic conditions of the Republic of Moldova, which are characterized by short winter with little snow and hot summer with insignificant amounts of precipitation. Regardless of the action of stressors such as dry weather, high temperatures, short-term rain showers, lacy phacelia plants in the Republic of Moldova show the ability to adapt to weather variability.

The morphological aspect of *P. tanacetifolia* plants is represented by annual growth from seeds planted at different stages, to encompass the entire active period from spring to late summer. Lacy phacelia passes annually and seasonally through the phenological cycle of growth and development consisting of vegetative and generative phases, completing the cycle with the formation of viable fruits and seeds, which are to be used as planting material in the following season. The germination capacity of seeds is 77.5±6.18% and the germination energy is 1-3 days *(figure 1A).* The experiments to determine the germination capacity were set up under laboratory conditions, in Petri dishes, in several repetitions by 100 seeds each. The fruit is a dehiscent capsule with 4 brown seeds. The weight of 1000 seeds is 1.96±0.03 g.

Initially, the young plants have succulent stems *(figure 1B)* and are a little sensitive to climate and soil conditions; they do not tolerate saline soils, but preferentially grow on light soils and on fertile, well-drained ones. The plants growth fast and produce significant amounts of nectar and seeds. Then, once the flower buds are formed, with the transition to full flowering stage, the stem at the base becomes fibrous and lignifies, the process advancing towards the apical area.

A B

Figure 1 **A – seeds of *Lacy phacelia tanacetifolia* in the 3rd day after germination; B – lacy phacelia on the experimental sector of NBGI, vegetative stage/stem development**

Ph. tanacetifolia, under the climatic conditions of the Republic of Moldova, develops stems on average 115-120 cm tall, branched, which develop about 20 lateral shoots, tap root and sessile, pinnate leaves, with 7-8 linear or pinnately-lobed leaflets with toothed margin. In the investigated growing seasons of lacy phacelia (from the moment of seedling emergence until seed ripening) plants complete a biological cycle, on average about 80-92 days. The start of the flowering stage depends on the time of sowing;

the floral shoots are formed in sequence, with staggered flowering influenced by environmental factors, this stage usually occurs in May-July. The flowering process lasts about 55 days, due to the successive development of secondary shoots, at the top of which inflorescences are produced; this peculiarity contributes to prolonging this important stage, benefiting to the high value of this species for nectar production in beekeeping. During this period, a plant produces about 15-20 fan-shaped scorpioid inflorescences with 4-6 one-sided coils, which straighten as the flowers mature, wither and the fruits develop. An inflorescence develops 18-22 flowers – blue-violet, sessile, actinomorphic, with a double perianth and long style protruding from the flower. The lifespan of a flower is 1-2 days. Due to the sequenced blooming, on a lacy phacelia plant, there can be inflorescences in different stages of development *(figure 2)* at the same moment – buds in the apical part of the inflorescence, open flowers in the middle area, and fruits at the base.

Figure 2 **Inflorescences in various stages of maturity developed on a shoot**

In the research program, experimental sectors were planted with lacy phacelia seeds at various timing in order to determine the most effective planting timing and flowering period for nectar and pollen production. The seeds were planted into the soil in spring (March-May), at different dates, in correlation with the recorded weather conditions. Seedlings emerged at the soil surface 7-15 days after sowing. The seeds sown in March were the most difficult to germinate (about 20 days) as the soil temperatures were lower, as compared with those sown later. There follows a period when the plants develop their root system and intensively form the green mass, the main shoots appear, from which the lateral ones – of 2nd and 3rd order branch out.

The dates when the phenological stages started, according to the biological cycle, were recorded and analyzed comparatively in correlation with the sowing date, in the research years 2020-2022. Analyzing the results obtained according to the implemented program, the values were indicated in *table 1*, which reflects the date of the start of each phenological stage, from sowing to the ripening of the lacy phacelia seeds. From the obtained data, we can infer that by sowing in different periods, we can plan the needed flowering period, which will coincide with the end of April to end of July, providing the useful entomofauna with food in the required period according to the beekeepers' schedule. In cases if there are seeds left from the previous harvest on the field planted with lacy phacelia, in early spring (mid-March) the seeds germinate as soon as favorable temperatures are recorded, and in May there are already plants in the flowering stage. These periods established according to the calendar program are beneficial to prevent entering the dry and arid periods that usually occur in the second half of summer, which are practically ineffective for the formation of honey production, but significantly accelerate the processes of seed ripening and drying of plants that induce the premature end of the growing season.

Table 1.

Stages of development of *P. tanacetifolia* plants in the growing seasons 2020-2022.

Taxon	Year	Sowing	Seedling emergence	Stage of development				
				Budding (full)	Flowering (full)	Fruiting (full)	Seed ripening (full)	Seed harvesting
***Ph. tanacetifolia* 'Melifera'**	2020	11.05	18.05	22.06	26.06	09.07	28.07	02.08
***Ph. tanacetifolia* 'Melifera'**	2021	22.04	04.05	10.06	21.06	28.06	20.07	26.07
***Ph. tanacetifolia* 'Melifera'**	2022	19.03	13.04	20.05	01.06	20.06	26.06	08.07
***Ph. tanacetifolia* (Rusia)**		14.04	26.04	07.06	13.06	29.06	18.07	28.07
***Ph. tanacetifoloa* (Franța)**		14.04	03.05	14.06	20.02	02.07	10.07	19.07

The species is mentioned in various bibliographic sources and specialized literature as plant with multiple uses: production of honey, fodder and as green fertilizer in agriculture. In ecological terms, this species is relatively resistant to various stressful pedoclimatic conditions. The minimum temperature necessary for seed germination is +5+7 °C, and the optimal

temperature for plant growth is +15..35 C, with moderate humidity (Țîței V., Roșca I., 2021). The biomorphological aspect of lacy phacelia plants is attractive and preferred by pollinating and honey-making insects since the appearance of the first flowers. Honeybees are particularly abundantly present on flowers throughout the day. Lacy phacelia nectar, in addition to being a source of food for honeybee insects, also serves as food for 60 species of parasitoids described and reported by various authors and specialists (Brown M., 2021).

At the same time, on the territory of NBGI, entomological monitoring was also carried out on the experimental sectors planted with lacy phacelia since 2019. The identification of insects begins at the stem elongation stage of plants. Special attention was paid to the entomofauna when the plants entered the generative phase of development (budding-flowering), when a large diversity and varied spectrum of insects was detected and categorized according to trophic specialization, taxonomic affiliation, frequency and abundance. The analyzed samples allowed the revision of the entomological list made previously (Cîrlig N. *et al*, 2021) and its completion with new species of insects. In total, 27 insect species were identified, representing 6 orders, 20 families and 24 genera, insects with a diverse trophic spectrum and enormous significance in the flower pollination process.

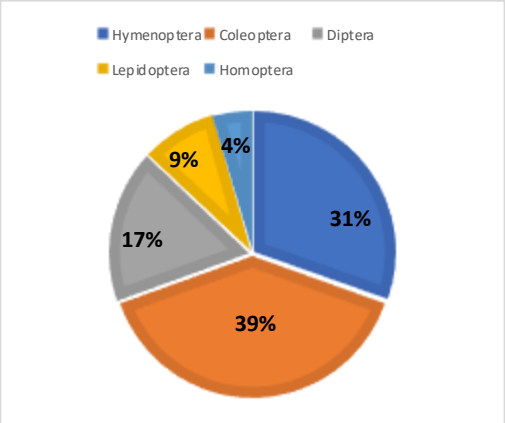
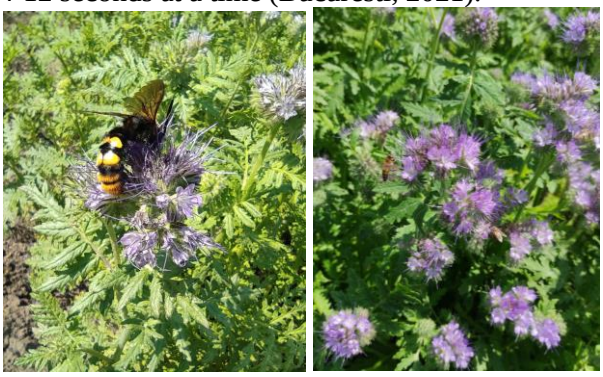


Figure 4 **Comparative share of insect species according to orders**

The comparative analysis of the number of insects, demonstrated that the maximum share belongs to the order Coleoptera with 38% of the total number of determined species, followed by the order Hymenoptera with 31 %, Diptera – 17 %, Lepidoptera – 9 % and the order Homoptera – 4 %, represented by *Cercopis arcuata* (Fieber, 1844).

Lacy phacelia flowers are also attractive to giant insect species. One of them is *Megascolia maculata*, the mammoth wasp, a vulnerable species, included in the Red Book of the Republic of Moldova *(figure 3).* It feeds on lacy phacelia nectar and pollen and plays an important role in the pollination process.

Studying the activity of insects on lacy phacelia plants in NBGI, it was found that a honey bee collects pollen/nectar from an inflorescence for 4-12 seconds at a time (Bucuresti, 2021).

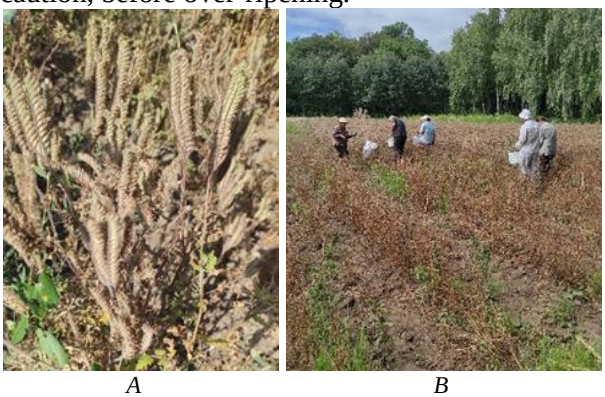


A B

Figure 3 **A – a representative of the species *Megascolia maculata* (Drury, 1773) feeding on lacy phacelia flowers; B – lacy phacelia in the full flowering stage**

About 5-9 insects belonging to 2-4 species were detected on one plant at the same time. The species of the genera *Apis* L., *Bombus* Latr., *Coccinella* L. have the maximum frequency during the day, but also during the entire flowering period of the plants.

At the same time, the study was continued on the formation, ripening and harvesting of seeds, which coincide with the last days of June - July - beginning of August, shown in figure 5. Seeds are harvested manually, preferably in the first half of the day, after which, there are several stages of seed processing/cleaning. The productive potential of lacy phacelia plants under the climatic conditions of the Republic of Moldova is about 53 t/ha of fresh mass, 260-300 l/kg biogas and the calorific value is 18.1-18.4 MJ/kg, being used as agricultural residues after harvesting the seeds (Țîței V., Roșca I., 2021). The seeds fall off easily, for this reason harvesting must be done with caution, before over-ripening.



A *B*

Figure 5 ***Ph. tanacetifolia* at the end of the growing season; A – full fruiting stage/beginning of seed ripening; B – manual harvesting of lacy phacelia seeds at NBGI**

CONCLUSIONS

The conducted research highlighted the valuable biological features of the species *Lacy phacelia tanacetifolia* Benth., a high-potential honey plant, as an important contribution to the enrichment of the range of honey plants. Under the climatic conditions of the Republic of Moldova, the flowering period of the plants lasts for about 55 days, a plant producing on average 15-20 fan-shaped inflorescences with 4-6 coils. In an inflorescence, there are 18-22 blue-lilac flowers, with double perianth and long style protruding from the flower. The lifespan of a flower is 1-2 days. Due to the structure of the inflorescences and the sequenced flowering, lacy phacelia plants provide insects with food over a long time. Planting lacy phacelia seeds at different timing can provide honeybees with food for the period needed by beekeepers, thus controlling the production of bee products. Lacy phacelia flowers are a source of nectar and pollen for a wide range of honeybees and pollinators. The list of insects detected and determined on *P. tanacetifolia* plants from the "Alexandru Ciubotaru" National Botanical Garden (Institute) has been revised and supplemented, currently including 27 species of insects classified into 6 orders, 20 families and 24 genera. The identified species are recognized as valuable honeybees and important pollinators.

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