

The Impact of Willow Flowering Time on Species Composition and the Number of *Apoidea* Pollinators

Monika Konatowska¹, Paweł Rutkowski¹, Jacek Wendzonka²

¹Poznań University of Life Sciences, Poznan, Poland

²Adam Mickiewicz University, Poznan, Poland

Email: monika.konatowska@up.poznan.pl, pawel.rutkowski@up.poznan.pl, setauron@gmail.com

How to cite this paper: Konatowska, M., Rutkowski, P. and Wendzonka, J. (2021) The Impact of Willow Flowering Time on Species Composition and the Number of *Apoidea* Pollinators. *Journal of Biosciences and Medicines*, 9, 89-100.
<https://doi.org/10.4236/jbm.2021.911009>

Received: October 28, 2021

Accepted: November 27, 2021

Published: November 30, 2021

Abstract

Pollinators are important to wild and cultivated plants, and the same plants are important to pollinators as well. A very important source of pollen and nectar to pollinators are willows (*Salix* spp.). The aim of this study was to demonstrate which *Apoidea* species are attracted by a species-diverse willow plantation (Poznań University of Life Sciences Willow Collection, Poland), the proportion of the number of honeybees to other species from the *Apoidea* superfamily visiting willow plantations, and whether the flowering date of male and female willow individuals affect the species composition and number of pollinators. Observations of willow phenology were carried out in the second year of willow growth, from March 9 to December 7, 2012. The insects were observed between April 6 and May 11, 2012. The results of this study showed 30 *Apoidea* species. Among 1591 *Apoidea* individuals, only 17 honeybee individuals were noted. The results show that the willow pollen production optimum occurred when the minimum air temperatures stopped dropping below zero. This parameter and this period are also related to the intensification of the occurrence of the noted insects. It can also be concluded that the pollen production season precedes the flowering optimum of female flowers and that the optimum flowering of female flowers is correlated with a significant increase in air temperature.

Keywords

Willows, *Apoidea* Pollinators, Air Temperature

1. Introduction

Pollinators are important to wild and cultivated plants, but the same plants are

important to pollinators. A very important source of pollen and nectar for supporting pollinator populations early in the growing season are willows (*Salix* spp.) [1]. In the Polish flora there are 26 native species of *Salix* genera, but many non-native willows were introduced to Poland because of their utility as a source of renewable energy, in basketry, medicine, and furniture industries, phytoremediation and many other fields. The results of Konatowska *et al.* [2], conducted on 150 genotypes of willows, including 8 species, 16 interspecies hybrids, cultivars, and sex-differentiated specimens from Poznań University of Life Sciences Willow Collection indicated that in all papers devoted to willows, both practical and scientific, it is necessary to refer not only to the willow species and environmental conditions in which they grow, but also to the sex of the examined or cultivated individuals. It is especially important for pollinators. In many studies, the alarm sounds that pollinators are threatened, but most articles refer to honeybees. However, wild native bee populations have also been declining due to the loss and degradation of nesting sites and floral resources [1]. Therefore, the aim of this study was to demonstrate which *Apoidea* species are attracted by a species-diverse willow plantation, the proportion of the number of honeybees to other species from the *Apoidea* superfamily visiting willow plantations, and whether the flowering date of male and female willow individuals affects the species composition and the number of pollinators.

Plants of *Salix* genera produce catkins reminiscent of anemophilous inflorescences but also possess traits typical of entomophilous flowers such as nectaries and sculpted pollen. Thus, the pollination mode of willows has been considered to be transitional between entomophily and anemophily [3]. However, the cited authors have shown that 99.9% of seeds of tested *Salix lasiolepis* resulted from insect visitation while 0.1% resulted from wind transferred pollen and concluded that insects are the chief pollen vectors. However, other authors note that the role of insects and wind could depend on willow species and ecological context [3]-[9].

These divergent views may be one of the reasons why Füssel [10] found that despite the worldwide distribution and great ecological importance of willows, little is known about the specific interaction of *Salix* species with their pollinators. The most important managed pollinators are honeybees and bumblebees [11], but the interactions between honeybees and the wild species are not much studied [12]. Therefore relationships between willows, honeybees and other pollinators seem to be an important objective of the studies.

2. Research Area and Methods

2.1. Research Area

Nicholson & Wright [13] stated, that for pollinators, the maintenance of connectivity and landscape heterogeneity is critical. The research area represents a high level of heterogeneity, including: forests, arable lands, and waters with a radius of 300 m from the center of research area (**Figure 1**). Under such conditions, in

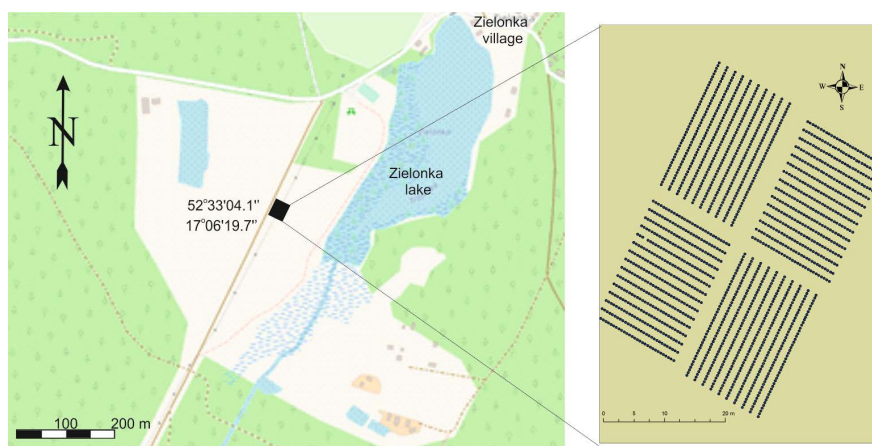


Figure 1. Location of the research area. From the right-side, study design with 4 research plots comprising 150 *Salix* taxa per plot.

2011, cuttings from 150 willow taxa, collected since 1966 in Poznań University of Life Sciences Willow Collection [14], were planted in the form of four experimental plots (**Figure 1**). In two plots of 14.5 m width and 21 m length, three cuttings of each taxon in a row were planted in the NW-SE direction; in the remaining two plots of 13.5 m width and 22.0 m length they were planted in the NE-SW direction (**Figure 1**). Maintaining the random planting of taxa, the changes in the planting direction, was aimed at ensuring the diversified access of sunlight to the taxa of individual rows. The total research area was 1472 m² (32 × 46 m).

2.2. Methods

Observations of willow flowering were carried out in the second year of willow growth, as a part of phenological studies, covering the period from March 9 to December 7, 2012, at weekly intervals. Of all 150 taxa, 75 taxa bloomed in the second year since the establishment of the plantation, and included 47 female flowers, 26 male flowers, and 2 showing male and female flowers on one shrub (**Table 1**). The insects were observed between April 6 and May 11, 2012. The observations were conducted directly by the authors of this study.

The description of flower development took into account the following phases developed and adopted by the authors:

- 1) The appearance of the first flower buds
- 2) First flowers bloom
- 3) The beginning of full flowering (when approximately 25% of flowers flowered)
- 4) Appearance of first faded flowers (when the first flowers have withered or shed)
- 5) End of full flowering (approximately 75% of flowers stopped flowering)
- 6) End of flowering (date of the last flowers blooming)

Most of the insects visiting willow flowers were marked directly in the field. In the case of the occurrence of species that could not be identified in the field,

Table 1. List of studied taxa (F-Female, M-Male, MF-Female and Male flowers on one shrub).

No.	Clone number	Names	Sex
1)	56, 196/187	<i>Salix</i> × <i>pontederana</i> Schleich.	F
2)	10, 19, 47, 93, 94, 101, 102, 26/18, 106/93	<i>Salix</i> × <i>rubra</i> Huds.	F
3)	1	<i>Salix</i> × <i>smithiana</i> Willd.	F
4)	210	<i>Salix eriocephala</i> Michx × <i>S. cordata</i> Michx.	F
5)	51, 202, 237, 241, 253,	<i>Salix eriocephala</i> Michx.	F
6)	307/307	<i>Salix eriocephala</i> Michx. × <i>Salix</i> sp.	F
7)	204	<i>Salix eriocephala</i> “Nicholsoni Purpurescens”	F
8)	150/137	<i>Salix eriocephala</i> “Nicholsoni Purpurescens”	F
9)	9	<i>Salix fragilis</i> L.	F
10)	52	<i>Salix myrsinifolia</i> Salisb.	F
11)	53	<i>Salix myrsinifolia</i> “Prunifolia”	F
12)	7, 21, 23, 58, 63, 65, 71, 75, 79, 81, 82, 87, 39/26, 41/27, 158/145, 167/154, 168/155	<i>Salix purpurea</i> L.	F
13)	15	<i>Salix purpurea</i> L. × <i>triandra</i> L. × <i>viminalis</i> L.	F
14)	46	<i>Salix purpurea</i> L. × <i>triandra</i> L. × <i>viminalis</i> L.	F
15)	76	<i>Salix purpurea</i> “Scharfenbergensis”	F
16)	224/209	<i>Salix</i> sp.	F
17)	10-1	<i>Salix viminalis</i> L.	F
18)	304/304	<i>Salix viminalis</i> “PR3”	F
1)	28, 29, 30, 78/64	<i>Salix</i> × <i>rubra</i> Huds.	M
2)	17	<i>Salix</i> × <i>sepulcralis</i> Simonk.	M
3)	89	<i>Salix</i> × <i>smithiana</i> “Semipalatinskiensis”	M
4)	5, 38, 221/206	<i>Salix</i> × <i>smithiana</i> Willd.	M
5)	255	<i>Salix eriocephala</i> Michx.	M
6)	47/33	<i>Salix fragilis</i> L.	M
7)	159/146	<i>Salix purpurea</i> “Angustifolia”	M
8)	160/147	<i>Salix purpurea</i> “Helix Pyramidalis”	M
9)	68	<i>Salix purpurea</i> “Angustifolia”	M
10)	26, 67, 70, 74, 78, 86, 125, 19/15, 151/138	<i>Salix purpurea</i> L.	M
11)	302/302	<i>Salix viminalis</i> “PR1”	M

Continued

12)	303/303	<i>Salix viminalis</i> "PR2"	M
13)	305/305	<i>Salix viminalis</i> "PR4"	M
1)	45	<i>Salix fragilis</i> L.	MF
2)	83	<i>Salix purpurea</i> L.	MF

individual specimens were caught using an entomological mesh with a rim diameter of 30 cm, and their species affiliation was determined.

3. Results

A total of 1591 individuals belonging to the group of stingers (*Apoidea*) were noted (**Table 2**).

The following groups of species were distinguished:

- *Bombus* "terrestribombus" or a group of bumblebees (*Bombus terrestris* and three critical species: *B. lucorum*, *B. cryptarum* and *B. magnus*). The latter is rarely recorded in Poland, and it can be ruled out with a high probability. However, it is difficult to assess the proportions of the other three species in the research results. Despite the possibility of isolating *B. terrestris* in the field [15], it was abandoned because of the difficulty of observing fast-moving bumblebees while collecting pollen and nectar.
- *Andrena cineraria* and *A. vaga*, species were easily distinguishable by the appearance of females, but the vast majority of the counted specimens were males, which are difficult to identify in the field. Nevertheless, based on the size of the females, the proportions of the species were set at 1:9.
- *Andrena apicata*, *A. mitis*, and *A. praecox*. A group of very similar species, cannot be identified in the field. Based on the caught specimens, the proportions in the group were set to 4:1:9.

The analysis of the data contained in **Table 2** shows that *Colletes cunicularius* is dominant, and 938 individuals were counted, constituting 58.7% of the entire material. It is a species associated with willows, rarely visiting the flowers of other plant species. Its appearance is closely correlated with the beginning of flowering willows. When analyzing the time of appearance, it can be seen that the first counting period had highest abundance (93.6%) of all specimens of the species (**Table 2**). Later, its abundance declined sharply, and the appearance of the species essentially ended when the flowers faded. The other dominant species in the groups: *Andrena cineraria/vaga*, *Andrena apicata/mitis/praecox* and *Bombus* "terrestribombus" behave similarly. In their case, however, it is not related to the biological end of the appearance of the species, but to the flight to other flowering plants, for example, dandelion (*Taraxacum*) which begins flowering at the end of willow flowering. Other species on willows often appear later, which is related to their different life cycles.

The collected data on the number of insects and the flowering of willows were compared under the weather conditions shown in **Figure 2**.

Table 2. List of species with their numbers at particular observation dates. None of the stinger bees were observed in the period before April 14.

Species	14 - 20 IV	21 - 28 IV	29 IV - 05 V	06 - 11 V	Total
Superfamily Apoidea					
Family Apidae					
1) <i>Bombus pratorum</i>	7	11	-	-	18
2) <i>Bombus lapidarius</i>	-	5	-	1	6
3) <i>Bombus ruderarius</i>	-	-	-	1	1
4) <i>Bombus pascuorum</i>	8	2	-	-	10
5) <i>Bombus</i> gr. " <i>terrestribombus</i> "	65	10	-	-	75
6) <i>Bombus</i> aff. <i>campestris</i>	2	1	-	-	3
7) <i>Apis mellifera</i>	15	2	-	-	17
8) <i>Nomada flavoguttata</i>	1	-	-	-	1
9) <i>Nomada bifida</i>	-	-	-	2	2
10) <i>Nomada moeschleri</i>	-	-	-	1	1
Family Colletidae					
11) <i>Colletes cunicularius</i>	878	38	22	-	938
Family Andrenidae					
12) <i>Andrena cineraria/vaga</i>	153	114	24	2	293
13) <i>Andrena fulva</i>	11	8	6	2	27
14) <i>Andrena ventralis</i>	1	5	3	1	10
15) <i>Andrena dorsata</i>	-	1	-	-	1
16) <i>Andrena minutula</i>	-	1	-	-	1
17) <i>Andrena haemorrhoa</i>	9	12	-	1	22
18) <i>Andrena flavipes</i>	-	10	4	2	16
19) <i>Andrena nigroaenea</i>	-	1	2	-	3
20) <i>Andrena nitida</i>	-	-	-	1	1
21) <i>Andrena clarkella</i>	1	1	-	-	2
22) <i>Andrena apicata/mitis/praecox</i>	67	13	12	2	94
Family Halictidae					
23) <i>Halictus rubicundus</i>	-	1	-	-	1
24) <i>Halictus confusus</i>	-	-	1	-	1
25) <i>Lasioglossum xanthopus</i>	1	-	-	-	1
26) <i>Lasioglossum subfasciatum</i>	1	2	-	-	3
27) <i>Lasioglossum sexnotatum</i>	-	-	1	1	2
28) <i>Lasioglossum quadrinotatum</i>	-	1	-	-	1

Continued

29) <i>Lasioglossum calceatum</i>	5	24	7	3	39
30) <i>Sphecodes albilabris</i>	-	-	1	-	1
Total	1225	263	83	20	1591

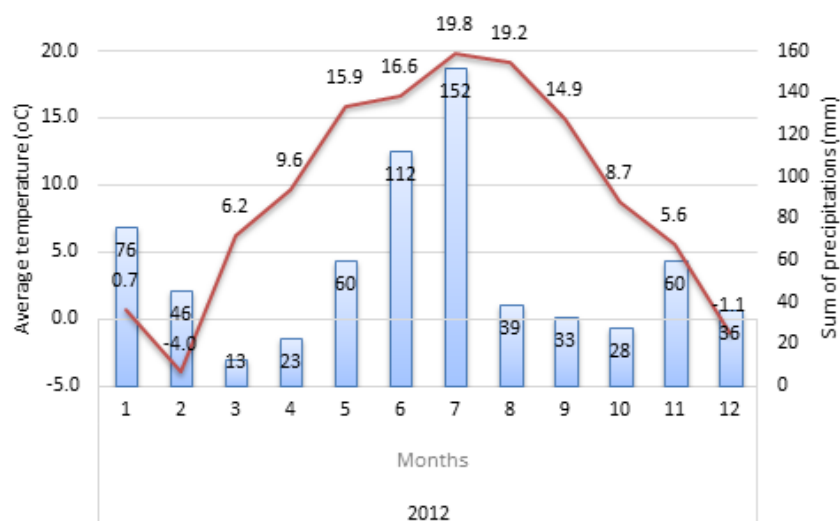


Figure 2. Average monthly values of temperature [(°C) red line] and precipitation [(mm) blue bars] in 2012.

Figure 3 shows the changes in the number of insects in relation to the flowering dates of male and female willows, while in **Figure 4**, the flowering dates of willows are correlated with weather conditions.

As shown in **Figure 3**, the greatest number of insects was recorded during the period of the most abundant pollen production. During the period of maximum flowering in female specimens, the number of insects clearly decreasing.

The data presented in **Figure 4** show that the willow pollen production optimum occurred when the minimum air temperatures stopped dropping below zero. This parameter and this period are also related to the intensification of occurrence of the noted insects. From **Figure 4**, it can also be concluded that, the pollen season precedes the flowering optimum of female flowers. It can also be noticed that the optimum flowering of female flowers is correlated with a significant increase in air temperature.

In the described research area of 1472 m², from April 14 to May 11, 2012, a total of 1591 *Apoidea* representatives (including only 17 honeybee individuals) were noted, representing 30 species. The culmination of the number of specimens took place from April 14 to 20, during pollen production optimum of willows. After this period, a clear decrease in the number of specimens was observed. After May 11, when pollen production ceased, willow plantation was no longer attractive to the studied pollinators. In the last week of observation (May 5-11), only 20 specimens were recorded. Additionally, differences in the activity of individual species were observed, as shown in **Table 3**.

Table 3. Changes in species composition and number of insects at different appearance dates.

Species	Appearance dates and number of insects			
	14 - 20 IV	21 - 28 IV	29 IV - 05 V	06 - 11 V
<i>Colletes cunicularius</i>	878	38	22	
<i>Andrena cineraria/vaga</i>	153	114	24	2
<i>Andrena apicata/mitis/praecox</i>	67	13	12	2
<i>Bombus</i> "terrestribombus"	65	10		
<i>Apis mellifera</i>	15	2		
<i>Andrena fulva</i>	11	8	6	2
<i>Andrena haemorrhoea</i>	9	12		1
<i>Bombus pascuorum</i>	8	2		
<i>Bombus pratorum</i>	7	11		
<i>Lasioglossum calceatum</i>	5	24	7	3
<i>Bombus</i> aff. <i>campestris</i>	2	1		
<i>Nomada flavoguttata</i>	1			
<i>Andrena ventralis</i>	1	5	3	1
<i>Andrena clarkella</i>	1	1		
<i>Lasioglossum xanthopus</i>	1			
<i>Lasioglossum subfasciatum</i>	1	2		
<i>Andrena flavipes</i>		10	4	2
<i>Bombus lapidarius</i>		5		1
<i>Andrena dorsata</i>		1		
<i>Andrena minutula</i>		1		
<i>Andrena nigroaenea</i>		1	2	
<i>Halictus rubicundus</i>		1		
<i>Lasioglossum quadrinotatum</i>		1		
<i>Halictus confusus</i>			1	
<i>Lasioglossum sexnotatum</i>			1	1
<i>Sphecodes albilabris</i>			1	
<i>Nomada bifida</i>				2
<i>Bombus ruderarius</i>				1
<i>Nomada moeschleri</i>				1
<i>Andrena nitida</i>				1

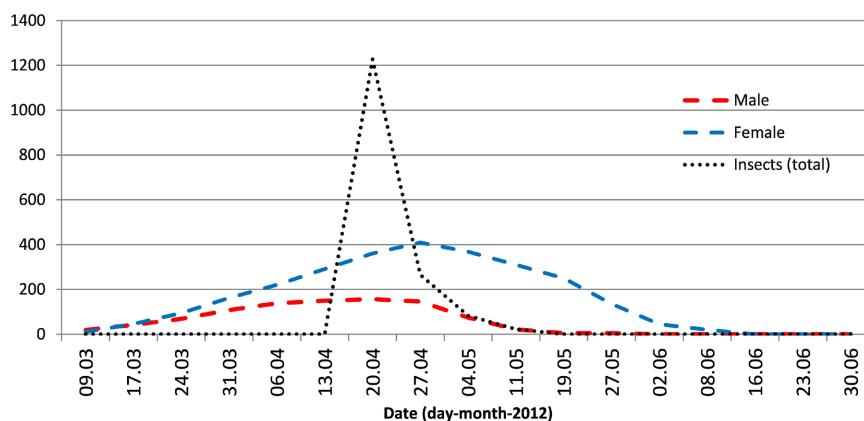


Figure 3. Changes in the number of insects during the flowering of willows.

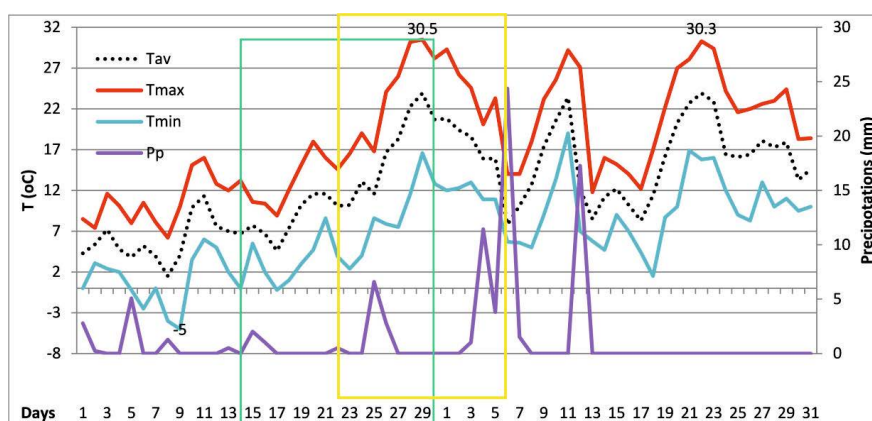


Figure 4. Daily values of temperature and precipitation from April 1 to May 31, 2012. The green rectangle marks the willow pollination optimum, which corresponds to the maximum numbers of insects recorded on the experimental plot. Yellow optimum of flowering of female flowers. Tav, average temperature; Tmax, maximum temperature; Tmin, minimum temperature; Pp, precipitations.

4. Discussion

Willow is an extremely valuable first encountered and basic food for pollinators in early spring, allowing them to survive until the period when other nectar and pollen-bearing plants, including crops, bloom. This is important for species with a long period of occurrence, especially for honeybees and bumblebees, which require a continuous food base that determines the number of these valuable insects and the subsequent strength of their families. The research showed the beginning of flowering of male willow flowers from March 9 to May 11, culminating from April 13 to 20, when most pollen-bearing plants in Poland are still in winter dormancy. Female flowers appeared from March 9 to June 8, culminating on April 27. The period of intense pollen production lasted for April. Undoubtedly, it may be subject to natural fluctuations related to weather changes in individual years, which was demonstrated for the eastern part of Poland by, inter alia, Weryszko-Chmielewska *et al.* [16]. In the cited study, it is also worthwhile to compare the difference in pollen availability depending on the research area,

which was demonstrated by comparing an urbanized area with the total area of a national park. The study showed higher amounts of willow pollen in the air in urbanized areas. This shows the complexity of the relationships that influences the interpretation of research findings on interactions in the natural world, including interactions between willows and pollinators. Undoubtedly, these relations should take into account not only the places of obtaining food, but also the availability of places where bees find shelter [17]. In relation to plants, both local and global climatic conditions are of significant importance for the interpretation of results. With regard to willows, it is necessary to refer to their sex, which is often omitted in many activities related to the cultivation of willows [2]. Research has shown that the very approach to the roles of native and non-native plant species in the environment, are debatable. The collection of willows on which the research was conducted included 150 taxa, including native and non-native species from the flora of Poland. In the present study, the combined effect of all willows was given, but the study of relationship between individual taxa and specific insect species would undoubtedly require further research. Similarly, it would be advisable to continue the observations so that the obtained results could be interpreted in a more complete way. The relationship between bees and willows of a certain age remains an open question. The study was carried out on willows during the second growing season. In the first one, none of the willows has bloomed yet. In the third year of life (1 year after the research), the willows bloomed more. Therefore, it is difficult to compare the results annually. In particular, the climate of Poland is highly variable. The investigated interactions would therefore require long-term research, taking into account the age of willows, willow species, sex of willows, weather conditions in a given year, environmental features affecting bees, mutual relations between bees, relations between bees and their competitors, and/or the separation of research plots with native and alien species. A possible future appearance of hives close to willow plantations could also be important and could affect other wild species. Repeating the research in the same place but with different components of the experiment (e.g., with a different age of willow trees) may therefore lead to results that are difficult to interpret, for example, in the light of crop planning and calculation of potential yields, which raises the issue of crop profitability. In Poland, approximately 60 species of cultivated plants depend on pollinating insects [18]. The most important are alfalfa, clover, rapeseed, buckwheat, apple tree and other fruit trees and shrubs. Not all bee species fly evenly around these plant species. Honeybees prefer buckwheat and apple trees, bumblebees—clover, and solitary species such as—alfalfa [18], fruit trees and shrubs [19].

Nevertheless, the collected data show the importance of a rich and long-blooming first food base for pollinators, which are willows, including willows of foreign origin. In this context, the creation of targeted plantings of species and varieties with different and at the same time overlapping flowering periods can be of measurable importance in the increased yield of field and fruit crops. This is all the more important when a decrease in the number of pollinators is observed as

a result of environmental contamination [20], reduction of the nesting area, wastelands with wild flowering plants and other reasons [21].

5. Conclusions

The study showed the influence of a small (1472 m²) willow plantation, consisting of 150 taxa of both native and foreign origin, on the presence of 30 *Apoidea* species. There was also a small proportion of honeybees (17) in relation to the total number of insects observed (1591). This shows that the change in environmental conditions may have an impact not only on the most important representative of *Apoidea*, but also on other pollinators.

The significant correlation between the number of pollinators and the period of pollen production by willows and the decrease in insect number after the pollination period, despite the peak flowering of female specimens in the studied area, is considered to be a significant result. The observed species of insects were also ranked according to the date of their appearance, distinguishing 4 groups among them. The first to appear were: *Andrea mitis*, *A. praecox*, *A. vaga*, *A. apicata*, *A. cineraria*, *A. clarkella*, *A. fulva*, *A. haemorrhoea*, *A. ventralis*, *Apis mellifera*, *Bombus* “*terrestribombus*”, *B. pascuorum*, *B. pratorum*, *B. campestris*, *Colletes cunicularius*, *Lasioglossum calceatum*, *L. subfasciatum*, *L. xanthopus*, *Nomada campestris* followed by *Andrena dorsata*, *A. flavipes*, *A. minutula*, *A. nigroaenea*, *Bombus lapidarius*, *Halictus rubicundus*, *Lasioglossum quadrinotatum*.

The last species, with single individuals of a given species, were: *Andrena nitida*, *Bombus ruderarius*, *Nomada bifida* and *N. moeschleri*.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Ostaff, D.P., Mosseler, A., Johns, R.C., Javorek, S., Klymko, J. and Ascher, J.S. (2015) Willows (*Salix* spp.) as Pollen and Nectar Sources for Sustaining Fruit and Berry Pollinating Insects. *Canadian Journal of Plant Science*, **95**, 505-516. <https://doi.org/10.4141/cjps-2014-339>
- [2] Konatowska, M., Rutkowski, P., Budka, A., Goliński, P., Szentner, K. and Mleczeek, M. (2021) The Interactions between Habitat, Sex, Biomass and Leaf Traits of Different Willow (*Salix*) Genotypes. *International Journal of Environmental Research*. <https://doi.org/10.1007/s41742-021-00323-3>
- [3] Sacchi, C.F. and Price, P.W. (1988) Pollination of the Arroyo Willow, *Salix lasiolepis*. *Role of Insects and Wind American Journal of Botany*, **75**, 1387-1393. <https://doi.org/10.1002/j.1537-2197.1988.tb14200.x>
- [4] Kevan, P.G. (1972) Insect Pollination of High Arctic Flowers. *Journal of Ecology*, **60**, 831-847. <https://doi.org/10.2307/2258569>
- [5] Argus, G.W. (1974) Experimental Study of Hybridization and Pollination in *Salix* (willow). *Canadian Journal of Botany*, **52**, 1613-1619.

- <https://doi.org/10.1139/b74-212>
- [6] Elmqvist, T., Ågren, J. and Tunlid, A. (1988) Sexual Dimorphism and Between-Year Variation in Flowering, Fruit Set and Pollinator Behaviour in a Boreal Willow. *Oikos*, **53**, 58-66. <https://doi.org/10.1139/b74-212>
- [7] Vroege, P.W. and Stelleman, P. (1990) Insect and Wind Pollination in *Salix repens* L. and *Salix caprea* L. *Israel Journal of Botany*, **39**, 125-132.
- [8] Fox, J.F. (1992) Pollen Limitation of Reproductive Effort in Willows. *Oecologia*, **90**, 283-287. <https://doi.org/10.1007/BF00317187>
- [9] Douglas, D.A. (1997) Pollination, Capsule Damage, and the Production of Seeds in *Salix setchelliana* (*Salicaceae*), an Alaskan Glacial River Gravel Bar Willow. *Canadian Journal of Botany*, **75**, 1182-1187. <https://doi.org/10.1139/b97-831>
- [10] Füssel, U. (2007) Floral Scent in *Salix* L. and the Role of Olfactory and Visual Cues for Pollinator Attraction of *Salix caprea* L. Doctoral Dissertation. Universität Bayreuth, Germany.
- [11] Danforth, B.N., Minckley, R.L. and Neff, J.L. (2019) The Solitary Bees. Biology, Evolution, Conservation. Princeton University Press, 472. <https://doi.org/10.2307/j.ctvd1c929>
- [12] Michez, D., Rasmont, P., Terzo, M. and Vereecken, N.J. (2019) Bees of Europe. N.A.P Editions, France, 547.
- [13] Nicolson, S.W. and Wright, G.A. (2017) Plant-Pollinator Interactions and Threats to Pollination: Perspectives from the Flower to the Landscape. *Functional Ecology*, **31**, 22-25. <https://doi.org/10.1111/1365-2435.12810>
- [14] Rutkowski, P., Konatowska, M., Goliński, P., Mleczek, M., Szentner, K. and Waliszewska, B. (2015) The Use of GIS Database in the Documentation of Willows of Their Collection at the Poznań University of Life Sciences (Poland). In: Maciej, N., Ed., *Scientific, Technological and Legal Background of Creating Integrated Biotic Databases*. Adam Mickiewicz University Press. *Seria Biologia*, **80**, 85-90.
- [15] Pawlikowski, T. (1999) A Field Guide to Identification of Bumblebees (*Hymenoptera: Apidae: Bombini*) in Poland. UMK, Toruń.
- [16] Weryszko-Chmielewska, E., Piotrowska-Weryszko, K., Sulborska, A., Żuraw, B., Dmitruk, M., Stępniewski, K., Pogorzelec, M. and Voloshchuk, K. (2017) Assessment of *Salix* spp. Pollen Availability to Insects Based on Aerobiological Investigations. *Acta Agrobot*, **70**. <https://doi.org/10.5586/aa.1717>
- [17] Bennett, A.B. and Isaacs, R. (2014) Landscape Composition Influences Pollinators and pollination Services in Perennial Biofuel Plantings. *Agriculture, Ecosystems and Environment*, **193**, 1-8. <https://doi.org/10.1016/j.agee.2014.04.016>
- [18] Banaszak, J. and Cierznia, T. (1995) Ekonomiczne efekty zapylenia roślin uprawnych przez pszczołę miodną i dziko żyjące pszczołowate (*Apoidea*). *Kosmos*, **44**, 47-61. <https://doi.org/10.1093/ajcn/61.1.44>
- [19] Wójtowski, F. and Eliszek, H. (1977) Apidofauna zapyłająca drzewa i krzewy owocowe w pracowniczych ogródkach działkowych Poznania. *Roczniki Akademii Rolniczej w Poznaniu*. **94**, 235-241.
- [20] Banaszak, J. and Izdebska, B. (1994) Wpływ skażeń środowiskowych na pszczoły dziko żyjące, pszczołę miodną i produkty pszczele. *Kosmos*, **43**, 285-302.
- [21] Banaszak, J., Czechowska, W., Czechowski, W., Garbarczyk, H., Sawoniewicz, J. and Wiśniowski, B. (2000) Zagrożenia i perspektywy owadów błonkoskrzydłych (*Hymenoptera*) *Wiadomości Entomologiczne*, **18**, 171-211.