

FLOWER PREFERENCES OF THE WROCLAW BOTANICAL GARDEN BUMBLEBEES (*Bombus* spp.)

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Received 28 March 2012; accepted 21 September 2012

S u m m a r y

Bumblebees (*Bombus* spp.) are morphologically different from each other as determined by the length of their tongue. Seven species of bumblebees were identified in the Wroclaw Botanical Garden: the long-tongued *Bombus hortorum*, and the medium-tongued *B. pascuorum*, and the 5 short-tongued species, *Bombus hypnorum*, *Bombus lapidarius*, *Bombus terrestris*, *Bombus lucorum*, and *Bombus pratorum*. Bumblebees were observed so that their choice of food within the botanical family could be determined. The shape and colour choice of the flower was particularly noted. Bumblebees showed the highest degree of preference for the Lamiaceae family. The Boraginaceae family was also used by all of the recorded species. Bumblebees found pink and purple, lipped, capitular/globular, and saucer-shaped flowers to be most attractive. The individual species of bumblebees showed different preferences, which may be explained by the differences in their morphology. However, bumblebee flower preference and selection seems to be more complex and requires further, detailed research.

Keywords: bumblebees, flowers, food preferences, entomogamic classes, colour.

INTRODUCTION

The attractiveness of flowers for pollinators, in particular for bees, has been in an evolutionary formation process for over 100 million years. A flower lures bumblebees with its shape, colour and odour. Bee morphology, particularly the length of the tongue, corresponds to the physical details of the flower (Szafer, 1969).

In our geographical region, the longest tongued bees are the bumblebees of the *Bombus* spp. Like every bee in its developing process, the bumblebee is entirely dependent on flower food. The short-tongued and long-tongued bumblebees are among the approximately 30 Polish species of this insects. During foraging, each of these species focuses its efforts on acquiring food from flowers. The shape and length of the flower tube is correlated with the length of the

tongue (Inouye, 1980). It means, that particular species may vary in their flower preferences. Such variation may be linked to the morphology, and method of foraging flowers (Brodie, 1996) as well as flower colour (Gumbert, 2000).

The short-tongued bumblebees, like *Bombus terrestris*, which have less specialized diets and are able to exploit the broad range of food resources, remain abundant and common (Goulson et al., 2004). A palynological feces analysis of *Bombus terrestris* revealed pollen belonging to plants from 28 botanical families. Furthermore, for the *Bombus terrestris* group (4 short-tongued species), plants from 70 botanical families are mentioned (Dylewska, 1996). In contrast, the long-tongued bumblebees are the most vulnerable to extinction (Goulson, 2005). The reason might be: a more narrower food-plant specialization, or the fact that they emerge late in the season (Ruszkowski,

1998), and their longer colony cycle might expose them to food losses in late summer (Williams et al., 2009). According to Goulson (2005), the bumblebee which remains abundant and ubiquitous, and has one of the longest tongues from among all the European species, is the *Bombus hortorum*. Perhaps it is less specialized in its diet.

All Polish species of bumblebees are protected, but most of them are in the Red List of Threatened Animals in Poland. Effective protection requires specific actions which can be taken only with essential knowledge of bumblebee ecology.

The objective of this study was to determine the food preferences of the Wrocław Botanical Garden bumblebees. The presence of 7 species was revealed, of which 2 belong to the long- and medium-tongued, and the rest are short-tongued bumblebee species (Tab. 1). Furthermore, the attractiveness of flowers from particular botanical families was analyzed, taking into consideration the shape and colour of the flowers.

MATERIALS AND METHODS

The study was conducted in the Wrocław Botanical Garden in the spring season of 2009 and 2011 as well as the summer season of 2010 and 2011.

The Wrocław Botanical Garden is one of the exemplary landmarks of Lower Silesia. It falls second only to the oldest Botanical Garden in Poland - which is in Kraków. It is located at the north side of the Cathedral of St. John the Baptist,

and the Church of the Holy Cross, partially within historic Ostrów Tumski (Cathedral Island), about 2 km from Market Square. The beginning of the Wrocław Botanical Garden dates back to 1811. The Garden has an area of 7.4 ha. There are more than 11500 species and varieties of ground and greenhouse plants in the Garden.

Observations were carried out at least three times a week, between 11.00 and 17.00, when the weather was favorable for bee activity. The bumblebees were observed on foraged plant species. Individual bee species were counted and recorded on the identified foraging plant area. The visited plants and their botanical family membership were recorded. To assess the number of botanical families most often visited by each bumblebee species, it was decided that to be counted, a plant family had to have at least 5% of the total bee visits. In addition, according to entomogamic classes (Szafer, 1969), the shape of the flower was defined. The color was defined by the observer (white, yellow, orange, pink, violet, red, blue).

Bumblebees were determined by the "live method" (Kowalczyk et al., 2004) based on the "Colored key to the recognition of national bumblebee species in field conditions" (Dylewska et al., 2000). The *B. terrestris* and *B. lucorum* bees were counted together, since distinguishing them in the field is unreliable. Morphological and phenological characteristics of tagged bumblebee species were compiled according to reference data (Tab. 1).

Table 1.
Morphologic characteristics and phenology of bumblebees

	Body length (Dylewska, 1996)			Tongue length (Ruszkowski, 1998)	Emerging spring periods of queens (Ruszkowski et al., 1998)
	♀	♀	♂		
<i>B. pascuorum</i>	15-18	9-15	12-14	Medium	medium late
<i>B. hypnorum</i>	17-23	10-15	14-16	Short	early
<i>B. lapidarius</i>	18-22	11-17	11-15	Short	medium late
<i>B. terrestris/lucorum</i>	20-23	11-17	14-16	Short	early
	18-21	9-16	14-16		
<i>B. pratorum</i>	15-17	9-14	11-13	Short	early
<i>B. hortorum</i>	17-22	11-16	13-15	Long	medium late

RESULTS

During the research period, 7 bumblebees species were observed: *Bombus pascuorum*, *B. hypnorum*, *B. lapidarius*, *B. terrestris/lucorum*, *B. pratorum*, and *B. hortorum*. The total number of bees was 1931. The dominating species was *B. terrestris/lucorum* - 59%, then *B. pascuorum* - 14%, and *B. lapidarius* - 11%. The remaining three species did not exceed 10% (Tab. 2).

For the entire observation period, the dominating bumblebees, *B. terrestris/lucorum*, foraged on 133 flowering plant species belonging to 32 botanical families. *B. pascuorum* foraged on 88 plant species from 29 families, and *B. lapidarius* foraged on 52 species from 22 botanical families. The rest of the studied bumblebees foraged on fewer than 50 plant species belonging to, at most, 19 botanical families (Tab. 2).

For all bumblebee species, the most attractive botanical family was Lamiaceae (Fig. 1). For *B. pratorum* and *B. pascuorum*, plants of the Lamiaceae family accounted for a 30% range of food. For other bee species, plants of the Lamiaceae family accounted for a 15-25% range of food. *B. terrestris/lucorum* and *B. pratorum* often visited plants of the Asteraceae family, but for *B. hypnorum* the Rosaceae family was attractive. In addition, only the Boraginaceae family was preferred by all bumblebee species at a level above 5%. It is clear that the broadest spectrum of 8 botanical families were preferred by *B. lapidarius*, 7 families were preferred by

B. hortorum and *B. terrestris/lucorum*, and 5 families were preferred by *B. pascuorum*. *B. pratorum* had the narrowest spectrum - 3 botanical families (Tab. 2).

The nutrient spectrum of *B. hortorum* was distinguished from that of other bee species by the presence of plants from the Rannunculaceae and Asparagaceae families. For *B. terrestris/lucorum*, this unique family was Amarylidaceae, and for *B. lapidarius* - Alliaceae (Fig. 1). Flower preferences based on entomogamic classes, highlighted the shape choice: lipped, capitular/globular, and saucer-shaped. This preference applies in particular to *B. terrestris-lucorum* and *B. hortorum*, which also preferred bell-shaped flowers to the same extent. Other bumblebee species preferred, in various degrees, certain shapes of flowers. For *B. pascuorum*, the most attractive was the lipped shape, foraged with a frequency of once every three visits. Three bumblebee species foraged the capitular/globular flowers at the same frequency that they foraged the lipped flowers. Saucer-shaped flowers was preferred by *B. lapidarius* and *B. hypnorum*. The least frequently visited flowers by bumblebees were: funnel-shaped, trumpet-shaped and pea-shaped (Fig. 2).

Pink and violet colors were the most attractive for all bumblebee species. On the average, one out of every two visited flowers were pink or violet. Nevertheless *B. lapidarius* preferred yellow flowers, and *B. pratorum* - blue

Table 2.

The number of individuals in particular species of bumblebees

	No. of individuals	Share in the cluster [%]	The no. of visited plant species	The no. of visited botanical families	The no. of visited botanical families (>5%)
<i>B. pascuorum</i>	264	14	88	29	5
<i>B. hypnorum</i>	112	6	41	19	4
<i>B. lapidarius</i>	218	11	52	22	8
<i>B. terrestris/lucorum</i>	1134	59	133	32	7
<i>B. pratorum</i>	154	8	46	16	3
<i>B. hortorum</i>	50	3	24	14	7

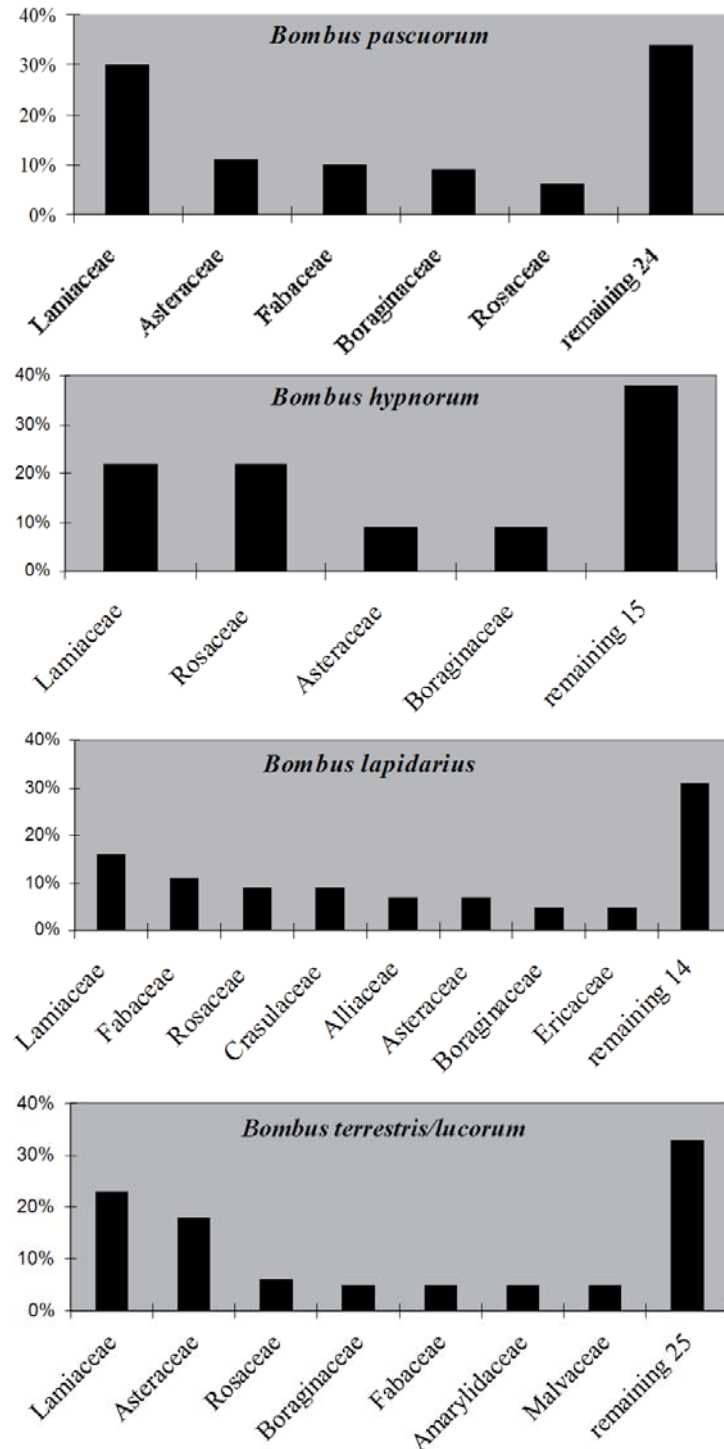


Fig. 1. Bumblebee food preferences within the botanic families.

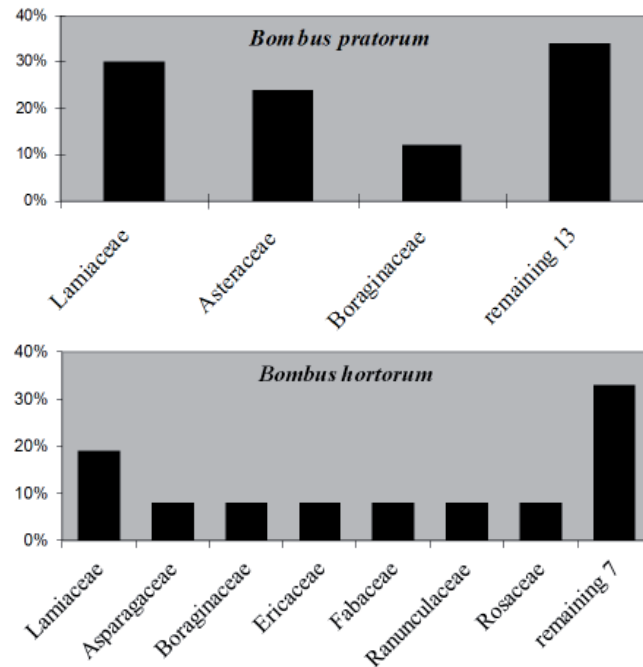


Fig. 1. Continued. Bumblebee food preferences within the botanic families.

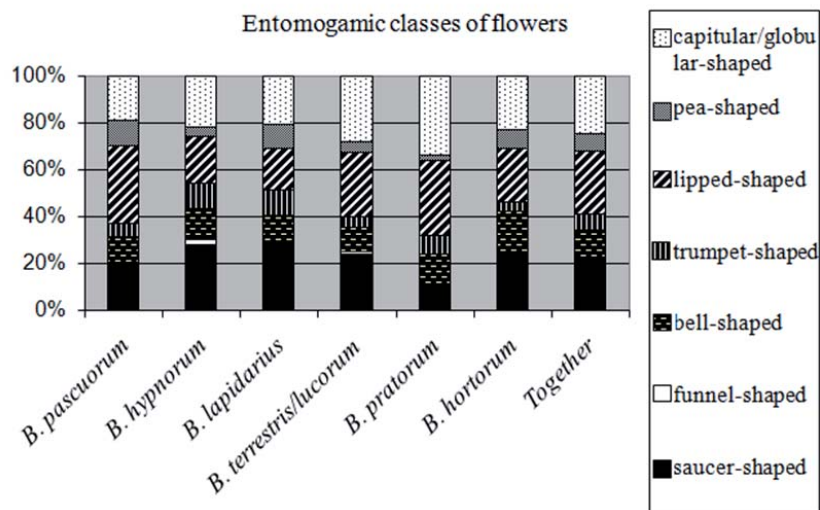


Fig. 2. Bumblebee preferences with regard to the entomogamic classes of flowers.

flowers at approximately 20%. The attractiveness of yellow, blue and white flowers did not exceed the 20% level for other bumblebee species.

The less attractive colors were red and orange - altogether, visited less than 10% (Fig. 3).

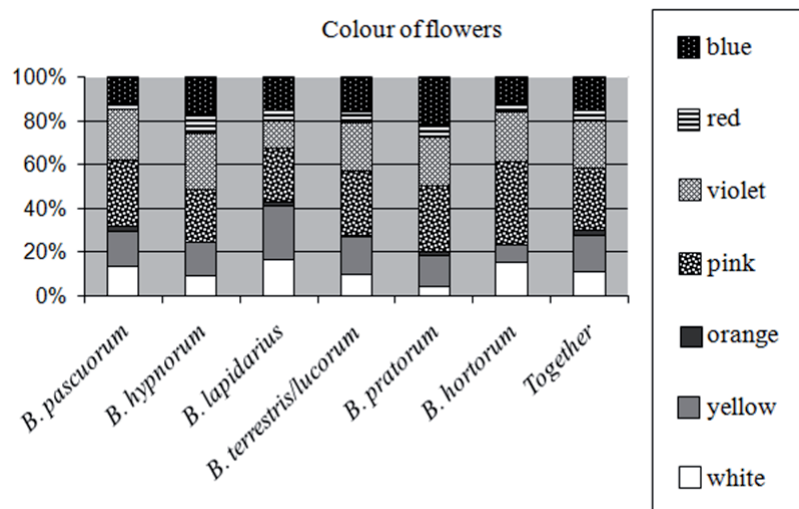


Fig. 3. Bumblebee preferences with regard to flower colours.

DISCUSSION

According to Pyke (1982), the composition of bumblebee species able to occupy a common habitat, is determined by the tongue length. This phenomenon can be explained by competition for food resources. However, some short-tongued bumblebees frequently occur together. In the Wrocław Botanical Garden 5 bumblebee species are short-tongued. Furthermore, this species forages on the same food resources (Lamiaceae, Asteraceae, Boraginaceae). The bigger the number of individuals of a particular species, the wider the spectrum of visited plant botanical families occurred. It is difficult to say if this result was because it was easier to observe abundant species, or because certain species had the ability to use broad food resources. Perhaps ubiquitous species can forage on a broad range of plant species resources suitable for them, because only the *B. terrestris/lucorum* bumblebee and *B. lapidarius* used such botanical families as Amariaceae and Alliaceae. Williams et al. (2009) believed a privileged position was achieved by the larger number of individuals in the colony cycle of those species which emerge early from hibernation. However, amongst short-tongued bumblebees, *B. lapidarius*

starts its annual activity later and achieves greater numbers in the Wrocław Botanical Garden, than *B. hypnorum* and *B. pratorum* which emerge earlier.

Long-tongued bumblebees have more specialized diets and thus are more vulnerable to extinction (Williams et al., 2009; Goulson et al., 2004). Nonetheless, two long-tongued bumblebee species (*B. hortorum* and *B. pascuorum*) as well as 4 short-tongued species belong to the “big six” UK common bumblebee species which are most often found in gardens (Goulson et al., 2006). *B. hortorum*, which has one of the longest tongues, is found throughout Poland (Dylewska, 1996; Pawlikowski, 2008). Goulson (2005) claims that *B. hortorum* is less specialized in its diet than other long-tongued species, so dwindling numbers of deep flowers are sufficient to support one long-tongued species but no more. *B. hortorum*, which had the lowest number of individuals, foraged on a relatively wide range of plant botanical families, including Asparagaceae and Ranunculaceae, which are unattractive for other species. For the medium-tongued bumblebees, *B. pascuorum* (second in terms of numbers), the plant botanical family spectrum was narrower, with the most attractive being the Labiateae

family. This bumblebee species more than other bumblebees, foraged more often on Fabaceae family plants. This data confirms the particular *B. pascuorum* preference for Pea family flowers recorded by Brodie (1996). This author conducted studies on 6 bumblebee species in North-East Scotland, and only *B. pascuorum* foraged on clover, vicia, and pea flowers.

The bumblebees preferred plants from the Labiateae family in which the plants were found in the open spaces (Brodie, 1996; Goulson et al., 2004) of the Cambridge University Botanical Garden (Comba et al., 1999) as well as the open spaces of allotment gardens (Ahrne, 2008). The results of the studies in the Wrocław Botanical Garden confirmed the bumblebee preference for the Labiateae family. In the Wrocław Botanical Garden, all bumblebee species foraged to the highest degree, on the Labiateae plant family. Goulson et al. (2004, 2005) state that Fabaceae appears to be the major pollen source for long-tongued bumblebees. In the Wrocław Botanical Garden, only *B. pascuorum* and *B. lapidarius* used the pollen resources from Fabaceae plants. According to Comba et al. (2004), short-tongued bumblebees (*B. terrestris*, *B. lucorum*, *B. lapidarius*, *B. pratorum*) collected nectar from Asteraceae. Our studies point out that Asteraceae was also a nectar source for medium-tongued *B. pascuorum*. Goulson et al. (2004) also noted Scrophulariaceae and Boraginaceae as other nectar sources. In the Wrocław Botanical Garden, the Boraginaceae family was visited as well by all bumblebee species.

But what exactly attracts bumblebees to flowers? From the standpoint of etiology, it is a congenital mechanism, released in response to flower stimuli (Seguin et al., 2008). This object can be colour, size and shape, and odour, or an advertising nutrient contained in the flower- nectar and pollen (Whitney et al., 2008).

The assumption that bees have a preference for colour, especially towards blue, was put forward in the 19th century by Müller. Laboratory experiments in which

insects were used to study the possibility of associating different colors with a yield of nectar, showed that bumblebees learn the quickest associations with the purple color (Gumbert, 2000). Another experiment showed that bumblebees, when making a first-time-in-their-life choice between blue and purple, prefer the latter (Raine et al., 2007b). It should also be pointed out, that bees see differently than humans. Von Frisch (1977), in the 19th century, proved that bees cannot see the color red but they see in the ultraviolet, and for them the absorption of light is essential. It is difficult for humans to imagine (Dylewska, 1996). In the Wrocław Botanical Garden, the observed color preferences within the pink, purple, and blue color agree with the assumptions made by Von Frisch (1977) that bumblebees prefer blue and UV-blue.

The favorite flower form most visited by bumblebees in the Botanical Garden in Wrocław were lip shaped. This shape is closely associated with the construction of flowers in the family Lamiaceae. The second choice was the capitular/globular shape. This flower shape usually belongs to the Asteraceae family. There are many small, single flowers collected in the bowl or basket which give the capitular/globular shape. Such a flower structure allows bumblebees to freely land, cool their body, and thus, save energy. On the other hand, these flowers require multiple probings to extract nectar. Prior to departure from the flower, the insect usually shivers to warm its body; but shivering is an energetically costly activity. In a series of biochemical transformations, using the fructose biphosphate enzyme, the insect can also raise its body temperature, using less energy than the shiver. *B. lapidarius* has the highest activity of this enzyme (Brodie, 1996). Capitular shaped flowers are a characteristic of the Alliaceae family, on which the bumblebees were foraging. Teper (2005), who studied differences in food preferences, used the farmed families of *B. terrestris* and *B. lapidarius* to draw attention to the predilection of *B. lapidarius* for plants of the genus *Allium*. Teper

(2005) saw the possibility of using *B. lapidarius* for pollination of seed crops. In experimental studies on the nutrients choices of bumblebees, concerning flower size, major preferences were not recorded. In the first flight, bumblebees associated the defined size of the flower with the resource of nectar. In later foraging stages, the bumblebees did not choose the same size of flowers. The above information suggests that bumblebees are guided by odour and colour, rather than a certain flower size (Blarer et al., 2002).

Apart from what attracts insects to a flower, there remains the question of what can repel insects from a flower? Darwin (1891) formulated a theory that insects forage on the flowers of one species as long as they have enough food resources. This means, that guided by instinct only, they strive to reduce the diversity of visited plants. Perhaps during flights from one plant to another, a bumblebee is forced to change and instead follow the fragrance trail left by another bee (Goulson et al., 1998), or short-term memory reduction (1-2 seconds) may play a role (Raine et al., 2007a). The number of botanical families (above 5%) most often visited by the different species of bumblebees in the Wrocław Botanical Garden is not proportional to the number of these insects. The reverse situation would explain the observations of the more numerous species. Bumblebee preferences in choosing flowers, although showing some trends in the shape and colour of flowers, appear to be more complex. Therefore, there is a need for further research on bumblebee behaviour.

CONCLUSIONS

1) Amongst the identified species of bumblebees in the Wrocław Botanical Garden, the majority were short-tongued bumblebees. The *Bombus pascuorum* species belonging to the medium-tongued bumblebees, came in second. *Bombus hortorum* representing the long-tongued species, occurred in the lowest numbers.

2) The number in the particular bumblebee species was correlated with the range of visited botanical families.

3) All species of bumblebees, regardless of the tongue length, found the following to be most attractive: the Lamiaceae family, pink and purple colour and lipped, capitular/globular and saucer-shaped flowers.

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TRZMIELE (*Bombus* spp.) W OGRODZIE BOTANICZNYM WE WROCŁAWIU I ICH POWIĄZANIA Z MORFOLOGIĄ OBLATYWANYCH KWIATÓW

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S t r e s z c z e n i e

Trzmiele (*Bombus* spp.) morfologicznie różnią się od siebie długością języczka. W faunie Ogrodu Botanicznego stwierdzono występowanie 7 gatunków trzmieli, a wśród nich długojęzyczkowego *Bombus hortorum* i średniojęzyczkowego *B. pascuorum*, oraz 5 gatunków krótkojęzyczkowych: *Bombus hypnorum*, *Bombus lapidarius*, *Bombus terrestris*, *Bombus lucorum*, *Bombus pratorum*. Obserwowano zachowania trzmieli przy wyborze pokarmu, aby określić ich preferencję w obrębie rodzin botanicznych, a szczególnie w wyborze kształtu i barwy kwiatu. Trzmiele wykazywały w najwyższym stopniu upodobania do rodziny Lamiaceae, ponadto wszystkie korzystały z roślin Boraginaceae. Kwiaty, które przyciągały trzmiele najczęściej miały barwę różową i fioletową oraz kształt typu wargowego, główkowatego/koszyczkowatego i talerzykowatego. Poszczególne gatunki trzmieli wykazywały odmienne upodobania, co można próbować tłumaczyć różnicami w ich morfologii. Jednak preferencje w wyborze kwiatu przez trzmiele wydają się na tyle złożone, że wymagają dalszych i bardziej szczegółowych badań.

Słowa kluczowe: trzmiele, kwiaty, preferencje pokarmowe, klasy entomogamiczne, kolor.