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ORIGINAL PAPER

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THE EFFECT OF VEGETATION IN APPLE ORCHARD EDGES ON THE PHENOLOGY OF PARASITOIDS FROM THE SUBFAMILY *Pimplinae* (*Hymenoptera, Ichneumonidae*)

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ABSTRACT

Wild vegetation neighbouring orchards may be a factor attracting imagines of parasitoids from the subfamily *Pimplinae* into fruit tree plantations and thus increase both their species diversity and population size in this habitat. For this reason in the years 2008–2010 a study was initiated on the phenology of 8 dominant *Pimplinae* species in apple orchards and on their edges, which included shrubberies and roadside avenues of trees and shrubs. Slightly higher numbers of *Pimplinae* were recorded in orchards compared to their edges. At strong correlation was observed between the counts of *Pimplinae* in both habitats. The preference of selection of orchards by *Pimplinae* was observed in the autumn period, while no such preference was found in the spring or summer months. Analyses showed that flowering plants in the orchard edges such as *Tilia cordata*, *Symphoricarpos albus*, *Cirsium arvense* and *Galium aparine* may have attracted *Pimplinae* to the orchards.

Key words: wasps, occurrence, fruit trees, wild plants

INTRODUCTION

Management of the ecological structure in agrocenoses, including also pomiculture plantations, may lead to an increased biological diversity of these habitats. Leaving buffer strips, in-field tree plantings, shrubberies, in-field ponds and fallows in these agrocenoses, as well as the introduction of belts of flowering plants provide advantageous living conditions for entomophages. In this way it enhances the impact of factors regulating the size of phytophage populations feeding on agricultural and pomiculture crops [Badenes-Pérez and Márquez 2012, Dąbrowski et al. 2013, Piekarska-Boniecka et al. 2015, Campbell et al. 2017]. Entomophages numerously colonising orchards include parasitoids from the family *Ichneumonidae*, including representatives of the subfamily *Pimplinae*. They effectively reduce the population of larvae and pupae of economically important pests in apple orchards [Płuciennik and Olszak 2010, Bąkowski et al. 2013, Velcheva and Atanassow 2016]. They are parasitized on by such pests feeding in orchards as e.g. *Choreutis pariana* (Cl.), *Coleophora anatipennella* (Hb.), *Cydia pomonella* (L.), *Yponomeuta malinellus*

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Zell., or species from the genus *Archips* [Zajančkauskas et. al. 1979]. Larvae of *Ichneumonidae* are ecto- or endoparasitoids, while imagines feed on nectar, sap and pollen. The diverse ecological structure of agrocenoses such as orchards and the surrounding vegetation provide advantageous environmental conditions for entomophages. Vegetation neighbouring orchards, thanks to its density and species diversity, is a source of food for parasitoids, while at the same time is constitutes a living environment for alternative hosts of these entomophages [Wäckers 2004, Fiedler and Landis 2007]. The effect of vegetation in the edges of orchards on the colonisation of pomiculture crops by entomophages, including parasitoids from the family *Ichneumonidae*, was presented in their studies e.g. by Debras et al. [2006] and Dib et al. [2012]. For this reason it was decided to conduct investigations on the effect of vegetation in the orchard edges boundary strips on the incidence of dominant parasitoid species from the subfamily *Pimplinae* within orchards. This subfamily is found numerously in apple orchards in Poland [Piekarska-Boniecka and Suder-Byttner 2002, Olszak 2010, Bąkowski et al. 2013].

The aim of this study was to determine the effect of shrubberies and the roadside vegetation of trees and shrubs neighbouring apple orchards on the phenology of imagines from 8 dominant parasitoid species from the subfamily *Pimplinae* in orchards and to identify preferences in the colonisation of orchards and their edges by *Pimplinae*. It was also decided to verify whether the flowering period of the vegetation in orchard edges influences the emergence of *Pimplinae* in orchards.

MATERIAL AND METHODS

Locality. The study was conducted in 2008–2010 in orchards located in the vicinity of Czempiń in Wielkopolska (Western Poland). These were two orchards in Gorzyczki, located 1 km away from each other.

The study sites included:

1. Apple orchard I (UTM, XT27; 52.10106°N, 16.81199°E) 20 ha in area (A1 = orchard I), where analyses covered 5-hectare plots with 15-year-old apple trees of cv. 'Paulared', 'Red Delicious', 'Golden Delicious' and 'Jonagold'. The apple tree plots were surrounded by shrubberies (A2 = shrubberies), namely thicket phytocenoses of *Euonymo-Prunetum spinosae* and the *Querco-Ulmetum* forest, herbaceous communities and ruderal plant communities. The tree communities were formed mainly by European elm (*Ulmus laevis* Pall.), sessile oak (*Quercus robur* L.), ash tree (*Fraxinus excelsior* L.), maple (*Acer platanoides* L.), boxelder maple (*Acer negundo* L.) and single apple trees (*Malus domestica* Borkh.) with hybrid black poplar (*Populus* × *canadensis* Moench) and white willow (*Salix alba* L.). Among herbaceous plants the dominant species included stinging nettle (*Urtica dioica* L.), Canada thistle (*Cirsium arvense* (L.) Scop.) and cleavers (*Galium aparine* L.). In the patches of ruderal shrubberies the following were recorded: elder (*Sambucus nigra* L.), common hawthorn (*Crataegus monogyna* Jacq.), matrimony vine (*Lycium barbarum* L.), dog rose (*Rosa canina* L.) and hazel (*Corylus avellana* L.).

2. Apple orchard II (UTM, XT27; 52.10208°N, 16.81451°E) 10 ha in area (B1 = orchard II). The studies were conducted on 2-hectar plots with 20-year-old 'Golden Delicious' apple trees. The orchard borders along a road (B2 = roadside) were overgrown with plants typical of class *Rhamno-Prunetea*. The road was lined with walnut (*Juglans regia* L.), 3 maple species, i.e. boxelder (*Acer negundo* L.), common (*A. platanoides* L.) and sycamore maple (*A. pseudoplatanus* L.), as well as sessile oak (*Quercus robur* L.), sweet cherry (*Prunus avium* L.) and small-leaved lime (*Tilia cordata* Mill.), with some dog rose shrubs (*Rosa canina* L.), common hawthorn (*Crataegus monogyna* Jacq.), hawthorn (*Crataegus* × *media* Bechst.), hazel (*Corylus avellana* L.), elder (*Sambucus nigra* L.), white dogwood (*Cornus alba* L.), European spindle (*Euonymus europaea* L.), blackthorn (*Prunus spinosa* L.), snow currant (*Ribes niveum* Lind.) and snowberry (*Symphoricarpos albus* Duhamel). The dominant herbaceous plants included grasses, stinging nettle (*Urtica dioica* L.), wormwood (*Artemisia absinthium* L.), yarrow (*Achillea millefolium* L.), Canada thistle (*Cirsium arvense* (L.) Scop.) and cleavers (*Galium aparine* L.).

In both studied orchards apple trees grew at a spacing of 1.4 m in rows set 3 m apart. Between the trees fallow land was maintained and the rows of trees were divided by sward. The orchards followed the integrated fruit production policy. The apple protection program was implemented at the same dates and against the same diseases and pests in both orchards. In each of the orchards 5–8 control treatments against diseases and 6–8 control treatments against pests were performed in the different years of study.

Weather conditions. The weather conditions in the years 2008–2010 are presented based on the data from the Research Station, Turew, which belongs to the Institute of Agricultural and Forest Habitat PAS in Poznań. The data include average monthly air temperatures (Fig. 1) and monthly precipitation levels (Fig. 2). They were compared with the data from the 1971–2000 multiannual period. The years 2008 and 2009 were the warmest, with 2008 being the warmest and 2010 the coolest in comparison with the multiannual period. All the years were very wet, with the highest precipitation reported in 2010. This was also confirmed in the comparison with the multiannual period.

Method. The study used the commonly used method of trapping *Pimplinae* imagines in yellow traps as described by Moericke [1953]. The trap was made from a yellow plastic pan (18 cm in diameter and 11 cm deep), filled with a mixture of water and glycol (preservative) and a surfactant. A total of 20 pans were laid out on each site, 1–1.5 m above the ground. The traps were distributed in the following manner: 10 of them in the orchard and the other 10 further away, several meters from the orchard's edge. The traps were placed up to 10 m from one another. Specimens were collected in ten-day intervals. Insects caught in one pan during ten days constituted one sample. The traps were placed in the orchard from April to October in each study year.

Species from *Pimplinae* were determined based on the key of Kasparyan [1981].

Data analysis. Analyses were conducted on 8 *Pimplinae* species, which were dominant in the total number of specimens (1278) captured in the course of this study. For these species the dominance index (D) reached a value ≥2.4%. Relationships between abundances of the dominant *Pimplinae* species found in orchards and in both neighbouring habitats in subsequent years were established by analysing the Pearson correlation coefficients. Next, we performed a significance test to determine whether this relationship is significant

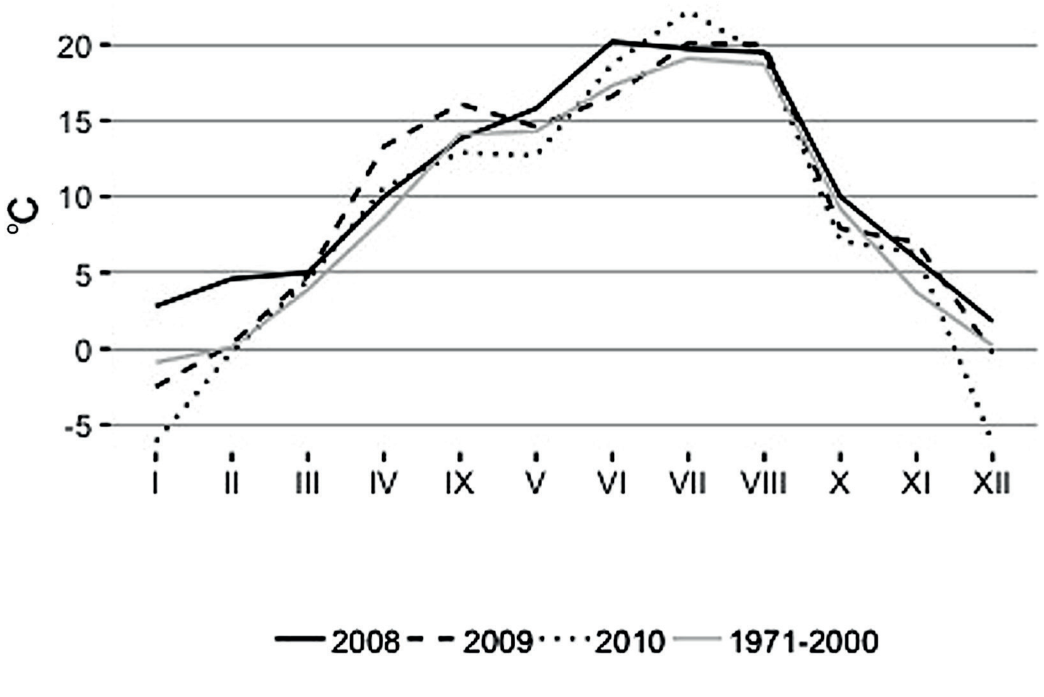

Fig. 1. Average monthly air temperatures in particular study year in comparison with the multiannual period

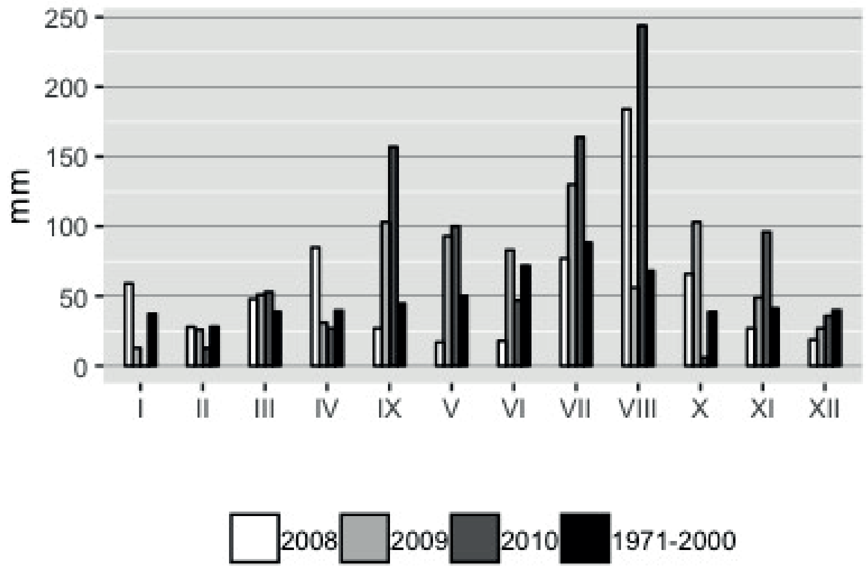

Fig. 2. Monthly precipitation in particular study years in comparison with the multiannual period

(at the significance level 0.05). Abundances of the dominant *Pimplinae* species in the orchards and edges in individual study years for peak periods (20 June–20 August) were compared using a non-parametric Wilcoxon test due to the non-normal data distribution. Finally, the Principial Component Analysis (PCA) was used to illustrate the qualitative and quantitative relationships between the habitats (A1 – orchard I; A2 – shrubberies; B1 – orchard II; B2 – roadside) and species (S1, S2, …, S8). PCA is one of the oldest and most commonly applied techniques used to reduce the dimensionality of datasets. In the analyses of multidimensional data PCA as a descriptive tool does not require any assumptions concerning the distribution and as such is largely an adaptive exploratory method that can be used for different types of data [Jolliffe et al. 2016]. As the graphical representation of the PCA analysis we used the biplot.

Statistical calculations were performed with the R software, version 3.5.1 [R Core Team 2018].

RESULTS

In the years 2008–2010 in the orchard habitat in Gorzyczki a total of 2438 samples were collected, of which 1208 were collected in orchards and 1230 were caught in their edges. Overall 1278 specimens belonging to 45 species of *Pimplinae* were found. In the orchards 709 specimens classified to 35 species were reported, while in the edges a total of 569 specimens from 40 species were caught. Phenology of *Pimplinae* imagines in orchards and their edges is presented based on the occurrence of 8 dominant *Pimplinae* species (Tab. 1). These included *Itoplectis maculator* (Fabr.) – D = 31.5%, *Liotryphon crassiseta* (Thoms.) – D = 26.7%, *Endromopoda detrita* (Holmgr.) – D = 5.4%, *Zaglyptus multicolor* (Grav.) – D = 4.1%, *Pimpla rufipes* (Mill.) – D = 4.0%, *Itoplectis alternans* (Grav.) – D = 3.4%, *Pimpla spuria* (Grav.) – D = 3.4%) and *Pimpla contemplator* (Muell.) – D = 2.4%. Species from the genus *Itoplectis* are polyphagous endoparasitoids of pupae in pests classified first of all to orders Lepidoptera, Coleoptera, Diptera and Hymenoptera. *Liotryphon crassiseta* is an ectoparasitoid of Lepidoptera and Coleoptera larvae. *Endromopoda detrita* is an ectoparasitoid of larvae belonging to Lepidoptera, Coleoptera, Diptera and Hymenoptera. Species from the genus *Pimpla* are endoparasitoids of pupae in pests from the orders Lepidoptera and Hymenoptera. Only *Z. multicolor* does

Table 1. Abundances of the dominant *Pimplinae* species caught in apple orchards and on their edges during study years (a – 2008, b – 2009, c – 2010)

Species	Habitats																Sum
	orchard I (A1)				shrubberies (A2)				orchard II (B1)				roadside (B2)				
	a	b	c	sum	a	b	c	sum	a	b	c	sum	a	b	c	sum	
S1 *Endromopoda detrita* (Holmgren, 1860)	1	12	–	13	8	13	–	21	4	20	1	25	4	4	2	10	69
S2 *Itoplectis alternans* (Gravenhorst, 1829)	4	5	6	15	2	4	3	9	4	2	1	7	7	4	2	13	44
S3 *Itoplectis maculator* (Fabricius, 1755)	38	59	5	102	12	43	11	66	58	111	12	181	25	23	6	54	403
S4 *Liotryphon crassiseta* (Thomson, 1877)	36	14	5	55	23	8	2	33	125	25	9	159	78	13	3	94	341
S5 *Pimpla contemplator* (Mueller, 1776)	1	1	–	2	4	9	1	14	–	6	–	6	3	2	3	8	30
S6 *Pimpla rufipes* (Miller, 1759)	3	5	2	10	10	5	2	17	8	2	2	12	11	1	–	12	51
S7 *Pimpla spuria* (Gravenhorst, 1829)	4	1	–	5	2	2	1	5	8	2	–	10	22	1	–	23	43
S8 *Zaglyptus multicolor* (Gravenhorst, 1826)	2	–	–	2	26	5	4	35	1	–	–	1	10	3	1	14	52
Total	89	97	18	**204**	87	89	24	**200**	208	168	25	**401**	160	51	17	**228**	**1033**

not belong to entomophages regulating the population of pests feeding in apple orchards, since it is an ectoparasitoid of adult *Araneae*.

Throughout the period of analyses in orchards and their edges the 3 dominant parasitoid species included *I. alternans*, *I. maculator* and *L. crassiseta* (Tab. 1).

Overall throughout the study slightly higher numbers (58.6%) of imagines from dominant *Pimplinae* species were caught in the orchards compared to their edges (41.4%).

Analyses of the numbers of dominant *Pimplinae* species caught in individual years in the orchard-edge system showed that in 2008, which was the warmest compared to the other years, the highest numbers of *Pimplinae* were recorded in the orchard (B1) and the neighbouring roadside (B2) – Table 1. The smallest population sizes of *Pimplinae* were found in both orchards (A1 and B1) and in their edges (A2 and B2) in 2010, which was characterised by the lowest air temperatures and the highest precipitation levels compared to the previous years of the study (Figs 1 and 2).

In turn, analyses concerning the population sizes of dominant *Pimplinae* species recorded in individual years between the orchards and their edges indicated that they were comparable in the orchard (A1) and adjacent shrubberies (A2) in the successive years of the study (Tab. 1). Generally the populations of *Pimplinae* differed in the case of the orchard (B1) and the neighbouring roadside (B2). In 2008 and 2009 markedly higher numbers of *Pimplinae* were caught in the orchard (B1) in relation to the roadside (B2). Only in 2010, in which low counts of *Pimplinae* were recorded in both orchards and their edges, the population sizes in the orchard (B1) and the roadside (B2) were similar.

Analyses of the values of the correlation coefficients (r) between the populations of dominant species caught in the orchards and in their edges in individual years of the study showed very high or average values of the coefficients of correlation between them (Tab. 2). Generally in 2008 and 2009 in orchards and in their edges

Table 2. Pearson correlation coefficient (r) and p-values for the test of significance for the correlation coefficient between the abundances of the dominant *Pimplinae* species of the orchards and edges in individual study years (at the significance level 0.05)

Habitats	Years					
	2008		2009		2010	
	r	p-value	r	p-value	r	p-value
Orchard I (A1) – shrubberies (A2)	0.41	0.31	0.97	<0.001***	0.44	0.31
Orchard II (B1) – roadside (B2)	0.96	<0.001***	0.94	<0.001***	0.76	0.04*

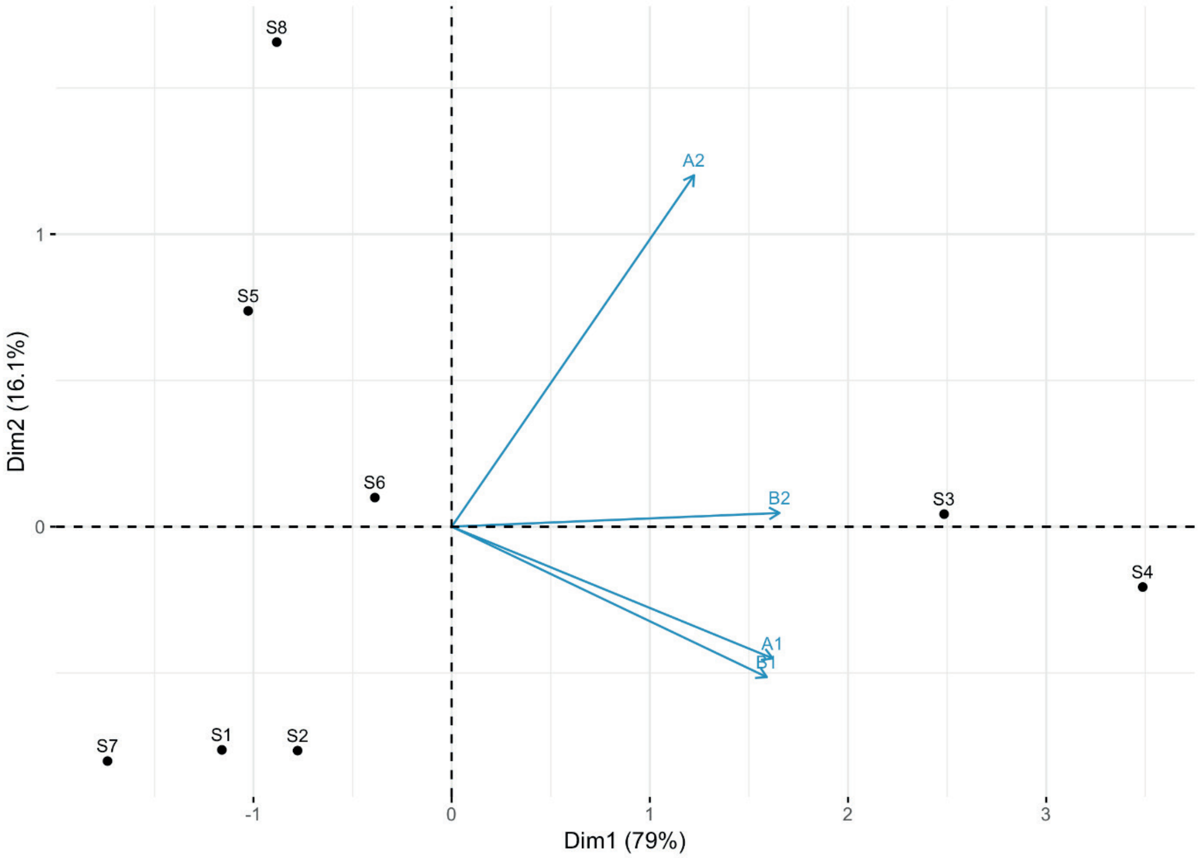

Fig. 3. Principal component analysis (PCA) of the biplot illustrating the relationship between the habitats and species (A1 – orchard I; A2 – shrubberies; B1 – orchard II; B2 – roadside) and *Pimplinae* species (S1–S8)

the correlation was very high and statistically significant. This shows a very strong dependence between the numbers of dominants caught in these habitats and indicates the mobility of *Pimplinae* between orchards and their edges. Only in 2010, at a small population size of the dominant *Pimplinae* species, an average and statistically non-significant correlation was found.

Analyses of the numbers of dominant *Pimplinae* species caught in orchards and in their edges, conducted using PCA (Fig. 3), confirmed a high correlation between counts of *Pimplinae* in the orchard (B1) and the neighbouring roadside (B2), as well as a weaker correlation of the numbers of dominants in the orchard (A1) and in the shrubberies (A2). At the same time a very high correlation was observed for the count of *Pimplinae* between both orchards (A1 and B1). The species showing the strongest relationship with individual habitats included *L. crassiseta* (S4) with orchards (A1 and B1) and *I. maculator* (S3) with the roadside (B2).

Generally the dominant species of *Pimplinae* were caught the earliest in all the decades of April, predominantly in the 3rd decade of that month, both in the orchards and in their edges (Figs 4–9). These were imagines of *I. maculator* and *L. crassiseta* in the orchards (A1 and B1) and in the shrubberies (A2), as well as *L. crassiseta* and *Z. multicolor* in the roadside (B2). An exception in this respect was observed in 2008, in which the first specimens were reported as late as the 1st and 2nd decade of May in the orchards and in their edges. They were the same species as those reported in April in the orchards and in the roadside. In the shrubberies *L. crassiseta* and *P. contemplator* were the first to appear.

Based on the capture of the last specimens of the dominant *Pimplinae* species this period was observed to extend further depending on the environment (Figs 4–9). In the orchards (A1 and B1) it was reported in all the decades of October, primarily in the 1st and 2nd decades of that month. In the shrubberies (A2) capture of imagines ended in September, generally in its 3rd decade. In the roadside (B2) the period of imagine capture was markedly shorted, since the last specimens were reported already in the 1st decade of August, but also in the 3rd decade in September. The last imagines in the orchards were *I. alternas*, *L. crassiseta* and *P. rufipes*, in the shrubberies it was *L. crassiseta*, *P. rufipes*, *P. contemplator* and *Z. multicolor*, while in the roadside it was *E. detrita*, *I. maculator*, *L. crassiseta*, *P. rufipes* and *Z. multicolor*.

Due to the low numbers of the dominant *Pimplinae* species in 2010 in the orchards and in their edges no peak of imagine capture was recorded in that season. In 2008 and 2009 in the orchards the peak of imagine capture was generally reported in the 1st or the 2nd decade of July, while in the orchard edges it occurred in various seasons. In the shrubberies it was typically in all the decades of July, while in the roadside at the turn of June and July and in the 1st decade of August.

When comparing the periods of capture for the dominant *Pimplinae* species in individual years in the orchards and in their edges the onset of the emergence of imagines in both habitats as a rule occurred in the same period. Only in 2008 in the shrubberies (A2) imagines were caught one decade earlier than in the orchard (A1). Also in 2009 in the orchard (A1) one specimen appeared in the 1st decade of April, i.e. earlier than in shrubberies, while the other imagines were found in the same period in both habitats. This indicates mobility of parasitoid specimens between the orchards and the edges. The last specimens were predominantly caught for a longer period in the orchards than in the edges. Only in 2010 in both habitats insect capture ended in the same period, in the 2nd decade of October. This indicates a preference for the selection of both neighbouring habitats by *Pimplinae* in the autumn period.

When comparing the peak of capture for *Pimplinae* imagines in 2008 and 2009 in the orchards and in their edges it was stated that mass capture of imagines occurred primarily in the same period in the orchards and in their edges. Only in 2008 in the orchard (A1) the peak of capture was recorded one month earlier than in the shrubberies (A2). The coinciding peaks of capture for *Pimplinae* imagines in both habitats did not differ statistically significantly in terms of their numbers, as indicated by the fact that all the recorded p-values for the non-parametric Wilcoxon tests were greater than the assumed significance level $\alpha = 0.05$ (Tab. 3). Such dates of mass capture of imagines in the orchards and in their edges confirmed mobility of parasitoids between these habitats. Also the values of the correlation coefficient (r) between the numbers of *Pimplinae* in both habitats indicated an interaction between the

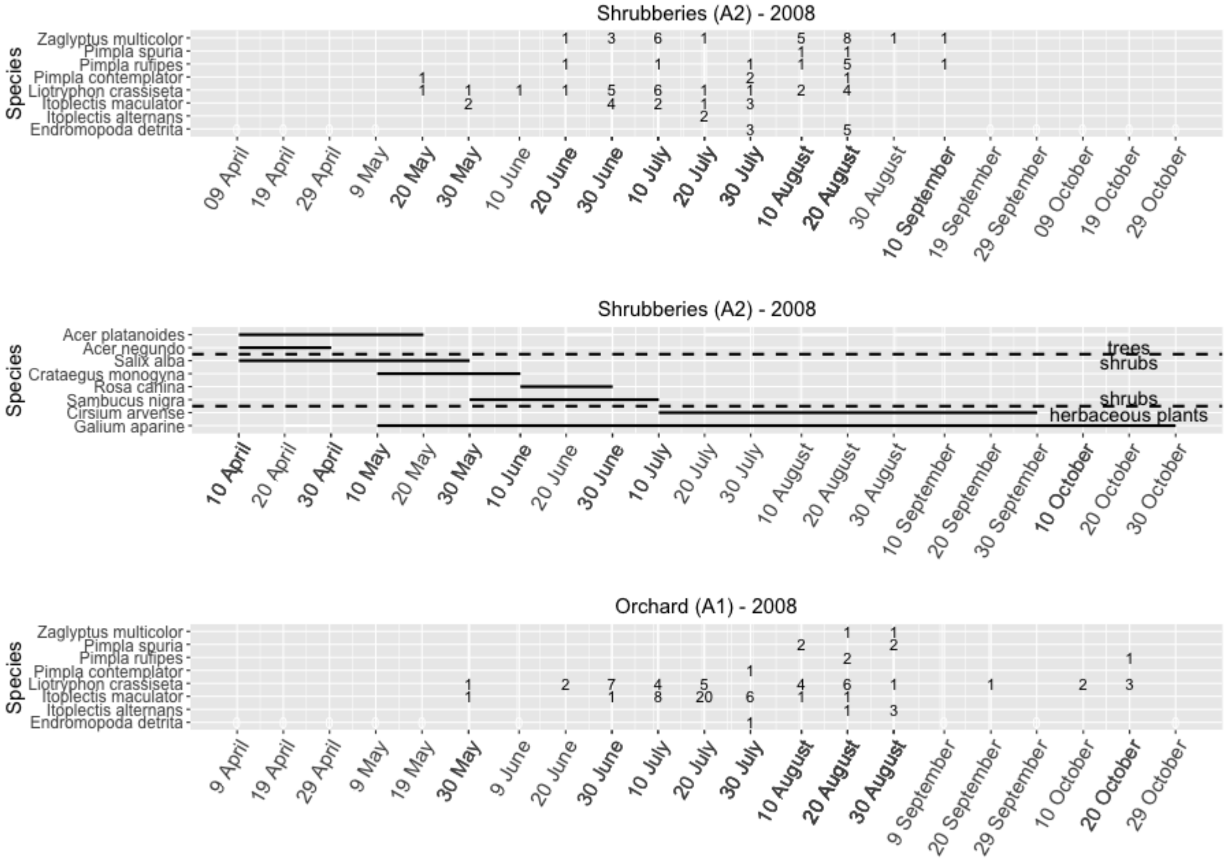

Fig. 4. Phenology of the occurrence of dominant *Pimplinae* in orchard I (A1) and shrubberies (A2) in 2008

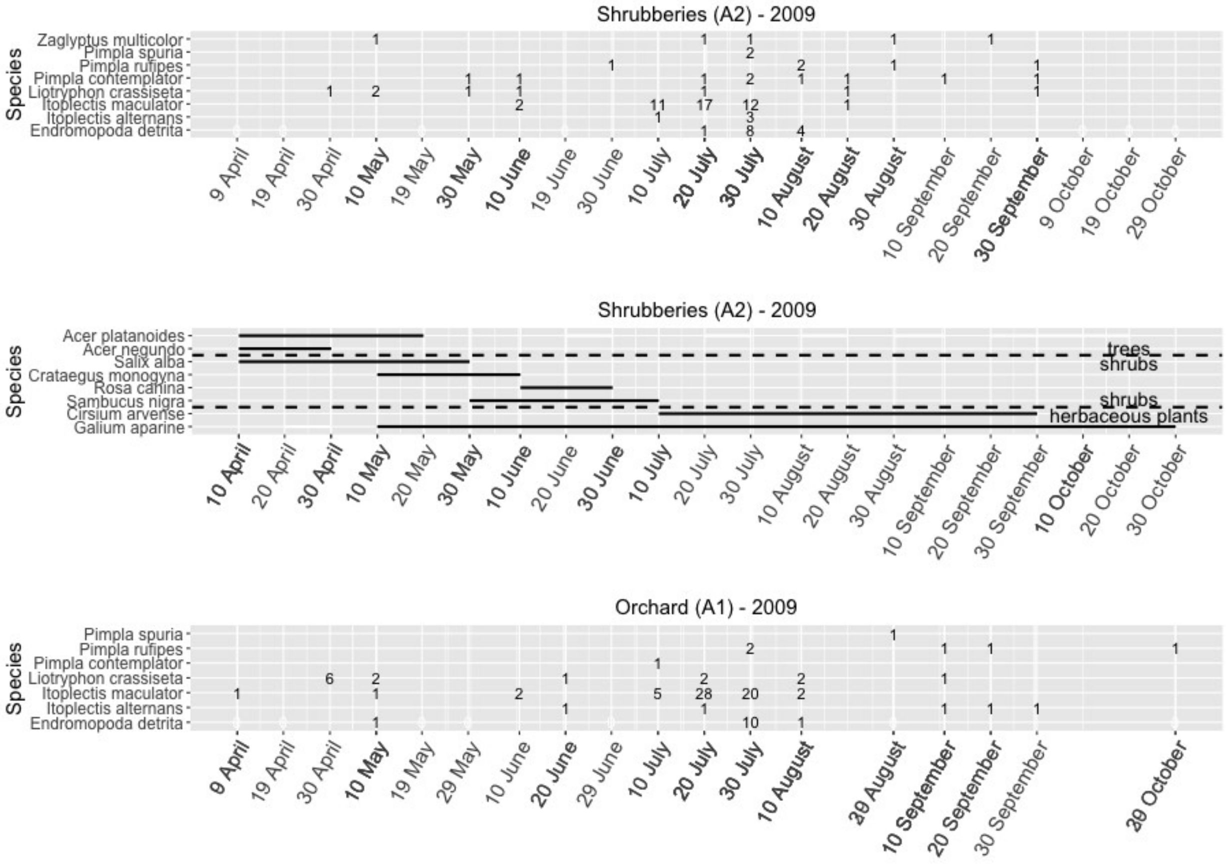

Fig. 5. Phenology of the occurrence of dominant *Pimplinae* in orchard I (A1) and shrubberies (A2) in 2009

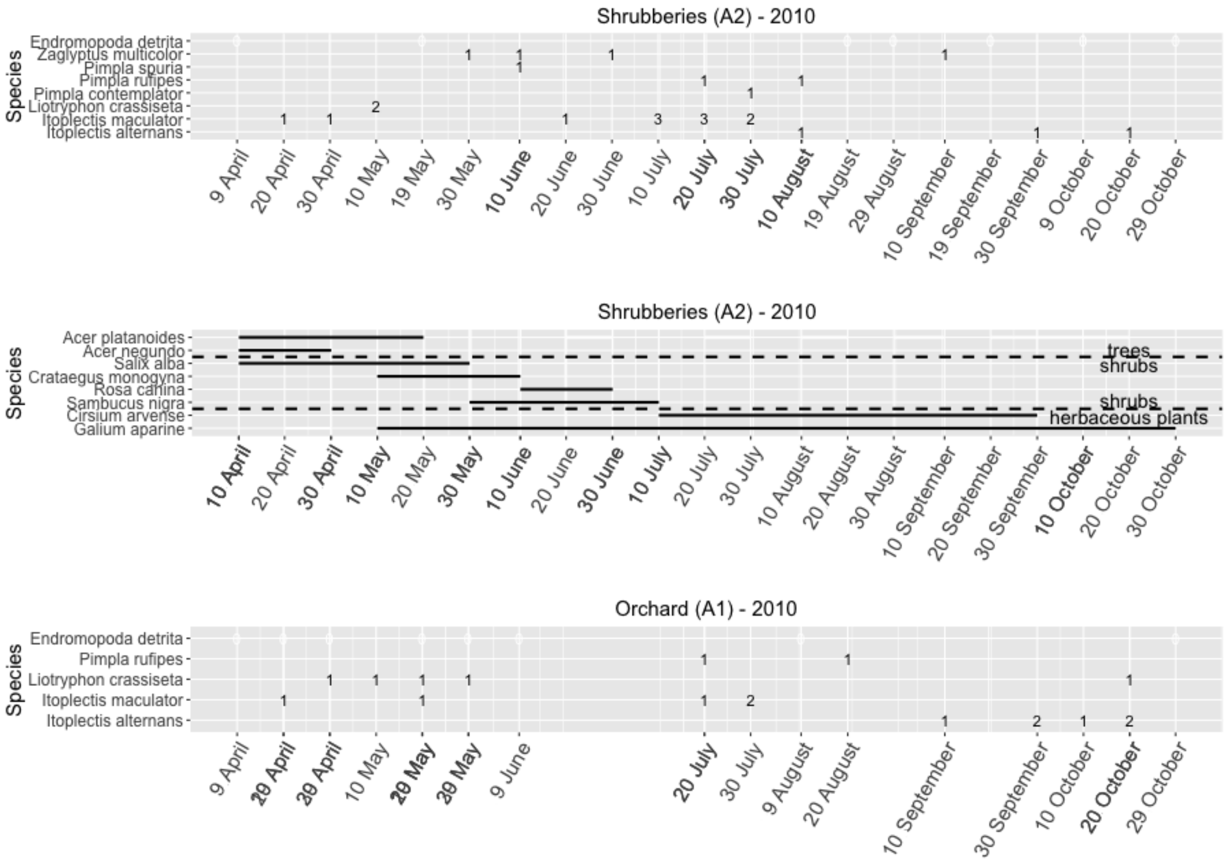

Fig. 6. Phenology of the occurrence of dominant *Pimplinae* in orchard I (A1) and shrubberies (A2) in 2010

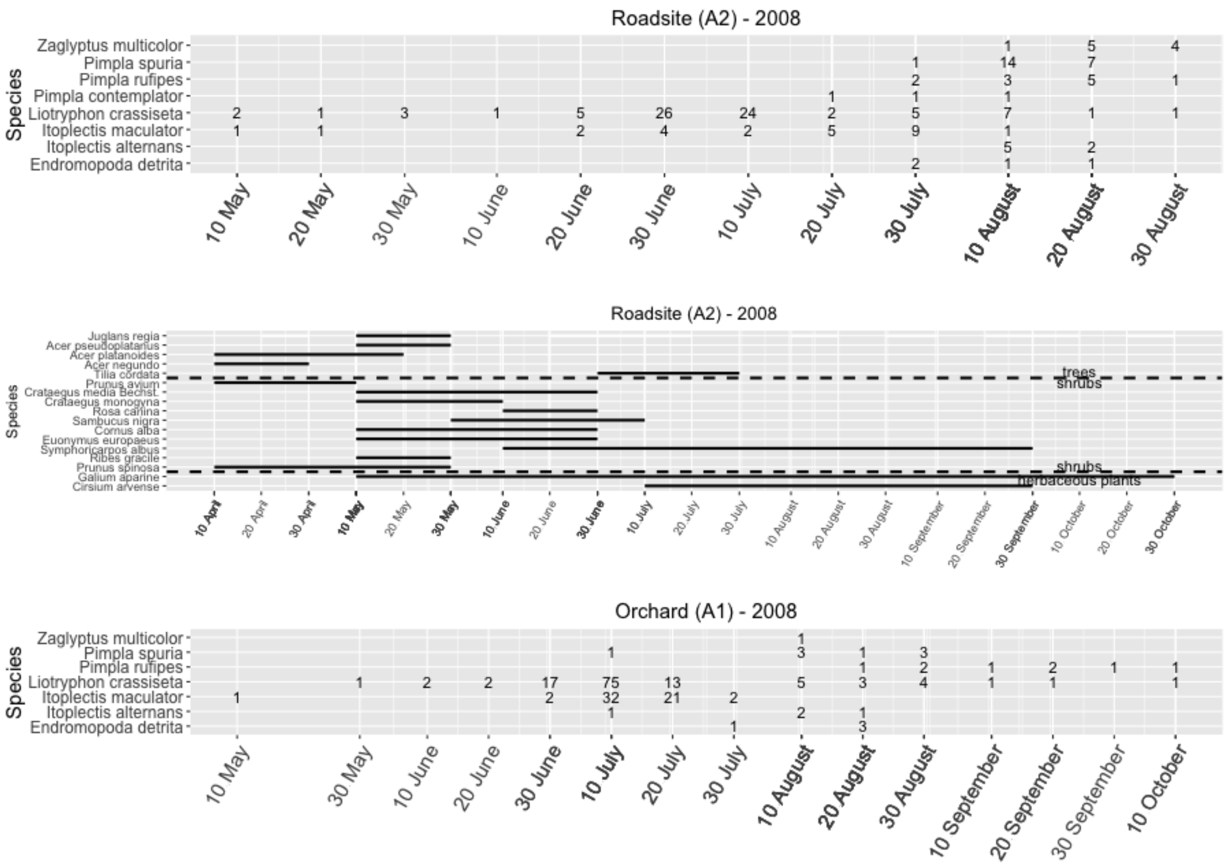

Fig. 7. Phenology of occurrence of dominant *Pimplinae* species in orchard II (B1) and the roadside (B2) in 2008

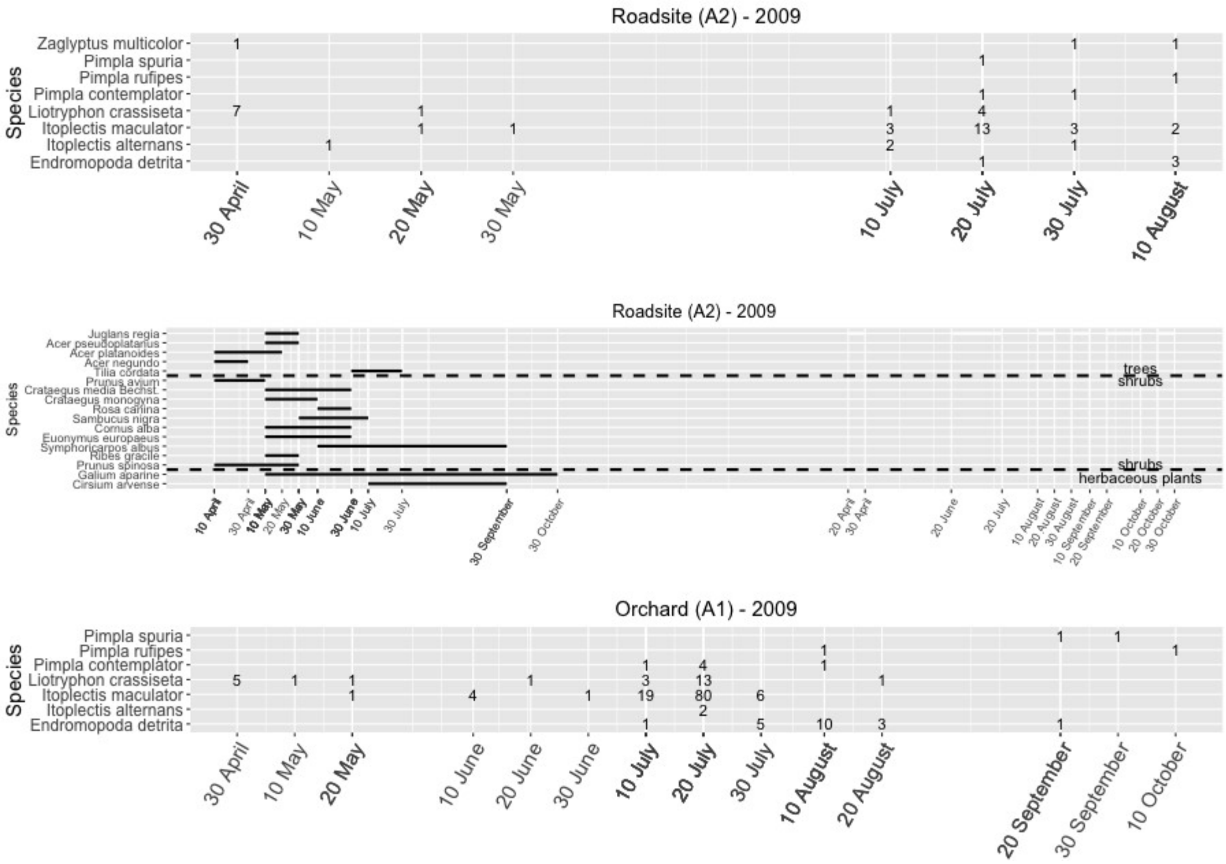

Fig. 8. Phenology of occurrence of dominant *Pimplinae* species in orchard II (B1) and the roadside (B2) in 2009

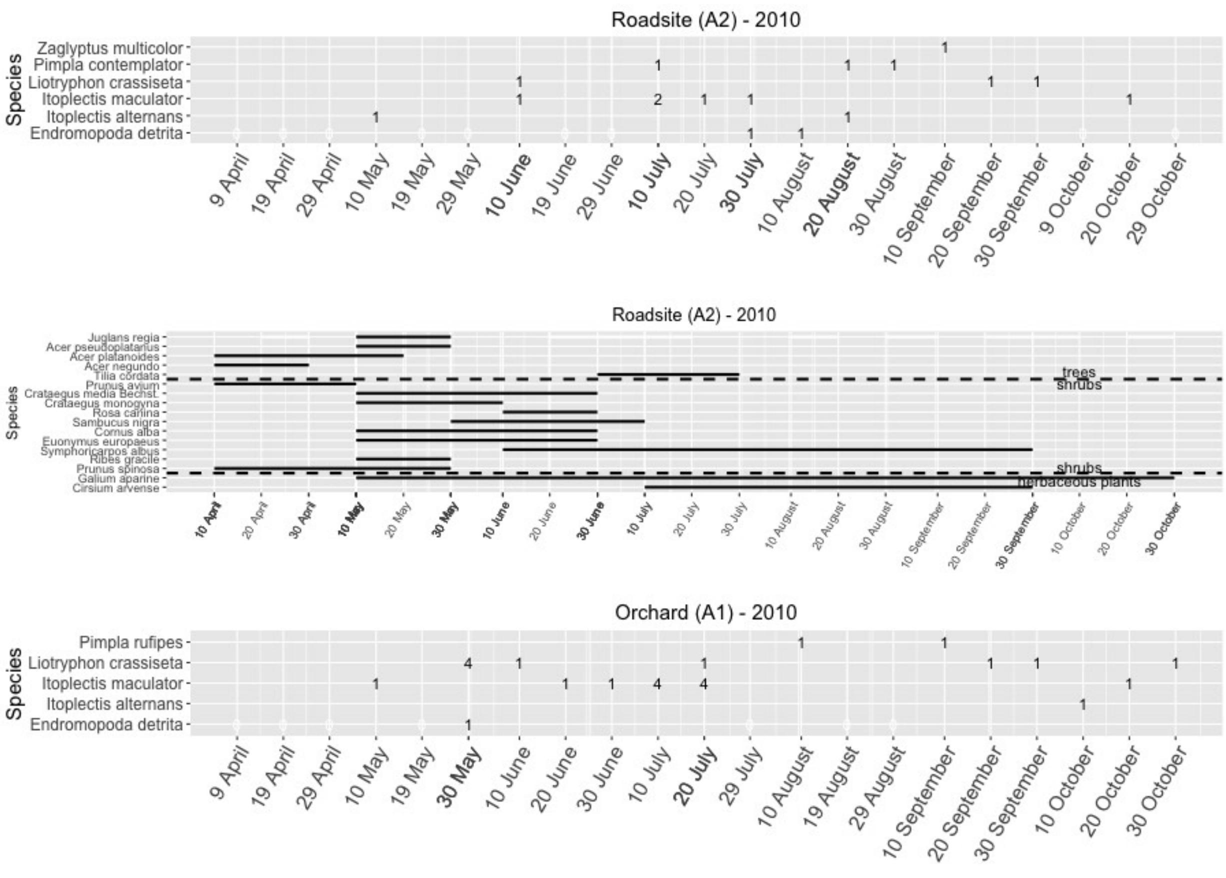

Fig. 9. Phenology of occurrence of dominant *Pimplinae* species in orchard II (B1) and the roadside (B2) in 2010

Table 3. P-values for the Wilcoxon Signed-Rank test for peak periods (20 June – 20 August) of the greatest abundances of the dominant *Pimplinae* species in the orchards and edges in individual study years (at the significance level 0.05)

Habitats	Years		
	2008	2009	2010
	p-value	p-value	p-value
Orchard I (A1) – shrubberies (A2)	0.75	0.90	0.08
Orchard II (B1) – roadside (B2)	0.62	0.20	1.00

orchards and their edges for the occurrence of the dominant *Pimplinae* species in both neighbouring habitats.

Analyses of the flowering period in the vegetation forming the orchard edges and the occurrence of *Pimplinae* in the orchards indicated no definite relationship between the period of plant flowering in the orchard edges and the presence of *Pimplinae* in the orchards. The flowering period for plants in the shrubberies occurred much earlier than the abundant emergence of *Pimplinae* in the orchard (Figs 4 and 5). Most plants ended the flowering period already at the beginning of May, except for *Rosa canina* and *Sambucus nigra,* which were overblown immediately before the mass gradation of imagines in the orchards. Peak capture of *Pimplinae* in the orchards was observed primarily in the 1st and 2nd decade of July. In that period *Cirsium arvense* and *Galium aparine* were flowering and thus they may be considered attractive for these entomophages. It was also stated that the same time dependencies were observed between plant flowering in the shrubberies and occurrence of *Pimplinae* in those habitats.

A greater species diversity was observed in the roadside when compared to the shrubberies. Most plants also finished blooming before *Pimplinae* appeared in large numbers in the orchard (Figs 7 and 8). Some of them finished blooming immediately before the peak of *Pimplinae* capture in the orchards. These were *Cornus alba*, *Euonymus europaeus*, *Crataegus* × *media*, *Rosa canina* and *Sambucus nigra*. The period of mass gradation of imagines in the orchards occurred primarily in the 1st and 2nd decade of July. In that period *Tilia cordata*, *Symphoricarpos albus*, *Cirsium arvense* and *Galium aparine* were blooming. Thus it may be stated that the flowering period of these plants may have influenced the emergence of imagines in the orchard. The same time dependencies were observed between flowering of the roadside vegetation and occurrence of parasitoid imagines in that habitat, while the mass capture in that habitat took place also during the flowering period of only *Symphoricarpos albus*, *Galium aparine* and *Cirsium arvense*.

DISCUSSION

Studies conducted in the years 2008–2010 on the effect of vegetation in the edges of apple orchards on phenology of parasitoids from the subfamily *Pimplinae* showed the dominance of 8 entomophagous species from that subfamily. All of them, except for *Zaglyptus multicolor*, are parasitoids, economically important pests feeding in that habitat. All the reported dominant *Pimplinae* species are found in agrocenoses in Poland and Europe [Piekarska-Boniecka and Suder-Bytner 2002, Yu et al. 2012, Piekarska-Boniecka et al. 2015].

Analyses on the dominant *Pimplinae* species showed slightly better attractiveness of apple orchards compared to their edges, such as shrubberies and the roadside, since more parasitoid imagines were caught in the orchards than in their edges. This may be explained by the fact that orchards due to the size of their area provide most stable living conditions for parasitoids than the neighbouring belts of wild vegetation. However, attractiveness of the wild vegetation in the orchard edges in relation to parasitoid imagines has been confirmed by numerous authors. Sarvary et al. [2010] showed that parasitizing of *Choristoneura rosaceana* (Harris) larvae in apple orchards was greater when orchards was located next to shrubberies formed by *Cornus* spp. According to Ricci et al. [2011], for this reason parasitizing of diapausing *Cydia pomonella* (L.) larvae in orchards surrounded by hedges may have been greater than in orchards with no vegetation in the edges. Also Dib et al. [2012] stated that the number of diapausing *C. pomonella* larvae was limited by parasitoids e.g. from the family *Ichneumonidae* to a greater extent in apple orchards neighbouring belts of wild, flowering vegetation. According to Pfannenstiel et al. [2012], belts of *Rossa woodsii* shrubberies increased parasitizing of pest larvae belonging to *Tortricidae* feeding in orchards. Also Campbell et al. [2017] stated that belts of flowering vegetation may attract entomophages to the neighbouring apple orchards.

Analyses showed mobility of the dominant *Pimplinae* species between the orchards and their edges. This causes interactions of both these habitats in terms of their effect on counts of parasitoids in those habitats. Mobility of parasitoids between the orchards and their edges indicates that orchard edges may serve a protective function for entomophages e.g. during cultivation operations or pesticide treatments in orchards. After more advantageous conditions are found in orchards these entomophages may return to orchards.

The investigations of both neighbouring habitats showed a preference in the selection of orchards by *Pimplinae* in the autumn period, which was not shown in the spring and summer months.

The analyses indicated that the abundant occurrence of the *Pimplinae* species in the orchards occurred primarily in the 1st and 2nd decade of July. Also Rzańska et al. [2014] reported the peak capture of parasitoids from the subfamily *Pimplinae* in the collection of ornamental plants of the Poznań University of Life Sciences among other dates also in the 2nd decade of July. Additionally, Rzańska et al. [2015] established that mass capture of parasitoids from the family *Ichneumonidae* in the Botanical Garden of the Adam Mickiewicz University in Poznań occurred in the 1st and 2nd decade of July. Phenology of the emergence of imagines is dependent on weather conditions and thus it may vary from year to year. Piekarska-Boniecka [2004] and Rzańska and Piekarska-Boniecka [2016] reported that the period of mass emergence of parasitoids from the family *Ichneumonidae* in the urban green areas of the city of Poznań occurred in the 2nd decade of June and the 3rd decade of August. The effect of weather conditions on the period of parasitoid emergence in orchards and their edges was markedly evident in 2010. This was the coolest year with the highest precipitation total compared to the other years of the study. In that year the numbers of parasitoid were so low that it was impossible to identify the periods of abundant emergence of these entomophages.

Analyses showed that *Tilia cordata* (*Tiliaceae*), *Symphoricarpos albus* (*Caprifoliaceae*), *Cirsium arvense* (*Asteraceae*) and *Galium aparine* (*Rubiaceae*), growing on edges of apple orchards may attract *Pimplinae* imagines to orchards. Flowers of plants from the families *Apiaceae*, *Asteraceae*, *Fabacea*, *Lamiaceae*, *Ranunculaceae* and *Rosaceae* as sources of nectar and pollen for imagines of *Ichneumonidae* were reported by Sawoniewicz [1973], Wäckers [2004], Fiedler and Landris [2007], Çoruh and Çoruh [2008] and Kopta et al. [2012]. In turn, Sawoniewicz [1973] stated that *Ichneumonidae* most willingly visit flowers of plants from the family *Apiaceae*, which have readily accessible nectaries. According to that author, 214 *Ichneumonidae* species, of which 17 belonged to the subfamily *Pimplinae*, were associated with flowers of *Peucedanum oreoselinum* (*Apiaceae*). These included e.g. *Endromopoda detrita*, *Itoplectis alternans*, *I. maculator* and *Pimpla rufipes*. In turn, Çoruh and Çoruh [2008] indicated that among 5 species of plants from the family *Apiaceae*, *Seselis libanotis* and *Carum carvi* were visited most frequently and by the greatest numbers of *Ichneumonidae*. Kopta et al. [2012] reported that *Anethum graveolens* and *Foeniculum vulgare* (*Apiaceae*) were the most attractive species for *Ichneumonidae*. Also Maingay et al. [1991] indicated *F. vulgare* as a plant most attractive for *Ichneumonidae*. Bugg et al. [1987] and Bugg and Wilson [1989] stated that *Polygonum aviculare* (*Polygonaceae*) and *Amni visnaga* (*Apiaceae*) are the main plants providing sources of nectar for beneficial entomofauna, including also *Ichneumonidae*. Also Badenes-Pérez and Márquez [2012] reported that *Barbarea vulgaris* (*Brassicaceae*) proved to be a good source of nectar for parasitoids, including also *Ichneumonidae*.

Summing up, the emergence of imagines of the dominant *Pimplinae* species in apple orchards and in their edges were strongly correlated. This indicates mobility of these entomophages between these habitats and thus the mutual effect on the numbers of these entomophages in both habitats. Wild vegetation in orchard edges, particularly plants from the families *Asteraceae* and *Rubiaceae*, attracted *Pimplinae* and as a result had a positive effect on the occurrence of these entomophages in apple orchards.

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