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FLOWERING AND NECTAR SECRETION IN TWO FORMS OF THE MOLDAVIAN DRAGONHEAD (*DRACOCEPHALUM MOLDAVICA* L.) – A PLANT WITH EXTRAORDINARY APICULTURAL POTENTIAL

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Abstract

Dracocephalum moldavica **is a valuable reward plant for flower visitors. The aim of the study was to ecologically characterise its flowers and leaves and assess the seasonal and daily dynamics of flowering in two white- and blue-flowered forms of this species in 2004 and 2005. Additionally, the duration and abundance of plant flowering as well as the nectar amount and sugar content were analysed. The signalling attractants of the plant include an intense scent emitted by trichomes located not only on its flowers but also on its stem and leaf surfaces. The average corolla length is 24 mm and the corolla tube, which can be completely filled with nectar, is 8.6 mm long. The floral lifespan was shown to reach 2-3 days and the mean blooming duration of both forms of dragonhead 45-48 days. The white-flowered plants produced a substantially greater number of flowers (5352) than the blue-flowered form (2965). The nectar amount obtained from ten blue flowers was 15.33 mg and that extracted from white flowers reached 17.56 mg, with 49.4% and 51.5% content of sugar, respectively. The total sugar mass produced by one white-flowered plant was 4656 mg, while one blue-flowered plant yielded 2164 mg of sugars. The sugar yield calculated in the study for the white-flowered form (586 kg · ha^{-1}) was two-fold higher than that in the blue-flowered plants.**

Keywords: blooming, dragonhead, flower, glandular trichomes, nectar, sugar production

INTRODUCTION

The family Lamiaceae comprises 236 genera and approximately 7000 species (Harley et al., 2004). Floral nectar is a very important attractant to animals visiting flowers of the species of this family (Zhang et al., 2014). Nectar serves essential ecological functions, as it is a primary attractant for different pollinator groups (Pacini et al., 2003; Nicolson & Tornburg, 2007; Heil, 2011; Nepi et al., 2011, 2012). The rate and time of nectar secretion during the day are associated with the requirements of pollinating animals (Nicolson, 2007). Similarly, the sugar content of nectar is adapted to fulfil the needs of pollinator groups (Baker & Baker, 1983; Nicolson & Tornburg, 2007).

Given their abundant nectar secretion, Lamiaceae species are regarded as valuable apicultural plants in both Central Europe (Szklanowska, 1965; Maurizio & Grafl, 1969; Jabłoński, 1986; Pritsch, 2007; Sulborska et al., 2014) and the Mediterranean Basin (Herrera, 1985; Dafni et al., 1988; Petanidou & Smets, 1995; Petanidou et al., 1999). Pritsch (2007) emphasised the long flowering period in this species, which lasts from three to five months. Many species from this plant family are appreciated as aromatic spice, ornamental, medicinal and cosmetic plants, e.g. *Mentha*, *Thymus*, *Salvia*, *Lavandula*, or *Rosmarinus* (Podbielkowski & Sudnik-Wójcikowska, 2003; Naghibi et al., 2005; Kohlmünzer, 2016).

The Moldavian dragonhead (*Dracocephalum moldavica* L.) is another of these multipurpose plants (Wolski et al., 2004). The *Dracocephalum* genus from the family Lamiaceae comprises approximately 40 species native to Central Asia

(Brickell, 1999; Szweykowska & Szweykowski, 2003). Three of the four species occurring in Poland, i.e. *D. parviflorum* Nutt., *D. ruyschiana* L., and *D. tymiflorum* L., grow in natural habitats, whereas *Dracocephalum moldavica* L. is cultivated in gardens but can also be found as a wild species (Rutkowski, 2006).

The dragonhead, known in Europe since the 16th century first as *Melissa moldavica* or *M. turcica*, originates from southern Siberia and the Himalayas (Hegi, 1965). It is an annual species recommended for cultivation near apiaries as a valuable nectariferous and aromatic plant producing essential oils with an intense lemon scent (Bornus, 1989; Lipiński, 2010). The use of the dragonhead herb during work in the apiary is recommended, as the smell of this plant has a calming effect on honeybees (Bornus, 1989). The *D. moldavica* essential oil has been found to contain chemical compounds, e.g. citral (Kubiak, 1959), geranial, neral, and geraniol (Kakasy et al., 2002; Wolski & Kwiatkowski, 2005), that are valuable for pharmaceutical, cosmetic and food industries. The honeybee consumes geraniol from floral nectar and, after condensation, processes it into a trail-marking pheromone. A portion of geraniol is processed into citral in the bee's organism (Harborne, 1997). The essential oil of *D. moldavica* is secreted by numerous differently structured secretory trichomes located in the epidermis of flowers, leaves and stems (Kubiak, 1959; Weryszko-Chmielewska & Dmitruk, 2010).

D. moldavica flowers are arranged in pseudo-whorls growing in leaf axils. The calyx and corolla are clearly bilabial. The corolla can be purple-blue or white. At the basal part, it forms a relatively long tube accessible to insects with sufficiently long tongues. However, the widened throat of the flower provides bees with access to nectar as well. A disc-shaped nectary is located at the ovary base. The colourless nectar with a weak lemon scent accumulates in the corolla tube up to ¾ of its height or fills it completely (Maurizio & Grafl, 1969; Wolski et al., 2004; Lipiński, 2010). Maurizio & Grafl (1969) found the optimum duration of *Dracocephalum moldavica* nectar secretion from 12.00 to 14.00. The honey value of pure *Dracocephalum moldavica* culture is estimated by the authors at 129-650 kg·ha^{-1}.

The aim of the study was to determine the dynamics, duration and abundance of flowering depending on the meteorological conditions and to compare the amount of nectar secreted by two Moldavian dragonhead forms: white-flowered and blue-flowered. Additionally, the content and total mass of sugars in the nectar were compared as well as potential sugar and honey yield was calculated and some morphological traits of the floral nectary of this species were presented. The primary purpose of these investigations was to answer the question if flowers of these two dragonhead forms have a good apicultural potential for representatives of *Apis mellifera*.

MATERIAL AND METHODS

The research was conducted in 2004-2005 in the Medicinal Plant Garden of the Chair and Department of Pharmacognosy, Medical Academy in Lublin (51°15'23.3"N, 22°33'50.4"E). Two white-flowered and blue-flowered forms of the *Dracocephalum moldavica* L. were investigated. The plants seeds were collected in 2003 from the same area and kept in a room with a constant temperature of 22°C and approx. 55% air humidity. The seeds (seeding standard 6 kg ·ha^{-1}), previously treated with the Funaben T formulation, were sown directly to the soil (loess-podzolic soil, pH 6,5-7,4) on April 30 in 2004 and 2005 in 4 ·m^{-2} (2 x 2 m) plots, at 40 x 20 cm spacing (10 plants per raw, i.e. 12,5 plants ·m^{-2}). Several seeds were sown per point, and emerging seedlings were thinned, leaving one plant. Mineral fertilisation (Polifoska) with 300 kg ·ha^{-1} was applied in four doses: one application during preparation of the soil for sowing (150 kg ·ha^{-1}) and three top-dressing applications at doses of 30, 50, and 70 kg ·ha^{-1}. The seeds were sown in the same area for both years and in the same conditions. Ten specimens of each form were examined in both study years from the onset of plant flowering to the end of the process (July 20 – September 20).

The onset and duration of plant flowering were determined. The mean lifespan of single flowers in the inflorescence was determined based on daily observations of the development of previously labelled flower buds (n=20, for each form).

To estimate the flowering abundance, lateral shoots as well as flowers developing on the main shoot and on three lateral shoots were counted. Flowers were counted every day throughout the blooming period. The mean number of flowers was multiplied by the number of shoots per plant.

The daily flowering dynamics was determined for 30 lateral shoots in each form. The observations involved I- and II-order branches. The number of opened flowers was checked every two hours from 6:30 to 18:30 for five days. The results were calculated as the percentage proportion of flowers opening within two hours relative to the number of all opened flowers during the day (100%).

The investigations of nectar amount (mg) were conducted with the commonly accepted pipetting method (Demianowicz et al., 1960; Jabłoński 2002). Nectar was sampled from flowers that were isolated for 2.5 days. The nectar was collected from the flowers at ca. 12.00 o'clock for two days (three samples of different sets of flowers each day). One sample was composed of nectar collected from 10-40 flowers to get a measurable amount of the secret. The sugar content of nectar was determined using an Abbe refractometer. The amount of nectar and sugar content of nectar were used to calculate the total sugar mass in each sample. The total sugar mass produced in nectar by one flower and the number of flowers per unit area was used to calculate the sugar yield (kg · ha^{-1}) and the honey yield (kg · ha^{-1}).

The length of corolla and corolla tube as well as the diameter of the corolla tube (n=20; 2 flowers x 10 plants for each form) were measured each year of the investigations. The diameter and the height of the nectary of each form were measured (n=10). Trichomes secreting essential oils located on the calyx, corolla, stem, and leaves, which attract honeybees were observed under a light microscope.

The results were subjected to one-way Anova. The significance of the differences was assessed with Tukey's test. The level of statistical significance for all analyses was at P=0.05. The relationships between the analysed variables were examined using Pearson's correlation coefficients. The calculations were performed using Statistica ver. 6.0.

Fig. 1. Apoidea insects collecting nectar and pollen from dragonhead flowers (*Dracocephalum moldavica*). a. Representative of the genus *Bombus*. b-d. *Apis mellifera* workers. Arrowheads show pollen loads.

RESULTS

Floral and leaf characteristics

During the *D. moldavica* flowering period, we observed honeybees and bumblebees collecting nectar from the flowers as well as pollen grains (Fig. 1). The flowers of the investigated species grow at the plant apex and form whorls located at short distances from each other (Fig. 2a). The lanceolate leaves with a serrate margin exhibit the opposite arrangement. The margins of the lower part of leaf blades and bracts are equipped with long spiny appendages (Fig.

Fig. 2. Dragonhead (*Dracocephalum moldavica*) in the flowering stage. a. Fragment of a flowering plant. b. Upper surface of a bract. c. Lower surface of a bract with visible concavities (arrows) bearing large peltate glandular trichomes. d, e. Flowers of the purple-blue and white forms. f. Exposed ovary (O) with the nectary (N) after removal of the calyx and corolla.

2b,c). Both surfaces of the lamina of stem leaves and bracts bear abundant peltate trichomes located in concavities, which are visible already at low magnifications under the light microscope (Fig. 2c). Both these and varied-length capitate trichomes secrete essential oils and give a scent to the leaves, stems, and flowers (Fig. 3).

The flowers of *D. moldavica* have a zygomorphic and hirsute corolla. The length in both dragonhead forms differs only slightly and depends on the location in the inflorescence. The corolla length is 18-26 mm, the average length is 24 mm. The length of the corolla tube in which the nectar accumulates is 7.5-10.5 mm, with an average length of 8.6 mm. The diameter of the corolla tube, which expands slightly upwards, is 1-1.5 mm. The calyx covering the corolla tube is slightly longer than the tube (Fig. 2e).

The lower corolla lip, which is a landing site for insects, is very well developed. Dark purple spots on the lower lip and purple anthers highly contrasting with the basic colour of the petals are visual attractants of purple-blue flowers (Fig. 2d). The visual attractants in the white-flowered form are creamy and therefore hardly visible to the human eye against the petals (Fig. 2e).

The basal part of the corolla tube surrounds the pistil ovary with the adherent nectar gland. The nectary is orange-yellow, in contrast to the quadrilocular green ovary. The nectary forms an asymmetrical disc with a very well developed lobe near the lower lip (Fig. 2f). The diameters of the nectaries in the analysed *D. moldavica* forms were similar, i.e. 1.2 mm on average. Similarly, the average height of the highest lobe was 1.2 mm.

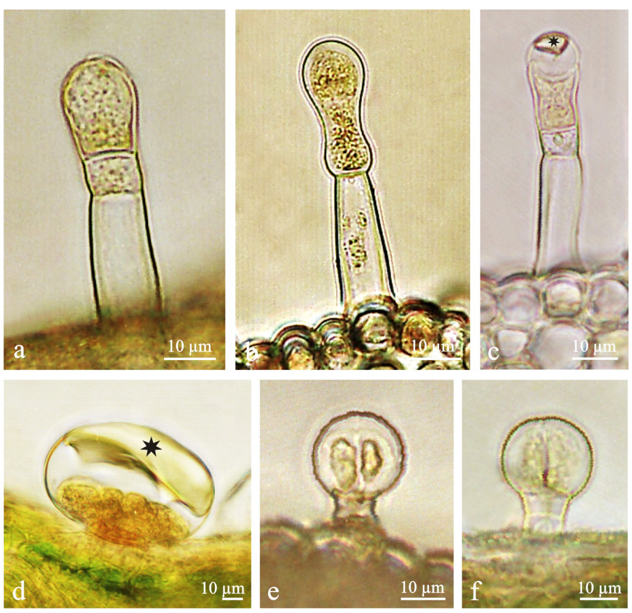

Fig. 3. Different types of dragonhead (*Dracocephalum moldavica*) perianth, stem and leaf trichomes secreting essential oils. a-c. Long (2-3-celled) trichomes with visible secretion in the apical cell (asterisk); a – calyx, b, c – stem. d. Multicellular peltate trichome with essential oil accumulated under the cuticle (asterisk) located on the outer surface of corolla. e, f. Short trichomes with a bicellular head producing essential oil, from: e – calyx, f – leaf.

Flowering duration and abundance

The flower lifespan of the two dragonhead forms in both study years (2004-2005) was 2-3 days. Plant flowering during the two vegetation periods started during the third ten days of July

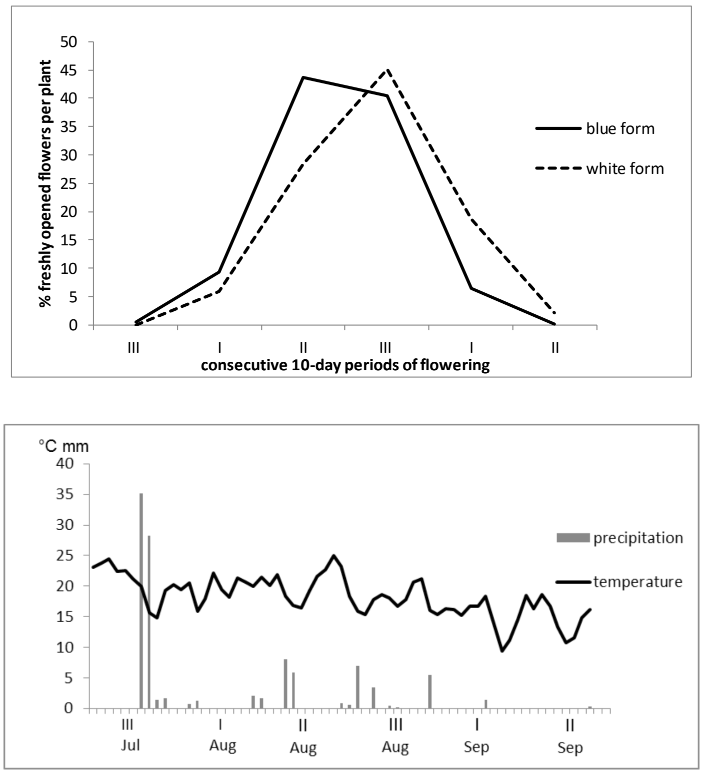

Fig. 4. Seasonal dynamics of *Dracocephalum moldavica* L. blooming and weather factors (rainfall and air temperature) in Lublin, 2004.

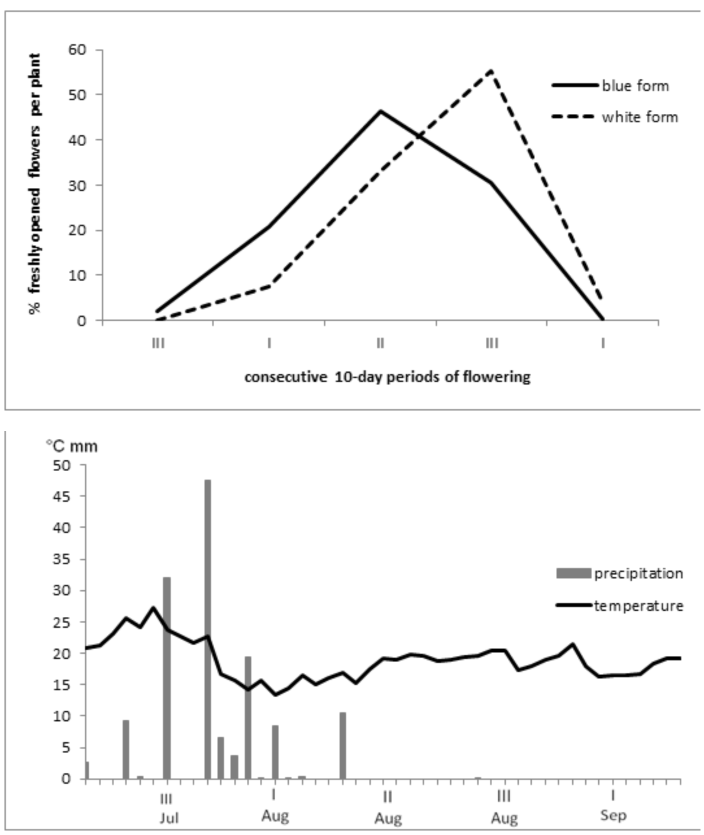

Fig. 5. Seasonal dynamics of *Dracocephalum moldavica* L. blooming and weather factors (rainfall and air temperature) in Lublin, 2005.

(Tab. 1). The blue-flowered plants began their flowering period five days earlier than the white-flowered ones. The flowering ended during the first and second ten days of September in 2005 and 2004, respectively. The flowering period lasted 45-48 days and was longer for the blue-flowered form. In 2005, more favourable weather conditions were noted during the dragonhead flowering period in comparison with 2004. This was related to the greater amount of total precipitation at the end of July and the beginning of August (onset of plant flowering) (Fig. 5) and the higher air temperature in July (average monthly temperature of 21°C and 19°C in 2005 and 2004, respectively). These conditions may have contributed to the greater number of flowers produced especially by the white-flowered form.

The dynamics of flowering in 2004 and 2005 were similar. The peak of flowering of the white-flowered form (over 45% of opened flowers) was noted during the last week of August in both years. The blue-flowered variety exhibited two peaks of intensive flower opening, i.e. during the second and last week of August. The maximum intensity of flower opening was noted on rain-free days with an air temperature of 18-20 ˚C and, less frequently, 21-25 ˚C (Fig. 4, 5).

On warm and sunny days, the dragonhead flowers opened from early morning hours. The analysis of the daily flowering dynamics revealed that the two flower opening peaks were at 6.30 and 10.30 in the case of the white-flowered form and at 6.30 and 12.30 for the blue-flowered variety. Over 60% of the white flowers bloomed until 10.30, and over 70% of the blue flowers bloomed intensively until 12.30 (Fig 6).

The number of floral whorls developing on the main shoots during the flowering period was 14-18 in both forms, and the number of flowers per whorl was constant, i.e. 6. In

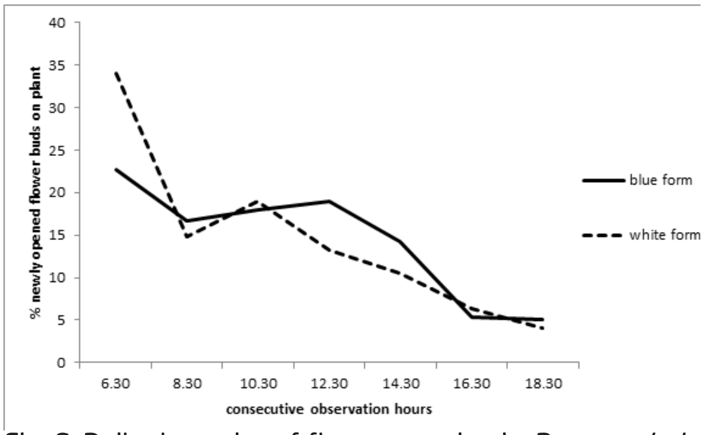

Fig. 6. Daily dynamics of flower opening in *Dracocephalum moldavica* L. in 2004.

turn, 3-5 floral whorls were formed on 1st order lateral shoots and on their numerous branching shoots.

The white-flowered plants were characterised by greater flowering abundance than the blue-flowered form. Throughout the flowering period, there were a substantially greater number of flowers on the main and lateral shoots in the white-flowered form. The white-flowered plants had more lateral shoots (17.8) than the blue-flowered form (14.8). The number of flowers on lateral shoots in the white-flowered form was by 28% higher in 2004 and by 40% in 2005 than that in the blue-flowered form. The mean number of flowers per plant during the entire vegetation period was 1.8 times bigger in the white-flowered variety than in the blue-flowered form. The differences between the flowering abundance of the two *D. moldavica* forms were confirmed statistically (Tab. 1).

Nectar characteristics

The amount of nectar, the sugar content of nectar and total sugar mass of nectar in the flowers of the blue-flowered form differed significantly between 2004 and 2005. The white-flowered form exhibited a statistically significant difference only in the sugar content of nectar between the study years (Tab. 2). The beneficial weather conditions in 2005 described above may have contributed to the greater sugar content in the nectar in both forms. The amount of nectar obtained from ten blue flowers was 13% lower than from white flowers. The sugar content of nectar was also smaller (by 2.2%) in the white-flowered form compared with the

Table 1.

Botanical aspects of *Dracocephalum moldavica* L. flowering in the years 2004 -2005

	Taxon	Flowering period	Average number of flowers on the main stem	Average number of lateral shoots on the plant	Average number of flowers on the lateral shoots	Average number of flowers on the plant during vegetation period
2004	**Blue form**	26.07-14.09	81.0 a	14.8	193.0 a	2937.4 a
	White form	31.07-17.09	102.9 a	18.1	266.4 a	4915.7 ab
2005	**Blue form**	25.07-6.09	96.9 a	14.8	195.7 a	2993.4 a
	White form	30.07-7.09	110.9 a	17.5	324.4 a	5788.3 b
Mean	**Blue form**	26.07-10.09	88.95 A	14.8	194.4 A	2965.4 A
	White form	31.07-12.09	106.9 B	17.8	295.4 B	5352.0 B

Means within columns with the same small letter do not differ significantly between years within a forms, and the means with the same capital letter do not differ significantly between forms at P<0.05 on HSD Tukey's test.

Table 2.
Amount of nectar, sugar content of nectar and total sugars mass in nectar per 10 flowers of *Dracocephalum moldavica* L. in 2004-2005.
Values are means ± SD.

Year	Term	No. of samples	Nectar amount [mg]		Sugars content in nectar [%]		Total sugars mass in nectar [mg]	
			White form	**Blue form**	**White form**	**Blue form**	**White form**	**Blue form**
2004	20.08	3	13.00^{a}±5.00	17.00^{Ab}± 0.00	54.87^{b}±0.32	53.23^{b}± 0.25	7.13^{a}±2.75	9.05^{a}±0.06
	27.08	3	22.67^{a}±6.11	21.33^{a}± 0.58	37.70^{d}±0.36	35.50^{d}± 0.50	8.55^{a}±2.34	7.57^{a}± 0.10
	Mean		**17.84^{A}±7.28**	**19.17^{A}**±2.40	**46.29^{B}**±9.41	**44.37^{B}**±9.72	**7.84^{A}**±2.41	**8.31^{A}**±0.79
2005	22.08	3	13.89^{a}±3.47	11.92^{b}±4.63	61.8^{a}±0.50	58.65^{a}±1.45	8.58^{a}±2.12	6.99^{a}±2.79
	24.08	3	20.67^{a}±2.33	11.05^{b}±0.43	51.80^{c}±0.30	50.30^{c}±1.08	10.71^{a}±1.35	5.56^{a}±0.23
	Mean		**17.28^{A}±4.56**	**11.49^{B}**±2.98	**56.80^{A}**±5.49	**54.48^{A}**±4.71	**9.65^{A}**±1.94	**6.28^{B}**±1.95
	Mean		**17.56±5.80**	**15.33±4.77**	**51.55±9.17**	**49.43± 8.99**	**8.75±2.30**	**7.31±1.76**
	RSD %		30.00	31.10	17.80	18.20	26.30	24.10

Means within columns with the same small letter do not differ significantly between years within forms, and the means with the same capital letter do not differ significantly between forms at P<0.05 on HSD Tukey's test. RSD (Relative Standard Deviation) for whole variable.

blue-flowered form.

Due to the differences in the nectar amount, there were substantial differences in the total sugar mass in nectar; in 2005, the differences were statistically significant. The great differences in the flowering abundance and the total sugar mass affected nectar sugars yield per plant of the analysed *D. moldavica* forms. The value of this parameter was nearly three-fold higher in the white-flowered form (5788 flowers x 0.965 mg sugars per 1 flower = 5585.42 mg/plant) than that in the blue-flowered variety (2993 flowers x 0.628 mg sugars per 1 flower = 1879.60 mg/plant) (Tab. 1-2). The calculated Pearson correlation coefficient revealed a strong correlation between the percentage sugar content and sugar mass in the nectar of the white- (p=0.903) and blue-flowered (p=0.975) forms.

The sugar yield calculated in our study was 586 kg $\cdot ha^{-1}$ in the white-flowered form and 271 kg $\cdot ha^{-1}$ in the blue-flowered form. The honey yield was 732 kg $\cdot ha^{-1}$ (white-flowered form) and 339 kg $\cdot ha^{-1}$ (blue-flowered form).

DISCUSSION

Floral phenotypes are usually characterised by 'pollinator syndromes', i.e. distinct combinations of colour, aroma and flower shape, which are closely associated with a specific group of pollinators (Waser, 1998; Fenster et al., 2004). In ecological systems, *Dracocephalum moldavica* flowers are classified as the bee-pollinated type. This is indicated by the following traits: the colour of the flower preferred by these insects, characteristic scent, flower size, symmetry, a well-developed lower lip facilitating pollinator landing, production of substantial amounts of nectar, appropriate content of sugar in the nectar and the pollination mechanism (Proctor et al., 1996).

The colour preferences of the honeybee have been determined by many authors. Faegri & van der Pijl (1979) and Harborne (1997) reported that honeybees choose yellow, intense blue and white flowers with specific patterns visible in the UV spectrum (Kugler, 1970). The colours of the flowers in both investigated *D. moldavica* forms as well as the presence of visual attractants closely correspond to the given range. As suggested by Harborne (1997), high sensitivity to pleasant, sweet, but not strong scents is typical for the honeybee. The odour of the essential oils secreted by *Dracocephalum moldavica* shoots is therefore attractive to honeybees (Bornus, 1989).

The numerous trichomes on *D. moldavica* leaves and stems observed in our studies greatly intensify the plant scent, which probably attracts insects from great distances. A similar opinion has been expressed by investigators of other species from the family Lamiaceae. It has been found that essential oils in *Melissa* species secreted by sepals, leaves, and stems have a different quality than these produced by the corolla. They are odour attractants exerting an influence on insects at a long distance, which allows them to find the appropriate plant. In turn, floral scents are perceived by insects from shorter distances than the odour of other plant parts (Schultze et al., 1992). Recently, many studies have been focused on the morphology of trichomes in plants from the Lamiaceae family and their content of essential oils (Zhang et al., 2014; Eiji & Salmaki, 2016; Giuliani et al., 2017; Haratym & Weryszko-Chmielewska, 2017; Yarmoohammadi et al., 2017).

The relatively large *D. moldavica* flowers (corolla length of ca. 24 mm) offer honeybees a possibility to land and collect nectar. Maurizio & Grafl (1969) described the presence of two large appendages on the lower lip, on which the honeybee usually puts the first-pair of legs. In this study, we have shown that the length of the corolla tube in the analysed species is 8.6 mm. In our opinion, this should not be a barrier for *Apis melifera* despite its shorter tongue (5.95-6.50 mm) (Demianowicz & Gromisz, 1998), as the abundantly secreted nectar reaches a high level in this narrow tube (1 mm diameter) and is therefore easily accessible.

As reported by Roubik & Buchmann (1984), the sugar content of nectar collected by *Apis mellifera* is 30-50%, and the optimum concentration for these insects is 60%. Similarly, Proctor et al. (1996) suggested that the mean sugar content of nectar collected by honeybees is 40%. As demonstrated by these authors, the sugar content of nectar of bee flowers often exceeds 50%. The sugar content of *D. moldavica* nectar determined in the present study (49-51%) is in the range specified by the researchers cited above, which confirms the adaptation of these flowers to pollination by the honeybee.

Nectar secretion in plants is genetically determined but can also be greatly modified by environmental conditions, e.g. light intensity, temperature, relative humidity, water availability, and CO_2 levels (Corbet, 1990; Jacobsen & Kristjansson, 1994; Petanidou & Smets, 1996; Petanidou, 2007, Nocentini et al., 2013). In the case of the plants examined in this study, we assessed the effect of temperature and precipitation on nectar secretion. The more beneficial weather conditions (i.e. higher temperature and higher precipitation rates) prevailing in 2005 in comparison with 2004 may have contributed to the higher sugar content in nectar in 2005.

As suggested by some investigators, the flower and nectary sizes are important for nectar abundance in plants from the family Lamiaceae. Dafni et al. (1988) found a positive correlation between nectar weight and nectary size in nine species of this family. In contrast, Petanidou et al. (2000) analysed the flowers of eleven species from this family and found no such correlation. In turn, they showed a positive correlation between the nectary diameter and sugar content. The large flowers (corolla length up to 26 mm) and relatively big nectaries (diameter 1.2 mm) in *Dracocephalum moldavica* may be a basis for abundant nectar secretion. Compared to other Lamiaceae representatives, the species analysed in this study is one of the most abundant nectar producers. Pritsch (2007) mentions species from the genera *Dracocephalum, Stachys, Lavandula*, and *Origanum* as Lamiaceae representatives with a high level of nectar secretion (grade 3 in a 4-grade scale). Among species investigated in Israel by Dafni et al. (1988), *Salvia hierosolymitana* and *Phlomis viscosa* were characterised by the greatest abundance of nectar secretion. In turn, *Salvia* *triloba* and *Prasium majus* investigated in Greece were found to produce the highest amounts of nectar (Petanidou et al., 2000), whereas *Lavandula dentata* and *Otostegia fruticosa* plants in Saudi Arabia were reported to secrete the greatest amount of nectar (Adgaba et al., 2017).

The amount of nectar secreted by one *Dracocephalum moldavica* flower throughout its lifespan (1.53-1.76 mg) determined in this study is higher than the average amount reported by Szklanowska (1965), i.e. 1.25 mg, and comparable to the maximum amount of nectar (1.7 mg) secreted per day by one flower of this species recorded by Maurizio & Grafl (1969). In turn, the sugar content of nectar analysed in this study was 49.4-51.5%, which differs from the mean values reported by Szklanowska (1965) (41.7%) and Maurizio & Grafl (1969) (36-42%). The sugar content in the nectar of the analysed species is comparable with the sugar concentration in *Stachys cretica* (51,9%) (Petanidou et al., 2000). The calculated total sugar mass in nectar produced by one *Dracocephalum moldavica* flower (0.73 and 0,88 mg) is similar to the maximum value of this parameter in this species reported by Maurizio & Grafl (1969) (0.76 mg) and substantially higher than the results obtained by Szklanowska (1965) (0.48 mg). These differences probably resulted from meteorological and soil factors (e.g. air temperature and humidity, vapour pressure, and soil moisture), plant fitness, genetic factors, etc. (Jabłoński, 1986, Mačukanović-Jocić & Durđević, 2005, Jarić et al., 2010), which is why the results may differ between the years of the study, plant growth localities, etc.

As reported by Maurizio & Grafl (1969), species from the family Lamiaceae with the highest efficiency of nectar secretion are represented by *Salvia officinalis* (1-5 mg nectar/flower/day) and *Lamium album* (2.0-2.7 mg nectar/flower/day). Similarly, Sulborska et al. (2014) demonstrated abundant nectar secretion in *Lamium album* (2.99 mg/flower/lifespan) with a high sugar content (43.1%).

In the present study, we have shown that the *D. moldavica* nectar contained a relatively large amount of sugars. On average, one flower of the white- and blue-flowered forms produced 0.88 mg and 0.73 mg of sugars, respectively. The mass of sugars yielded by one white-flowered plant producing 5352 flowers throughout the vegetation season was 4656 mg. In the case of the blue-flowered form, which produced 2965 flowers, the sugar mass yielded per plant was 2164 mg. The value of this parameter for the white-flowered *D. moldavica* plants was higher than that reported by Nuru et al. (2015) for *Lavandula dentata* (4078 mg/plant), which is regarded as a valuable apicultural plant as well. In turn, one blue-flowered *D. moldavica* plant yielded sugar mass comparable to the value calculated for *Lavandula pubescens* (2840 mg/plant) (Nuru et al., 2015). The comparison of honey yield in various representatives of the Lamiaceae family demonstrates that this parameter of the analysed white-flowered form of *D. moldavica* (732 kg $\cdot ha^{-1}$) was higher than that in *Salvia pratensis* – 171 kg $\cdot ha^{-1}$ (Ion, 2008), *Lamium album* – 191 kg $\cdot ha^{-1}$ (Sulborska et al., 2014), *Origanum vulgare* – 500 kg $\cdot ha^{-1}$ (Jabłoński, 1986), and *Phlomis tuberosa* – 500 kg $\cdot ha^{-1}$ (Jabłoński & Kołtowski, 1999). The honey yield of the blue-flowered form of *D. moldavica* (339 kg $\cdot ha^{-1}$) was lower than that noted in *Mentha longifolia* – 400-600 kg $\cdot ha^{-1}$ (Jabłoński, 1986) and *Salvia nemorosa* – 434,8 kg $\cdot ha^{-1}$ (Ion, 2008) but higher than in *Lamium purpureum* – 48 kg $\cdot ha^{-1}$ and *Lamium amplexicaule* – 66,2 kg $\cdot ha^{-1}$ (Ion, 2008).

An important role in the pollination process is played by a characteristic scent attractive to honeybees; in *D. moldavica*, it is emitted by all aboveground organs. Essential oils are emitted by numerous trichomes located on leaves, stems, calyces and corollas, which was demonstrated in our previous study (Weryszko-Chmielewska & Dmitruk, 2010).

The present study shows that *Dracocephalum moldavica* plants are very attractive to pollination insects owing to the following traits: large flowers and relatively large nectaries providing large amounts of nectar, a great number of flowers produced by plants, long flowering period (6-7 weeks) and a characteristic agreeable smell of the plant determined by the presence of many types of secretory trichomes. In Poland, it is not a wild-growing (or very rare) species but is cultivated in particular in herbal plantations (mainly for seeds used for oil extraction) and as an apicultural plant. The white-flowered form is cultivated more commonly. Our investigations have shown that the white form of *D. moldavica* is characterised by higher apicultural potential than the blue form. Nevertheless, both forms can be recommended for the enrichment of the honeybee reward source.

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