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FLOWERING DYNAMICS, NECTAR SECRETION AND INSECT VISITATION OF *Phacelia campanularia* A. GRAY

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Abstract

In the years 2004-2006, flowering dynamics and nectar secretion of *Phacelia campanularia* A. Gray flowers as well as the insect visitation rate were studied in the climatic conditions of Lublin, Poland.

The flowering of phacelia started in the middle of June and lasted for 1.5 up to 2 months. Full bloom occurred between the third and fifth week of the flowering period of this taxon. For the study period, the average weight of nectar produced by 10 flowers was 75.64 mg, weight of sugars 11.31 mg, while their concentration in the nectar was 20.2%. Among the entomofauna foraging on the flowers of phacelia, honey bees were predominant, with their proportion among the pollinators accounting for 84.8%.

Key words: *Phacelia campanularia*, flowering dynamics, nectar secretion, insect visitation

INTRODUCTION

The genus *Phacelia* Juss. includes more than half of all species of the family Hydrophyllaceae. Lacy phacelia (*Phacelia tanacetifolia*) is encountered most frequently in Poland, and it is grown primarily as an excellent melliferous plant. Flowers of different phacelia varieties provide a nectar and pollen source for pollinating insects (Demianowicz, 1953; Zimna, 1959, 1960; Warakomska, 1972; Jabłoński and Skowronek, 1983; Wróblewska, 2006). In favourable weather conditions, promoting intensive nectar secretion in flowers, monofloral honeys are obtained from *Phacelia tanacetifolia* in several European countries (Ricciardelli D'Albore and Intoppa, 2000; Persano Oddo et al. 2004; Stawiarz, 2006; Wróblewska et al. 2006; Wróblewska and Warakomska, 2009). In Argentina honeys from *Ph. secunda* have been obtained (Forcone et al. 2005; Forcone, 2008). Honey from *Ph. tanacetifolia* is colourless in liquid state, while after crystallization it takes on a whitish colour, sometimes with a golden tinge. It is characterized by aromatic scent and delicate flavour (Bodnarčuk et al. 1993; Stawiarz 2006). According to Ricciardelli D'Albore and Intoppa (2000), monofloral honeys obtained from the nectar of this taxon are amber coloured and have an intense scent and flavour.

The cultivated taxa of the genus *Phacelia* also include *Ph. campanularia*, characterized by high decorative values. This species is recommended for rock gardens, for borders and flowerbeds. Its flowers provide both nectar and pollen, and that is why they are visited by various insects (Howes, 1979; Mountain et al. 1981; Wróblewska, 2006).

The aim of the present study was to determine the diurnal and seasonal flowering dynamics of *Phacelia campanularia* and to estimate the nectar production rate and sugar yield of its flowers. Moreover, the intensity of foraging on its inflorescences by pollinating insects was investigated at different times of the day.

MATERIALS AND METHODS

In the years 2004-2006, flowering dynamics and nectar secretion of *Phacelia campanularia* A. Gray flowers as well as the insect visitation rate were studied in Lublin, Poland (51°14' N and 22°34' E).

Monitoring of the flowering pattern was carried out every day or every second day during two growing seasons (2004 and 2006), recording on 10 randomly selected plants the number of open flowers per plant

on each day. These observations were started when the first flower buds appeared and were continued until the end of flowering. In addition, in 2006 the daily flowering pattern was determined by recording, for several days at two-hour intervals, all open flowers on 10 marked plants. These investigations were conducted at full bloom of the species.

The rate of nectar production in flowers was investigated using the pipette method (J a b ł o ń s k i , 2003). Nectar was sampled during the successive growing seasons at two dates, each time from 10 flowers in six replications. The percentage sugar content in the nectar was determined with an Abbe refractometer. Sugar and honey yield per 10 flowers, per plant and per unit area of *Phacelia campanularia* were determined.

In order to determine the insect visitation rate for phacelia, the number of insects visiting its flowers at different times of the day was recorded on four plots with an area of 1m^2 each. Monitoring was carried out during two growing seasons, at full bloom, in favourable weather conditions for insect foraging. The number of insects was recorded at two-hour intervals, from 8:00 to 20:00 hours Eastern European Time.

The obtained results on sugar weight in nectar were subjected to statistical analysis using SAS 9.2 software. The significance of differences between means was evaluated at a significance level of α=0.05 using Tukey's test.

RESULTS

In the conditions of Lublin, the flowering of *Phacelia campanularia* lasted from 1.5 up to 2 months. The first flowers opened in the middle of June. Full bloom occurred between the third and fifth week of the flowering period of this taxon, when the mean number of flowers per plant was within the range of 23.5-33.8 in 2004 and 28.7-48.0 in 2006 (Fig. 1). High temperature and the lack of rainfall in the first and third decade of July 2006 reduced significantly the development of successive flower buds and, as a consequence of that, the intensity of flowering of the plants in the second half of this month. In both the seasons in question, phacelia finished blooming at the turn of the first and second decade of August (Fig. 1), but in 2005 nearly two weeks earlier, in the last week of July. The flower life span was, depending on weather conditions, 2-3 days. The investigations of the diurnal dynamics of flowering showed that the number of flowers per unit area changed throughout the day. At the full bloom stage, from 291.6 to 475.9 flowers were recorded per 1 m^2, but their number was the lowest at 14:00 hours and subsequently increased reaching its maximum at 20:00 hours (Fig. 2).

During the growing season, *Phacelia campanularia* produced on the main stem from several up to more than a dozen lateral branches which reached a height of 38 to 59 cm. An average of 388.7 to 437.8 flowers was recorded, and they were borne in inflorescences called drepanium (Fig. 3A). Depending on plant density per unit area and the abundance of flowering, the number of flowers produced per 1 m^2 of a flower crop was from 3692.6 in 2004 to 4159.1 in 2005, averaging 3943.4.

The nectary of phacelia is located within the flower, at the base of the ovary of the pistil (Fig. 3B). It has the shape of a disc and greenish-yellowish colour. The process of nectar secretion in flowers starts simultaneously with the opening of petals and is the most intense in the afternoon hours. The secreted nectar accumulates at the base of the corolla tube, whence it is collected by insects.

The weight of nectar from 10 flowers and the concentration of sugars contained in it varied both in particular years and between study years. The highest mean values of nectar per 10 flowers – 91.33 mg and 94.90 mg – were obtained in the first and third years of the study. The results in the 2005 season were more than twice lower, reaching only 40.71 mg (Table 1). Sugar concentration in nectar was closely correlated with nectar weight, and it ranged between 4.0 and 44.0%. Its mean values for the successive years of the study were 9.7%, 30.3% and 20.6%, respectively. The average weight of sugars from 10 flowers was the lowest in 2004 (7.57 mg), while in the next two years it was 12.67 mg and 13.70 mg (Table 1). Sugar yield per plant reached mean values within the range from 294.2 to 573.6 mg. From 2.79 mg to 5.45 mg of sugars could be obtained per 1 m^2.

Among the entomofauna foraging on the flowers of phacelia, honey bees were by far predominant (Fig. 3CDE), with their proportion accounting for 84.8% (Fig. 4). Their number was the lowest in the afternoon hours (Fig. 5). Solitary bees (7.8%) and bumblebees (4.6%) were characterized by much lower percentages (Fig. 4). Insects visited the flowers of the studied taxon throughout the whole day (Fig. 5).

Table 1

Nectar production of *Phacelia campanularia*

Year	Day and month	Weight per 10 flowers (mg)				Sugar concentration in nectar (%)	
		nectar		sugars			
		mean	range	mean ± SD	range	mean	range
2004	29 June	120.00	70.0-147.5	6.84 ± 2.35	4.00-10.80	5.8	4.0-8.0
	19 July	62.67	46.0-72.0	8.49 ± 1.56	6.30-10.50	13.6	12.5-14.0
	mean	91.33	-	7.66 A	-	9.7	-
2005	5 July	49.83	36.0-66.0	18.53 ± 2.94	15.84-22.95	34.0	25.5-44.0
	15 July	31.60	80.0-64.0	6.81 ± 2.28	3.44-9.60	26.6	15.0-43.0
	mean	40.71	-	12.67 B	-	30.3	
2006	29 June	149.20	108.0-220.0	14.20 ± 2.39	11.20-16.50	9.75	7.0-11.5
	7 July	40.57	20.0-72.0	13.20 ± 3.85	7.60-19.00	31.5	26.5-38.0
	mean	94.88	-	13.70 B	-	20.6	-
3-year mean		75.64	-	11.31	-	20.2	-

Means followed by the same letter are not significantly different at α=0.05

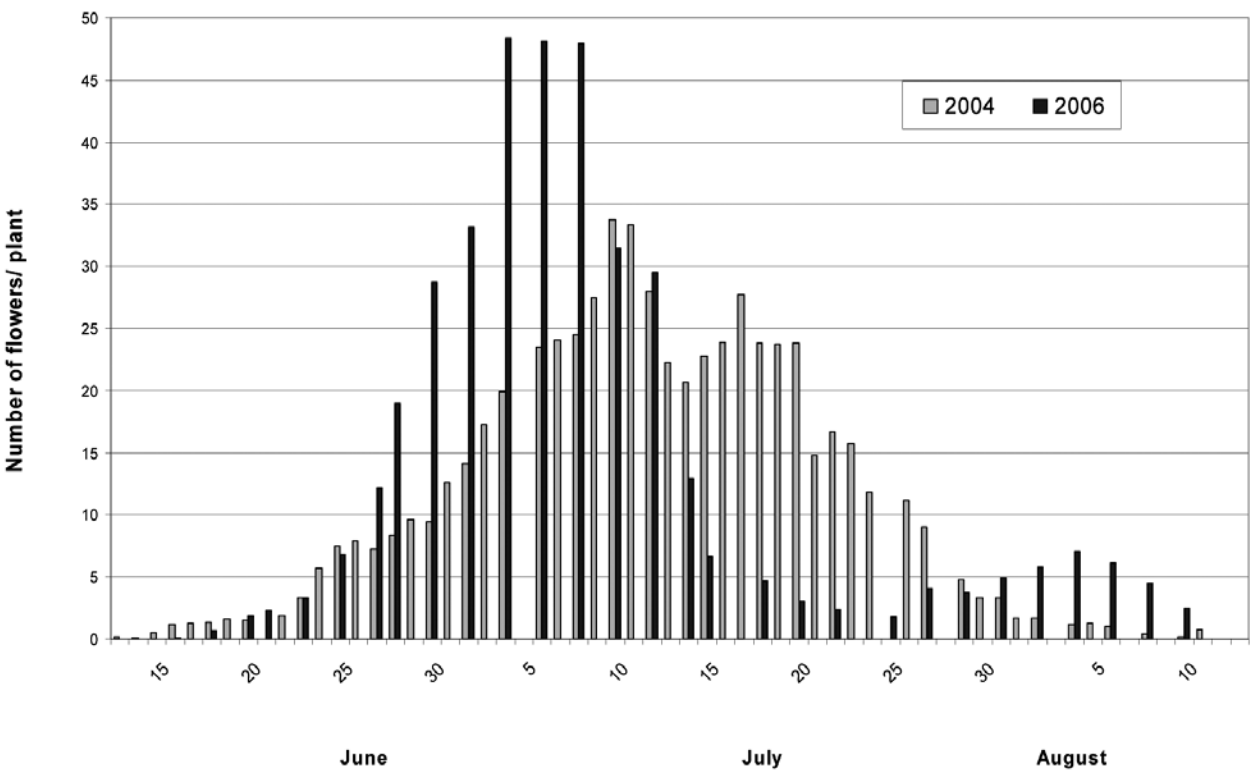

Fig. 1. Flowering of *Phacelia campanularia* in two growing seasons

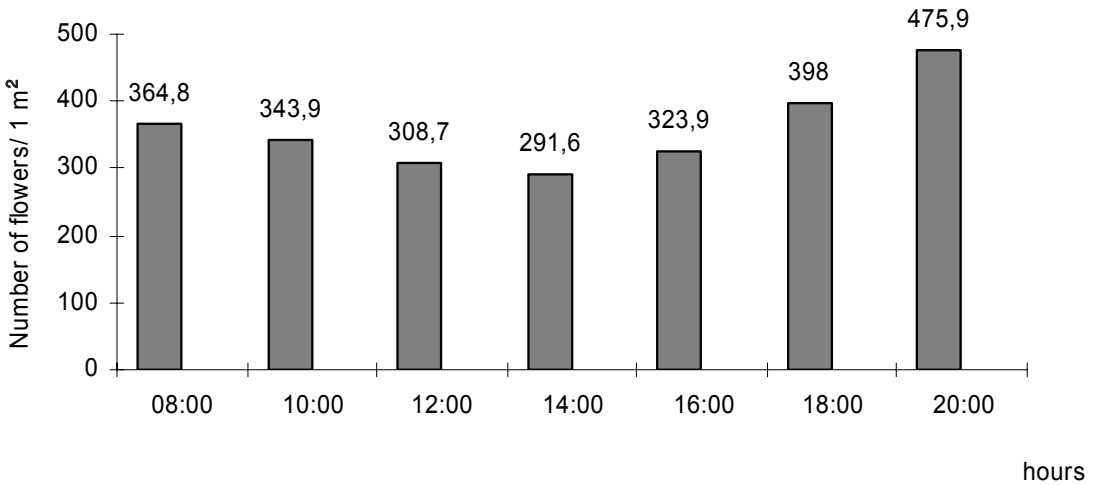

Fig. 2. Diurnal dynamics of *Phacelia campanularia* flowering

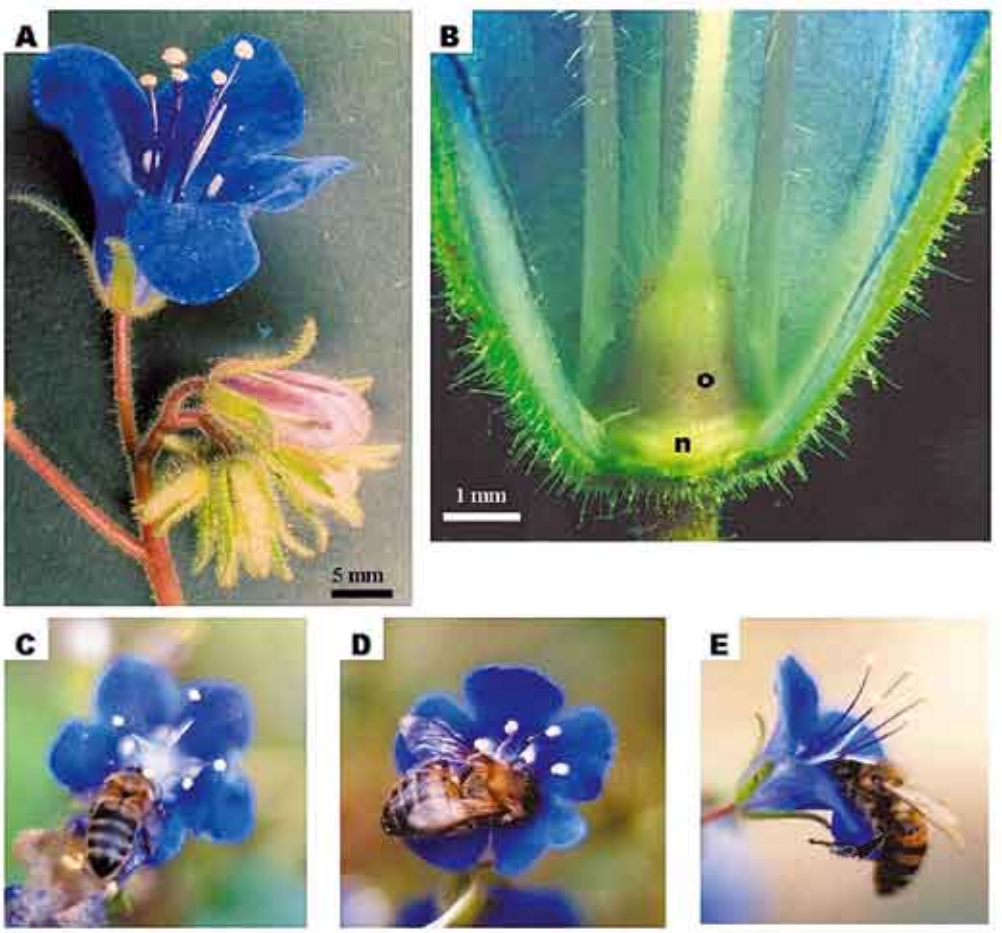

Fig. 3. *Phacelia campanularia*

A – Inflorescence at the start of flowering

B – Fragment of a flower with visible nectary (n) located at the base of the ovary (o)

C, D, E – Honeybees collecting nectar

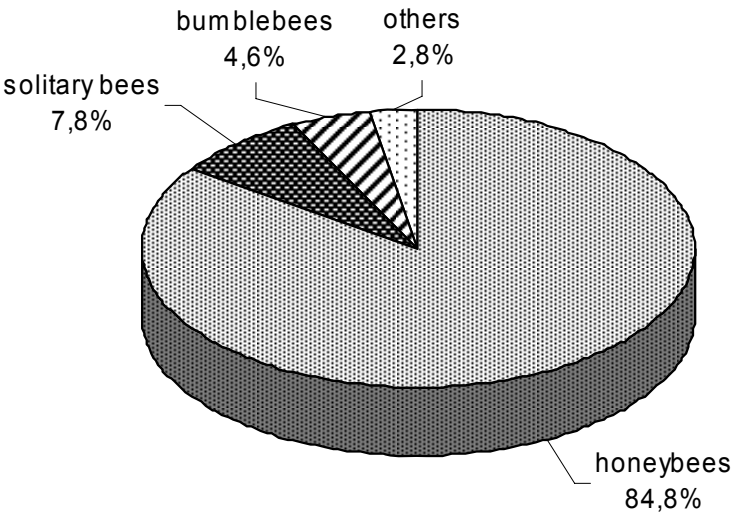

Fig. 4. Proportions of various groups of insects foraging on *Phacelia campanularia* flowers

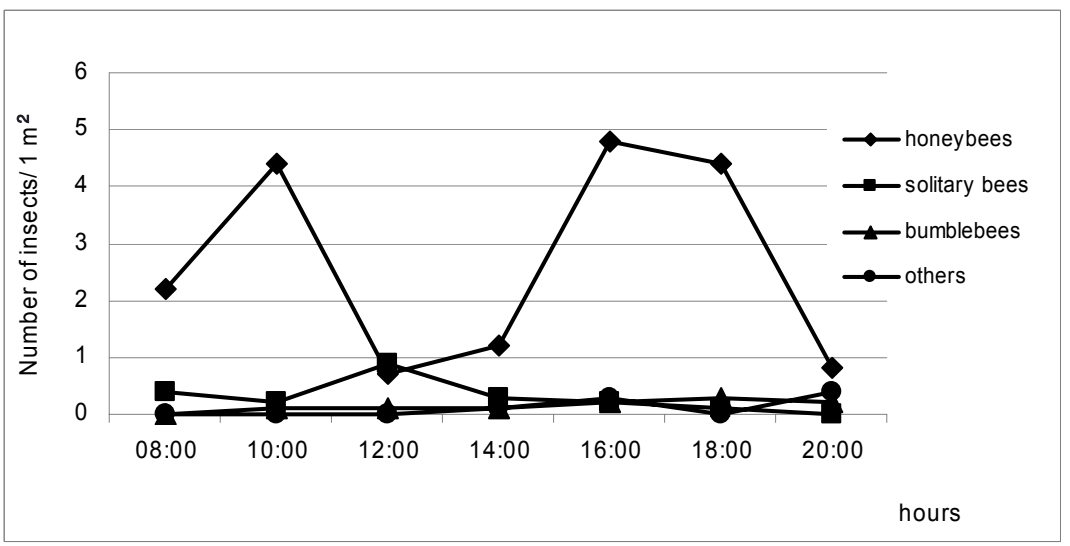

Fig. 5. Daily insect visitation of *Phacelia campanularia* flowers

DISCUSSION

In the conditions of Lublin, the flowering period of *Phacelia campanularia* occurs during the summer and lasts, depending on weather conditions, from the middle of June until the last days of July or until the end of the first decade of August. The number of flowers per 1 m^2 changed during the season and reached its maximum at the full bloom stage, which occurred after 3-5 weeks from the beginning of flowering of this species. The flowering times estimated for *Ph. campanularia* during the three-year study period are longer than those given by Krauze et al. (2004) for this species, but also longer than the times noted for *Ph. Whitlavia*, *Ph. grandiflora*, *Ph. viscida* and *Ph. tanacetifolia* (Zimna, 1960).

The observations of the diurnal dynamics of flowering showed that the number of flowers per plant changed throughout the day. From the morning hours, the number of open flowers decreased with an increase in temperature until noon, and then it increased reaching the maximum value in the evening hours. During the full flowering period, the number of *Ph. campanularia* flowers per 1 m^2 was 3.6-4.1 thousand. According to Wiliams and Christian (1991), *Ph. tanacetifolia* is characterized by similar abundance of flowering, producing from 2 up to 4 thousand flowers on such area, depending on the sowing date.

In the available literature, no information was found on nectar production of *Ph. campanularia* flowers and the insect visitation rates. Likewise in other phacelia species (Hofmann, 1999), the nectary of

the studied taxon has the shape of a disc located at the base of ovary. During its lifetime, one flower secreted on average 7.56 mg of nectar. This value is higher than that obtained by Zimna (1960), in the conditions of Poland, for *Ph. Whitlavia* (6.18 mg), *Ph. grandiflora* (4.76 mg), *Ph viscida* (2.70 mg), and *Ph. tanacetifolia* (1.42 mg). According to Florica and Illyés (1967), in the conditions of Romania, one *Ph. tanacetifolia* flower produced 0.173 mg of nectar per day. The study average for sugar yield per one *Ph. campanularia* flower was 1.13 mg, whereas in other phacelia species, studied by Zimna (1960), it was from 0.37 to 0.96 mg. Sugar concentration in the nectar of Ph. campanularia changed, depending on the weather conditions prevailing before and after nectar secretion, and it ranged between 4.0 and 44.0%. These values are comparable to those obtained for *Ph. Whitlavia*, *Ph. grandiflora*, *Ph viscida*, and *Ph. tanacetifolia*, in which the percentage sugar content in nectar was within the range from 8.9 to 35.9 (Zimna, 1960).

Among the insects foraging on the flowers of *Ph. campanularia*, honey bees predominated, with their proportion reaching as much as 84.8%. They were mostly interested in the collection of nectar. These results are similar to those quoted for *Ph. tanacetifolia* in Greece (Thrasyvoulou and Tsirakoglou, 1994; Petanidou, 2003). According to Wiliams and Christian (1991), in England only 22% of honey bees and 3% of bumblebees collect pollen from flowers of this species.

Insects foraged on the flowers of *Ph. campanularia* throughout the whole day. In the afternoon hours, there was observed a decline in the number of honey bees, which could be attributable to a smaller number of flowers per unit area which bloomed during that time. A significant decrease in the number of honey bees in the afternoon hours was also noted for *Phacelia tanacetifolia* in Germany (Walther-Hellwig et al. 2006), while in Greece the most intense foraging on the flowers of this species was observed between 10.00 h and 17.00 h (Thrasyvoulou and Tsirakoglou, 1994).

CONCLUSIONS

1. Sugar yield of *Phacelia campanularia* per unit area is closely correlated with the nectar production rate, the abundance of flowering of its plants as well as their density in a given area.
2. The flowers of the studied taxon were visited by various pollinating insects, among which honey bees collecting nectar were by far predominant.
3. *Phacelia campanularia* can be recommended for cultivation as an attractive ornamental species providing nectar forage for insects during the summer.

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Dynamika kwitnienia, nektarowanie i oblot przez owady *Phacelia campanularia* A. Gray

Streszczenie

W latach 2004-2006 badano w warunkach Lublina dynamikę kwitnienia, nektarowanie oraz intensywność oblotu przez owady zapylające kwiatów *Phacelia campanularia* A. Gray.

Kwitnienie facelii rozpoczynało się w połowie czerwca i trwało przez 1,5 do 2 miesięcy. Pełnia przypadała od trzeciego do piątego tygodnia kwitnienia taksonu. Średnia z lat badań masa nektaru wytworzona przez 10 kwiatów wyniosła 75.64 mg, masa cukrów 11.31 mg, a ich koncentracja w nektarze 20.2%. Spośród entomofauny oblatującej kwiaty facelii dominowały pszczoły miodne, których udział wśród zapylaczy osiągnął 84,8%.