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Original Article

ORNAMENTAL REPRESENTATIVES OF THE GENUS *CENTAUREA* L. AS A POLLEN SOURCE FOR BEE FRIENDLY GARDENS

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Abstract

The flowering phenology and pollen production of three ornamental *Centaurea* species were investigated in the years 2009 and 2012–2013. The study objects, *Centaurea montana* L. = *Cyanus montanus* (L.) Hill, *Centaurea mollis* Waldst & Kit, and *Centaurea dealbata* Willd. were cultivated within an area of the UMCS Botanical Garden in Lublin, Poland (51° 14' N, 22° 34' E). Under the environmental conditions of SE Poland, the *Centaurea* species flowered continuously from mid-May to the first week of June. The mass of pollen in anthers was found to be species-related: 3.70 mg (*C. montana*), 4.02 mg (*C. mollis*), and 6.01 mg (*C. dealbata*) per 100 anthers. The total pollen yield was related to the mass of pollen produced in flowers and the abundance of blooming. Pollen grains were medium-sized, spheroid (*C. dealbata*) or prolato-spheroid (*C. mollis* and *C. montana*) in shape, and characterized by high viability (over 80% on average). The pollen provided by the plants of ornamental *Centaurea* species amounted to 6.0 - 7.9 g per m^2 on average. The honeybee was the most frequent visitor of *C. dealbata*, accounting for 55.2% of the total pollinators, and bumblebee species predominated on the flowers of both *C. montana* (77.7%) and *C. mollis* (85.6%). Solitary bees and dipterans were also observed on the flowers of all species studied, but *C. mollis* was avoided by lepidopterans. Ornamental *Centaurea* species provide pollen reserves that could support communities of invertebrate pollinators, although the period of effective supply fluctuates annually due to changeable periods of blooming.

Keywords: bee pasture, *Centaurea dealbata*, *Centaurea mollis*, *Centaurea montana*, insect visitors, pollen production.

INTRODUCTION

Habitats for different bee species must consist of rewarding patches of floral resources and suitable nesting sites within the range of their flights (Kearns et al., 1998; Cane, 2001). Forage flora consist of crop plants (Delaplane and Mayer, 2000) and wild species from natural and anthropogenically transformed communities (Wrzesień and Denisow, 2006; 2007; Denisow, 2011). However, due to changes in crop structure and habitat loss or degradation, the value of countryside is decreasing but the value of urban areas, including ornamental gardens, is increasingly being recognized as an important source of food plants supporting a rich diversity of pollinators (Fussell and Corbet, 1992; Denisow and Bożek, 2006; Strzałkowska, 2006; Denisow, 2011; Garbuzov and Ratnieks, 2013). High flora diversity has been recorded among urban green spaces, such as parks, botanical gardens, private ornamental gardens, cemeteries, and railway areas; therefore, these areas are supportive to wild pollinators (Wrzesień and Denisow, 2006). A higher biodiversity of pollinating insects within urban areas compared to countryside was reported recently (Goulson et al., 2010). In Poland, ornamental gardening has become a popular hobby (Fajerski). Beside aesthetic attractiveness, such gardens may contribute to the maintenance and/or restoration of insect biodiversity. Because garden plants are often non-native, their usefulness for pollinator-friendly gardens requires observations of phenology, flowering biology and ecology, insect visitors, and the availability of floral reward (Denisow and Bożek, 2006; Strzałkowska, 2006; Masierowska, 2012; Denisow and Strzałkowska-Abramek, 2013). These studies are of great importance as the variation in the total number of insects attracted by ornamental species is broad (80–300-fold) (Garbuzov and Ratnieks, 2013). In Poland, the value of a floral reward from numerous ornamental herbaceous perennials, including species of the families Ranunculaceae, Saxifragaceae, and Malvaceae was highlighted by Denisow and Bożek (2006), Masierowska (2012), and Antoń and Denisow (2014). Ornamental species from the family Asteraceae are considered particularly important magnet plants for insect visitors (Strzałkowska, 2006; Wróblewska and Magacz, 2006; Wróblewska and Stawiarz, 2011). Species from the genus *Centaurea* have also been considered important (Kołtowski, 2006; Lipiński, 2010). The present study is one of a series of studies on ornamental species to determine the most suitable plants for bee-friendly gardens (Denisow and Bożek 2006; Strzałkowska, 2006; Denisow and Strzałkowska-Abramek, 2013). Here we evaluated the quantity and quality of the pollen of ornamental species from the genus *Centaurea* that are currently offered in the assortment of gardening centres in Europe, including Poland. In particular, we examined (i) the blooming biology (phenology and duration of pollen presentation), (ii) pollen production, (iii) proportion of pollen grains with protoplasts, and (iv) the spectrum of insect visitors. In addition, pollen grain size was determined, as the feature can be useful for identifying pollen grains by microscopically analysing bee products.

MATERIAL AND METHODS

Study area and study species. The study was conducted in the years 2009 and 2012 – 2013. The experimental plants were cultivated within an area of the UMCS Botanical Garden in Lublin, Poland (51° 14′ N, 22° 34′ E). The following ornamental perennials were included: *Centaurea montana* L. = *Cyanus montanus* (L.) Hill, *Centaurea mollis* Waldst & Kit, and *Centaurea dealbata* Willd. The species were grown in the taxonomy section on loess soil at pH 6 – 7 and fully exposed to the sun. Every year of the study, we used plants derived from the self-renewing populations of the same experimental patches. The species selected for the study were easy to grow and useful in different types of plant arrangements.

C. montana is native to Eurasia, 30 – 60 cm tall, tolerates some light shade and drought, and is particularly recommended to be grown on perennial beds and in the light shade of deciduous trees. *C. mollis* is native to Europe, 20 – 40 cm tall, grows in any soil, is drought- and cold-resistant, and recommended for both ground garden compositions and container gardens. *C. dealbata* is from the Caucasus range, 80 – 90 cm height, particularly resistant to drought, and recommended for open spaces in informal gardens, for superb borders, mixed plantings, and cutting gardens (Marcinkowski, 2002).

Blooming observations and foraging of insect visitors. Protocols described by Jabłoński and Szklanowska (1997) and Denisow (2009) were applied. The duration of successive phases of blooming (beginning, full, terminal) was recorded. The beginning of the blooming period was when 10% of head inflorescences bloomed, the full blooming period consisted of 70 – 80% of heads in bloom, and the termination of blooming was when over 85% of the heads came out of bloom. Due to a long period of blooming, insect visits were monitored for two consecutive days each (i) at the beginning of the full bloom phase, (ii) in the middle of the full bloom phase, and (iii) at the termination of full bloom. The exception was *C. mollis*, for which a 3–day observation was made in 2009. The total number of visiting insects was recorded (n = 3 – 4 plots; 0.5 – 1 m^2) during each observation period (10 min at 9.00, 13.00, and 16.00; GMT + 2.00 h).

In order to assess blooming abundance, the number of heads and number of florets per head were counted (n = 18 – 25). Head inflorescences were picked at random from 10 – 25 different plants. The number of flowering stems per 1 m^2 plots was also established (n = 3 – 4 plots; 0.5 – 1 m^2). The data were converted to the number of florets per 1 m^2 and the value used to estimate the total pollen output.

Pollen production and quality. The duration of pollen presentation was monitored on 10 – 25 florets from 3 – 4 heads for each species. The florets were checked every 2 h (between 9.00 and 17.00) and the progress in pollen presentation noted. We defined the pollen presentation phase as the time from the beginning of pollen release to the opening of stigma lobes.

The ether method was used to establish the amount of pollen. During each season, well-developed disc florets in the bud stage (with closed corolla) were chosen randomly (n = 20 – 30). The corolla was carefully separated from the lower ovary using a dissecting needle and the calyx hairs removed. The corolla lobes were opened, and the dissected stamen heads with their filaments removed and placed in a tarred vessel. Each sample contained 50 florets and 250 anthers. Four samples were collected from each species. To enforce the anther dehiscence, vessels with anthers were moved to a dryer (ELCON CL 65) at 33°C. The pollen was rinsed from the anthers using pure ether (2 mL) once and 70% ethanol (3 – 4 mL) four to five times. The accuracy of the procedure was checked with binocular. Next, the pollen samples were dried and weighed on a WPS 36 electronic balance (RADWAG, Poland). The mass of produced pollen was calculated for the 100 anthers, the head inflorescence, and per unit area (grams per metre squared) by multiplying the relevant data.

Pollen viability (n = 300 pollen grains per species) was examined on standard acetocarmine-stained slides, and pollen grain size (n = 200 pollen grains per species) was measured on glycerine jelly slides. The length of the polar (P) and equatorial (E) axes of the pollen grain, as well as the P/E ratio, were determined according to Erdtman (1954). Pollen grain observations were made under a light microscope (LM; Nikon Eclipse E-200) at a magnification of 40 x 10.

Statistical analysis. Data are presented as means and standard deviation (SD). The Kruskal-Wallis ANOVA and H-test were used to determine the species and year effect for non-normally distributed data (the number of heads and number of disc florets). A parametric statistical analysis (ANOVA) was applied for the pollen traits (Stanisz, 1996). A post hoc comparison of means was tested using the HSD Tukey's test. The level of significance for all analyses was at P = 0.05. All analyses were performed using Statistica ver. 6.0 (StatSoft Poland, Krakow).

RESULTS

Flowering biology and abundance. *C. montana* was the first to bloom, and was followed by *C. mollis* and by *C. dealbata* (Fig. 1). The duration of blooming differed between the years studied. *C. montana* bloomed for 29 – 52 days, *C. mollis* for 25 – 28 days, and *C. dealbata* for 31 – 51 days. An exceptionally late spring in 2013 delayed the flowering onset of *C. mollis* and *C. dealbata* compared to the flowering times recorded in the previous years.

The species formed a monopodial inflorescence head type. The peripheral florets are ligulate, sterile, and brightly coloured, from blue (*C. montana*, *C. mollis*) to light-pink (*C. dealbata*). Pollen is yielded only by the disc florets. The life span of a disc floret was 2 days for *C. montana* and *C. mollis*, and 1 – 2 days for *C. dealbata,* on average. The disc florets are protandrous. In the first hours of the life-span, the style extends and pushes through a tube formed by five stamen heads. Pollen released from the

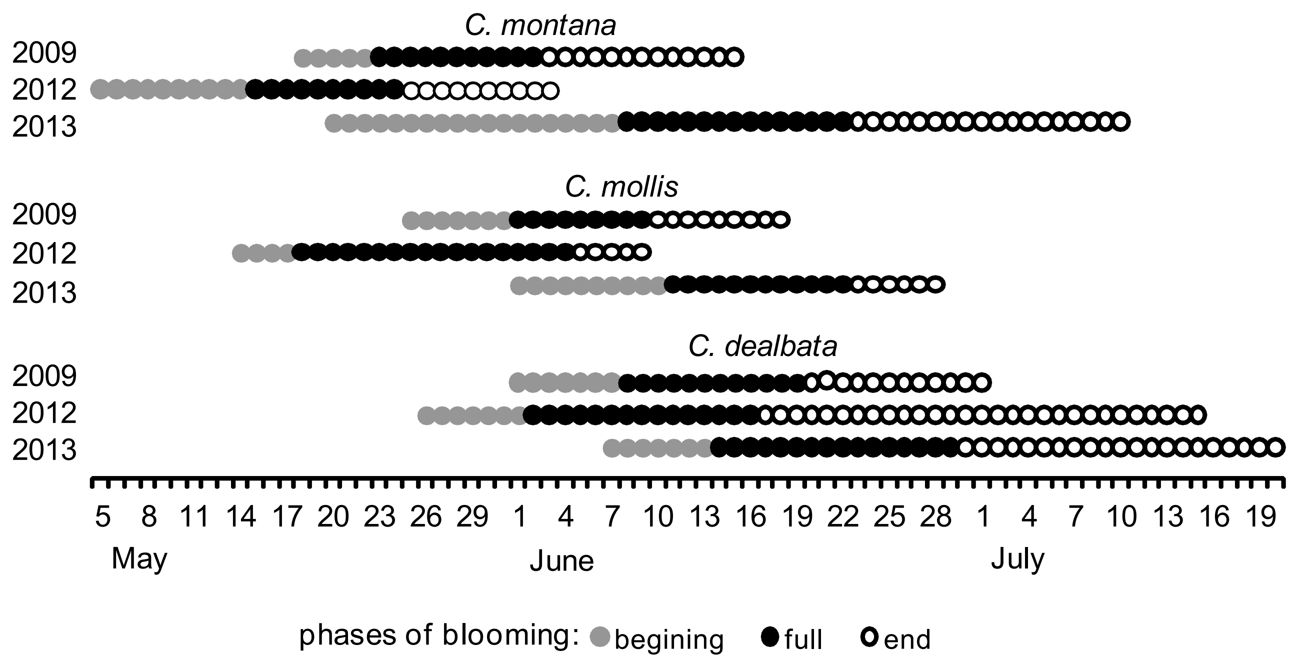

Fig. 1. Time and duration of blooming of *Centaurea* species in the years 2009 and 2012-2013.

Table 1.
The number of disc florets developed in heads and the number of heads per 1 m² for three ornamental species from the genus *Centaurea* studied in 2009 and 2012-2013

Species	Variable	2009		2012		2013		Mean	± SD	P-value
		Mean	± SD	Mean	± SD	Mean	± SD			
C. montana	disc florets per head	35.4	3.3	37.8	5.0	40.8	5.9	37.9	5.0	**0.148**
	heads · m^{-2}	126.5	21.1	80.8	11.6	76.5	20.9	94.5	28.8	**0.024**
C. mollis	disc florets per head	25.8	3.8	26.5	4.0	34.4	6.3	30.4	6.6	**0.009**
	heads · m^{-2}	182.0	27.7	93.8	11.5	67.5	16.6	114.4	54.2	**0.012**
C. dealbata	disc florets per head	39.4	4.0	39.8	8.1	38.0	2.9	39.9	4.7	0.792
	heads · m^{-2}	70.0	14.2	76.0	17.5	55.5	17.2	66.0	17.3	0.174

Significant effects based on the Kruskal-Wallis test are in bold; SD – standard deviation.

Table 2.
Pollen production and viability of three ornamental *Centaurea* species in the years 2009 and 2012-2013

Species	Year	Pollen per 100 anthers (mg)			Pollen production				Viability (%)	
					Per head (mg)		g · m^{-2}			
		Min – max	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD
C. montana	2009	4.10 – 5.30	4.78_b	0.50	8.46_b	0.88	10.68	1.12	99.6	0.7
	2012	2.50 – 3.20	2.90_a	0.32	5.47_a	0.60	4.42	0.48	92.6	2.6
	2013	3.47 – 4.10	3.42_a	0.51	6.98_a	1.04	5.34	0.80	94.6	1.6
	Mean		3.70_A	0.88	6.97_A	1.43	6.81	2.98	95.6	3.5
C. mollis	2009	3.10 – 4.20	3.63_a	0.48	4.68_a	0.62	7.99	1.06	99.0	1.7
	2012	3.00 – 5.10	4.13_a	0.90	5.47_b	1.19	5.12	1.11	98.2	1.0
	2013	3.33 – 5.40	4.32_a	1.01	7.42_c	1.73	5.01	1.17	96.6	2.1
	Mean		4.02_A	0.77	5.85_A	1.59	6.04	1.76	97.9	1.8
C. dealbata	2009	4.60 – 6.50	5.48_a	0.88	10.80_a	1.74	7.56	1.22	78.3	3.3
	2012	5.90 – 6.87	6.51_b	0.44	12.94_a	0.88	9.83	0.67	86.6	2.7
	2013	6.00 – 5.90	6.05_b	0.13	11.50_a	0.25	6.38	0.14	84.6	3.3
	Mean		6.01_B	0.65	11.74_B	1.32	7.92	1.66	83.2	4.6

Means followed by the same small letter are not significantly different between years within species, and followed by the same capital letter are not different among species, according to the Tukey HSD test; SD – standard deviation.

anthers is presented on the stylar trichomes to the insect visitors. Pollen exposition under sunny and dry weather conditions lasts only 3 – 4 hours. The number of disc florets per head is species-related (Kruskal-Wallis test: H = 3.29, P = 0.012; Tab. 1) and was lowest for *C. mollis* (mean = 30.4). *C. montana* and *C. dealbata* produced more disc florets, 37.9 and 39.9 per head on average, respectively. The development of all pollen-yielding florets in the head inflorescence lasted 3 – 4 days for *C. mollis* and 4 – 5 days for *C. montana* and *C. dealbata*.

C. montana and *C. mollis* developed one-headed shoots, whereas shoots of *C. dealbata* produced 2 – 3 heads. The number of heads per 1 m² plot depended on the species (H = 6.43, P = 0.044). The lowest average number of heads (66.0) was noted for *C. dealbata*. Within a species, an effect of year was found for the number of head inflorescences. Each species studied produced the lowest number of heads in 2013, when the winter was severe, spring

Table 3.

Morphological characteristics of pollen grains
from three ornamental *Centaurea* species in 2012 and 2013

Species	Year	Length of axis (μm)						Shape index P/E
		Polar (P)			Equatorial (E)			
		Min-max	Mean	± SD	Min-max	Mean	± SD	
C. montana	2012	45.0 – 52.5	47.5	1.8	38.8 – 46.3	42.9	1.8	1.1
	2013	40.3 – 50.5	47.2	1.1	40.5 – 45.0	42.6	1.1	1.1
	Mean		47.4	1.6		42.8	1.6	1.1
C. mollis	2012	45.0 – 51.3	47.8	1.7	35.0 – 48.8	42.8	2.5	1.1
	2013	45.3 – 51.3	47.8	1.5	40.0 – 47.5	43.0	2.1	1.1
	Mean		47.8	1.6		42.8	2.4	1.1
C. dealbata	2012	35.6 – 42.6	38.5	1.7	38.3 – 40.1	39.5	0.8	1.0
	2013	36.3 – 39.1	37.9	1.0	37.5 – 40.0	38.9	1.1	1.0
	Mean		38.3	1.5		39.2	1.0	1.0

SD – standard deviation.

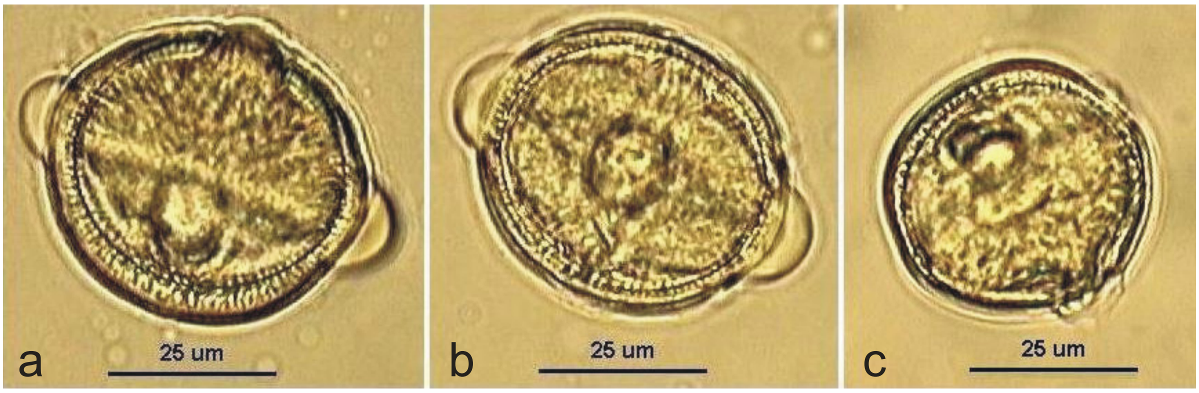

Fig. 2. Light micrographs of pollen grains in equatorial view a. *Centaurea montana*, b. *C. mollis*, c. *C. dealbata.*

delayed, and prolonged drought noted at the end of May and beginning of June.

Pollen production and quality. The mass of pollen in anthers was found to be species-related (Tukey's test: $F_{2,33}$ = 28.781, P<0.001; Tab. 2). The highest amount of pollen, an average of 6.01 mg per 100 anthers, was yielded by the anthers of *C. dealbata*. The amount of pollen produced in the anthers of *C. mollis* and *C. montana* was 30 – 40% lower than that of *C. dealbata*. Year-to-year variation was noted in the amount of pollen produced for *C. montana* ($F_{2,12}$ = 2.14, P = 0.033) and *C. mollis* ($F_{2,12}$ = 1.92, P = 0.014). The pollen production in the anthers of *C. mollis* was very stable across growing seasons ($F_{2,12}$ = 9.14, P = 0.261). The pollen provided by the plants of ornamental *Centaurea* species was 6.0 – 7.9 g per m^2 (Tab. 2). The pollen grain characteristics are presented in Table 3 and Figure 2. The pollen grains of *C. dealbata* were spheroid (shape index 1.0), whereas *C. mollis* and *C. montana* pollen grains were prolato-spheroid (shape index 1.1). The pollen grains were characterized by high protoplast content. In all study years, the viability of *C. mollis* and *C. montana* exceeded 90%, but the pollen viability for *C. dealbata* was substantially lower (mean = 83.2%).

Insect visitors. The honeybee was the most frequent visitor of *C. dealbata,* accounting for 55.2% of total visitors (Fig. 3). Bumblebee species predominated on the flowers of both *C. montana* (77.7%) and *C. mollis* (85.6%). Solitary bees were also observed on the flowers of all species studied. *C. dealbata* was also foraged by lepidopterans and dipterans.

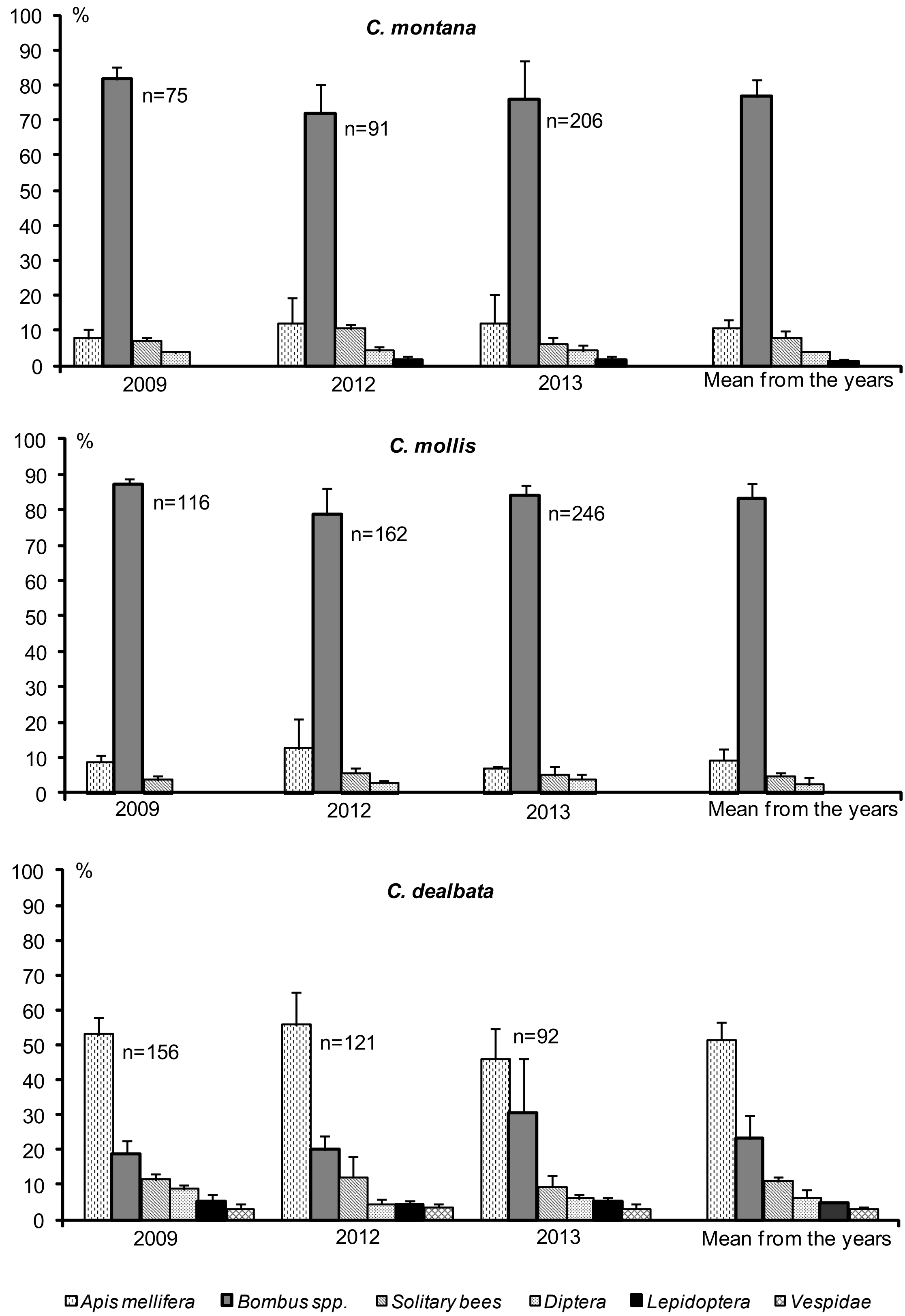

Fig. 3. The percentage participation of insect visitors on flowers of three ornamental *Centaurea* species. Mean values for the years of study are given; n = the total number of insect visitors recorded, vertical bars indicate ± SD.

DISCUSSION

The results concerning the flowering, pollen production, and insect visitors of the studied ornamental *Centaurea* species have not previously been reported in the literature. Our study can be considered to contribute to the lists of garden plants that attract insect visitors with floral reward. If planted together in flowerbeds, the species will provide pollen from the first week of May (*C. mollis*) until mid–July (*C. dealbata*) during the period of intensive activity among different visiting insects. However, the flowering phenology of the studied ornamentals differed considerably among growing seasons, indicating that these species are sensitive to abiotic factors, mainly different weather patterns over the years of the study. The influence of meteorological factors, including air temperature and precipitation level, on the onset, duration, and abundance of flowering has been described for different taxa (Jabłoński and Szklanowska, 1997), including species from the genus *Centaurea* occurring in natural habitats in Poland (Denisow, 2006).

In the present study, the mass of pollen produced in the anthers of *C. dealbata* was 1.2 to 2.0-fold higher than that of C. *mollis* or *C. montana*. As reported by Denisow (2009; 2011), the mass of pollen produced is a highly genetic-dependent trait and may vary greatly among species, even within the same genera. In addition, two out of three species studied exhibited significant year–to–year differences in the mass of pollen produced, which indicates that microsporogenesis and pollen production in *C. mollis* and *C. montana* are sensitive to external factors (e.g., temperature drops or shortage of precipitation). Otherwise the process of pollen production in *C. mollis* is less responsive to the environment. Differences in species tolerance to habitat conditions with respect to pollen production were demonstrated previously for Asteraceae species (Denisow, 2006; Czarnecka and Denisow, 2014). Similarly, any factors that affect the nutritional status of a plant may affect the amount and quality of pollen produced.

In ornamental *Centaurea* species, pollen is provided exclusively by tubular disc florets. Mature pollen is released from the anthers and pushed outside the staminal tube by the style, which elongates rapidly at the beginning of male-phase. The pollen is then presented for insects on the style trichomes. This mechanism of pollen presentation is known as secondary pollen presentation (SPP) and is characteristic of the Asteraceae species (Denisow, 2006; Czarnecka and Denisow, 2014); it has also been observed in other ornamentals, including *Solidago* x *hybrida* (Strzałkowska, 2006), *Zinnia elegans* (Wróblewska and Magacz, 2006), and *Ligularia* species (Wróblewska and Stawiarz, 2011).

The mass of pollen produced per plant and per unit area was found to be directly related to the abundance of blooming. The number of flowers or inflorescences is the major predictor of pollen yield in many species, including Ranunculaceae (Denisow and Bożek, 2006), Euphorbiaceae (Denisow, 2009), and Asteraceae (Denisow, 2006; Strzałkowska, 2006; Wróblewska and Stawiarz, 2011; Czarnecka and Denisow, 2014). Year-to-year variations in the number of head inflorescences developed by particular *Centaurea* species affected the fluctuation in the total mass of pollen available to insect visitors. However, we observed that *Apoidea* foraged for both pollen and nectar despite the fluctuations in blooming abundance.

Pollen grains of the *Centaurea* species are medium in size, within a range of 25 – 50 μm (Erdtman, 1954). According to Jafari and Ghaubarian (2007), four shape groups are distinguished for *Centaurea* species. The mean shape index of the studied ornamental *Centaurea* species ranged between 1.0 and 1.1, which classifies the pollen grains as spherical (shape index 1.0) or prolate-spherical (shape index 1.01 – 1.13).

The pollen production values in the present study were higher than those established for *Centaurea cyanus* (1.4 g per 1 m^2) but lower that those estimated for *Centaurea scabiosa* (28.3 g per 1 m^2) (Denisow, 2006). Therefore, we assume that the studied ornamental *Centaurea* may be placed among good pollen-yielding plants. However, while choosing the species for pollinator-friendly gardens, we have to consider that only approximately 40% of the pollen contained in flowers is accessible to feeding insects (Schlindwein et al., 2005). We also have to take into account the nutritional requirements of bees, which differ among species (Müller et al., 2006), and the nutritional value of pollen, which depends on the type of plant (Denisow, 2011). On average, one bee larva may need the pollen from 7 – 1100 flowers (0.9 – 4.5 head inflorescences) for sufficient growth (Müller et al., 2006). Thus, the studied ornamentals may feed 21 – 104 larvae (*C. montana*), 25 – 126 larvae (*C. mollis*), or 14 – 73 larvae (*C. dealbata*). Although the proportion of pollen grains with protoplasts varied significantly among the *Centaurea* species studied and among the years of study within species, it was high on average. According to Roulston et al. (2000), the changeable quality of pollen may potentially contribute in different ways to pollinator diet and fitness, but if the proportion of pollen with protoplasts is >80%, it supplies important nutritional resources for feeding insects. Moreover, the pollen of the Asteraceae species is considered to be particularly important for entomofauna due to its high caloric value, which is related to the relatively high starch and fat content, a feature that is known to be highly phylogenetically constant (Petanidou and Vokou, 1990).

Among the notable results of the current study is the pattern of insect visitors. The majority of visitors to *C. montana* and *C. mollis* were bumblebee species (77.7% and 85.6%, respectively), whereas honeybees predominated (55.2%) on the flowers of *C. dealbata,* and a variety of other foragers were present. Interestingly, we observed similar groups of insect visitors attracted to ornamental *Centaurea* species between the years of study. Some of the noted differences may be due to temporal variations in the presence of flower-visiting insect populations, which is a common phenomenon (Goulson, 1999; Masierowska, 2012; Zych and Stpiczyńska, 2012). A repeatable year-to-year pattern of foragers indicates that specific features of the species impacted the preferences of visitors. An analogous situation, a strong repeatable year-to-year pattern of insect visitors but with considerable disparities in foragers among *Centaurea* species (*C. cyanus, C. stoebe,* and *C. scabiosa*) occurring in the natural habitats, was reported by Denisow (2006). Presumably, the disc floret morphology restricted bumblebees to the flowers of *C. montana* and *C. mollis*. The mean corolla tube length of 7.2 mm was experimentally shown to be a disadvantage to honeybees (mean tongue length 6.6 mm) vs. bumblebees (mean tongue length 7.8 mm) (Balfour et al., 2013). Visitor preferences may also be due to the characteristics of the floral reward offered, including nectar features such as sugar composition (Carlson and Harms, 2006; Antoń and Denisow 2014) and pollen features such as starch content (Denisow, 2011). In the case of ornamental *Centaurea* species, these characteristics require further exploration.

Notably, a broad array of visitors, not only Apoidea bees, was observed on *C. dealbata*. In addition to reward accessibility, this observation may be due to the period and duration of blooming. For example, the onset of flowering of *C. dealbata* occurred later in the season than other *Centaurea* species. The colour of ray florets (pink in *C. dealbata* vs. blue in *C. mollis* and *C. montana*) may also impact the frequency of insect visitors. In fact, we observed visits by butterflies, more frequently to the pink flowers of *C. dealbata*, as strong preferences for flower colour (Pohl et al., 2011). Ornamental *Centaurea* species, mainly *C. dealbata,* were attractive to dipterans, which have been documented to be primary pollinators for many plant species in terrestrial ecosystems (Zych, 2007), crop plants (Klein et al., 2007), and whose zoophagous larvae play a major role in biocontrol, such as eating crop-damaging aphids (Ssymank et al., 2008). Therefore, we can assume that *Centaurea* species may indirectly support the pollination service of plants in small home gardens, or even prevent aphid outbreaks.

It is preferable to grow native plants in any kind of bee-pasture gardens (Fussell and Corbet, 1992; Szklanowska and Denisow, 1999; Delaplane and Mayer, 2000). However, as ornamental gardening progresses, different non-native plants will be popular and used. These species provide pollen reserves that could support communities of invertebrate pollinators, although the period of effective blooming fluctuates annually.

CONCLUSIONS

Under the environmental conditions of SE Poland, the ornamental *Centaurea* species flower continuously from mid-May to the first week of June, and the species support the floral resources mainly for honeybees (*C. dealbata*), bumblebees (*C. montana* and *C. mollis*), and solitary bees, dipterans, and lepidopterans.

Ornamental *Centaurea* species should be considered when creating multi-flower gardens that allow bees to forage on good quantity and quality pollen.

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