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The Impact of Apple Orchard Edge Plants on Communities of Pimplinae (Hymenoptera, Ichneumonidae)

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ABSTRACT

Plant communities made up by trees and shrubberies, which grow in the vicinity of orchards, constitute important elements of ecological infrastructure enriching these agrocenoses. The study was conducted in an orchard environment composed of apple orchards and their edges, such as agricultural fields, shrubberies and a road lined with trees and shrubs. The aim of the study was to determine the influence of diversity level of edge plants of an apple orchard on the quantitative and qualitative structure of parasitoid communities of the Pimplinae subfamily in the orchards. It was found that in an orchard environment composed of an apple orchard and well-developed edge plants a species diversity and abundance of parasitoids were higher than in an orchard environment composed of an orchard and neighbouring agricultural areas. It was established that the apple orchard edge, which was characterised by the highest species diversity of plants (road), influenced mainly the qualitative structure of parasitoids of the Pimplinae subfamily occurring in the orchard. It was found that the road as the orchard edge was the most attractive habitat for parasitoids. To sum up: the presence of edge plant communities which are well-developed and highly diversified in species favours species richness and the abundance of the parasitoids of the Pimplinae subfamily of the orchard environment.

Key words: Apple orchard, hymenoptera, parasitoids, Pimplinae, plants of orchard edge, Poland.

INTRODUCTION

The plant life of tree and shrubbery communities in agricultural areas stabilises and differentiates natural features of a cultural landscape. A diversified landscape structure, which includes woodlots, meadow communities, water bodies, remains of natural forests and planted native trees and shrubs, increases the diversity of fauna and flora, thus strengthening self-regulatory mechanisms in agrocenoses (Hunter, 2002; Piekarska-Boniecka *et al*., 2008a, 2015; Macfadyen *et al*., 2009; Holzschuh *et al*., 2010; Maisonhaute and Lucas, 2011; Kopta *et al*., 2012; Lu *et al*., 2014). Plant communities in the forms of woodlots and shrubberies in the vicinity of orchards are important elements of ecological infrastructure, which enrich those agrocenoses. Due to high density and species diversity such greenery creates favourable environmental conditions for entomophages, including the parasitoids of the Ichneumonidae family. It provides them with food such as pollen or nectar, shelter and wintering place for imagines, and also constitutes a habitat for the development of alternative hosts for parasitoids (Carreck and Williams, 2002; Fitzgerald and Solomon, 2004). The significance of adjacent habitats, i.e. orchards and their edges, and their positive impact on the activity of entomophages, including parasitoids of the Ichneumonidae family, was presented in the studies by Dewenter *et al*. (2002), Piekarska-Boniecka and Suder-Byttner (2002), Miliczky and Horton (2005), Debras *et al*. (2006), Euler *et al*. (2006) and Dib *et al*. (2012). Ichneumonidae constitute an important biotic factor controlling the abundance of phytophages which feed in orchards (Viggiani, 2000; Trandafirescu *et al*., 2004; Mills, 2005; Wallis and Shaw, 2008; Piekarska-Boniecka *et al*., 2008b; Cole and Walker, 2011; Boniecki *et al.* 2015). More abundant subfamilies of the Ichneumonidae family in apple orchards of Poland include the Pimplinae subfamily (Piekarska-Boniecka and Suder-Byttner, 2002; Olszak, 2010; Bąkowski *et al*., 2013). The subfamily includes ecto- and endoparasitoids of the larvae and pupae of the Lepidoptera, Coleoptera, Diptera and Hymenoptera. Representatives of this subfamily effectively parasitize economically significant pests of orchards, particularly of Lepidoptera (Piekarska-Boniecka *et al*., 2008b; Piekarska-Boniecka and Trzciński, 2013; Boniecki *et al.*, 2015).

The aim of the study was to determine the impact of diversity level of apple orchard edge plants (agricultural areas, shrubberies and road edges overgrown with trees and shrubs) on the qualitative and quantitative structure of parasitoid communities of the Pimplinae communities in orchards. According to an assumed hypothesis the habitats in the vicinity of orchards influence the qualitative and quantitative structure of parasitoid communities of the orchards.

We attempted to establish the following:

Whether apple orchard edge plants influence the structure of parasitoid communities in the orchard,

Whether the orchard edge plants influence the qualitative or quantitative structure of the parasitoid communities in the orchard,

Which habitats adjacent to the orchards are the most attractive for parasitoids.

MATERIAL AND METHODS

Study area

The study was conducted in 2008-2010 in three orchards located in the vicinity of Czempiń in Wielkopolska (Western Poland). They were an orchard located in

Głuchowo and two orchards in Gorzyczki. The orchard in Głuchowo was located 15 km from the orchards in Gorzyczki, while orchards in Gorzyczki were away from each other from a distance of 1 km.

The study sites included:

1. Apple orchard, Głuchowo (UTM, XT18; 52.17466°N, 16.71173°E) of 40 ha surface area (A1 = Głuchowo-orchard). The studies were conducted on 3-hectare plots with 15-year-old apple trees of the following cultivars: Gala, Ligol, Cortland, Paulared, Red Delicious and Golden Delicious. The apple tree plot was surrounded with cultivated fields (A2 = Głuchowo-field), where sweet corn was grown in 2008, oats in 2009, and triticale in 2010.

2. Apple orchard I, Gorzyczki (UTM, XT27; 52.10106°N, 16.81199°E) 20 ha in area (B1 = Gorzyczki - orchard I), where studies covered 5-hectare plots with 15-year-old apple trees of: Paulared, Red Delicious, Golden Delicious and Jonagold cultivars. The apple tree plot was surrounded by shrubberies (B2 = Gorzyczki - shrubberies, 250x10 m), namely thicket phytocenoses of *Euonymo-Prunetum spinosae* and *Querco-Ulmetum* forest, herbaceous communities and ruderal plant communities. Tree communities were formed mainly by: *Ulmus laevis* Pall., *Quercus robur* L., *Fraxinus excelsior* L., *Acer platanoides* L., *Acer negundo* L. and single *Malus domestica* Borkh. with *Populus* ×*canadensis* Moench. Herbaceous plants were dominated by *Urtica dioica* L. and *Cirsium arvense* (L.) Scop. In the patches of ruderal shrubberies the following were recorded: *Sambucus nigra* L., *Crataegus monogyna* Jacq., *Lycium barbarum* L., *Rosa canina* L. and *Corylus avellana* L.. In shrubberies 18 plant species were found.

3. Apple orchard II, Gorzyczki (UTM, XT27; 52.10208°N, 16.81451°E) 10 ha in area (C1 = Gorzyczki - orchard II). The studies were conducted on 2-hectar plots with 20-year-old Golden Delicious apple trees. The orchard borders on a road (C2 = Gorzyczki - road, 200x10 m) overgrown with plants typical of *Rhamno-Prunetea* class. The road was lined with *Juglans regia* L., *Acer negundo* L., *A. platanoides* L.), *A. pseudoplatanus* L. and *Quercus robuxr* L., with some *Rosa canina* L., *Crataegus*×*media* Bechst., *Corylus avellana* L. and *Symphoricarpos albus* Duhamel. Herbaceous plants were dominated by grass, *Urtica dioica* L., *Artemisia absinthium* L., *Achillea millefolium* L. and *Galium aparine* L.. On the road 39 plant species were found; this edge was the richest in plants of all the edges in the study area.

In all the studied orchards apple trees grew 1.4 m from each other in rows set 3 m apart. Between the trees fallow land was maintained and the rows of trees were divided by sward.

Study methods

The study used a commonly used method of trapping Ichneumonidae imagines in the yellow Moericke traps [Moericke 1953]. The trap was made from a yellow plastic pan filled with water and glycol (preservative) and liquid lowering surface pressure, 18 cm in diameter and 11 cm deep. 20 pans were laid out on each site, 1-1.5 m above the ground. The traps were situated 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 each other. 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.

Imagines of *Pimplinae* were identified based of the key by Kasparyan (Kasparyan,1981).

Statistical analysis

Biocoenotic characteristics of the Pimplinae recorded at individual check points was based on the following indicators: general species diversity by Shannon and Weaver (H') (Shannon and Weaver, 1963; Spellerberg and Fedor, 2003), Pielou species evenness (J') (Pielou, 1966), and Simpson's species diversity index (d) (Simpson, 1949). Therefore we used ACE (Chao *et al.*, 2000), i.e. abundance-based coverage estimator, which is based on estimating sample coverage, i.e. the proportion of assemblage richness represented by the species in a single abundance sample. Next, to extrapolate species richness, we calculated Chao1 (Chao, 1987) and Jack1 (Heltshe and Forrester, 1983) robust, non-parametric estimators, which do not assume a particular form of the species abundance distribution. Pimplinae groups were compared in qualitative categories with Sørensen index (So) (Sørensen, 1957; Wolda, 1981), in quantitative categories with Renkonen index (Re) (Wolda, 1981). Next, we drew the rarefaction curve of species richness of Pimplinae communities that is a plot of the number of species as a function of the number of individuals. In addition, their similarity was studied with a cluster analysis based on Bray-Curtis index, and the results were presented on the dendrogram (Everitt, 1974; Mardia *et al.*, 1979).

We used an unconstrained ordination methods: detrended correspondence analysis (DCA) for habitats position diagnostics and redundancy analysis (RDA) for analysis relation species with habitats (Ter Braak, 1986; Legendre and Legendre, 2012).

Statistical calculations were performed with R software, version 3.2.1 (R Core Team, 2016).

RESULTS

In the years 2008-2010 the total of 3644 samples were collected in the orchard environment in Czempiń vicinity, out of which 1818 in the orchards and 1826 on their edges (Table 1). The total of 47 Pimplinae species was found, which constituted 34.1% of native fauna of this subfamily (Bogdanowicz *et al.*, 2007). The orchards hosted 41 species, the edges 43 species. The total of 1639 Pimplinae specimens were caught, with 977 individuals in the orchards and fewer, i.e. 662 ones, on the edges.

In orchard environments B1-B2 and C1-C2, where the orchards bordered on edges with well-developed plants, i.e. shrubberies and a road lined with trees and shrubs, more parasitoid species of the Pimplinae subfamily were found than in orchard environments A1-A2, in which the orchard was adjacent to agricultural areas (Table 1; Fig.1). As for environments B1-B2 and C1-C2, 39 species were caught in each, while environment A1-A2 yielded 33 species. A higher species diversity in habitats with abundant plant life on edges corroborated the values of Shannon (H') and Simpson (d) indices.

More Pimplinae individuals were caught in orchard environments with well-developed plants on edge (B1-B2, C1-C2) than in the orchard environment made up by an orchard and agricultural areas (A1-A2) (Table 1; Fig. 1). The highest abundance of parasitoids was found in the environment where the orchard was adjacent to the road (C1-C2), while the lowest (361 individuals) in the orchard adjacent to agricultural areas. In orchard environment B1-B2, where the orchard bordered on shrubberies, the distribution of species abundance was the most even of all the orchard environments. Pielou index (J') reached its peak value for this community, namely 0.7. The Pimplinae communities of the other environments obtained lower values of J' index.

Table 1. Biocoenotic indices of Pimplinae communities in the orchard environment near Czempiń in 2008-2010.

Habitat	Number of samples (n)	Number of specimens (N)	Number of species (S)	Shannon index (H')	Pielou index (J')	Simpson index (d)
Głuchowo - orchard (A1)	607	268	33	1.98	0.57	5.72
Głuchowo - field (A2)	597	93	14	1.26	0.48	2.87
Total	1204	361	35	1.88	0.53	5.74
Gorzyczki - orchard I (B1)	613	255	28	2.17	0.65	4.87
Gorzyczki - shrubberies (B2)	616	271	30	2.67	0.78	5.18
Total	1229	526	39	2.56	0.70	6.07
Gorzyczki - orchard II (C1)	598	454	29	1.79	0.53	4.58
Gorzyczki - road (C2)	613	298	35	2.54	0.72	5.97
Total	1211	752	39	2.18	0.60	5.77
The orchard environment	3644	1639	47			

In apple orchard A1, adjacent to agricultural areas, the highest species richness of the Pimplinae of all the orchards was found. The total of 33 species was caught there, while in the remaining orchards the numbers reached 28 (B1) and 29 (C1)(Table 1; Fig. 2). Such species diversity was confirmed by the values of d index. The value of H' index reached its peak for the community inhabiting orchard B1.

Orchard C1, which bordered on the road lined with trees and shrubs, yielded the highest abundance of Pimplinae, i.e. 454 individuals, in comparison with other orchards and all the edges (Table 1; Fig. 2). A lower and at the same time similar abundance of entomophages was established for orchards A1 and B1, regardless of how developed plant communities were in their vicinity. Orchard A1 yielded 268 individuals, while orchard B1 - 255 individuals. Orchard B1, bordering on shrubberies, showed the most even distribution of species abundance. J' index reached the highest value for this community, namely 0.65, while in the other orchards it assumed lower and at the same time similar values.

The highest species diversity of the Pimplinae was found on the orchard edge which was a road lined with trees and shrubs (C2), i.e. 35 species in comparison with other edges and orchards (Table 1; Fig. 2). It was over twice as high as the ones reported for agricultural areas (A2), from which only 14 species of these entomophages were reported. In shrubberies (B2) there were slightly fewer species (30) than on the road. Such species diversity of communities in these habitats was confirmed by the values of H' and d indices.

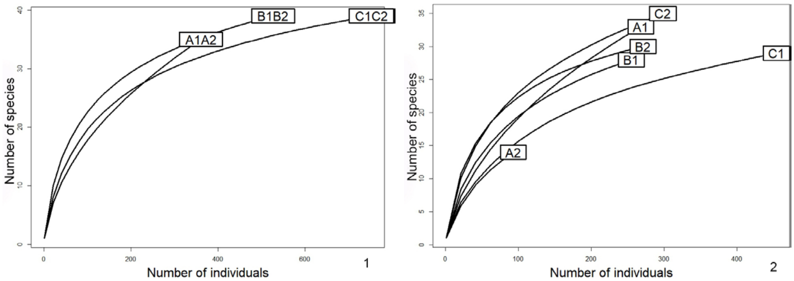

Fig. 1-2. Expected species accumulation curves of species richness of Pimplinae communities in the orchard environment near Czempiń 1. (A1, A2 habitats in Głuchowo; B1, B2 habitats I in Gorzyczki; C1, C2 habitats II in Gorzyczki). 2. in 2008-2010 (A1 Głuchowo, orchard; A2 Głuchowo, field; B1 Gorzyczki, orchard I; B2 Gorzyczki, shrubberies; C1 Gorzyczki, orchard II; C2 Gorzyczki, road)

A similar abundance of entomophages as on other edges was found in shrubberies (B2) and on the road with trees and shrubs (C2) (Table 1; Fig. 2). These habitats yielded 271 and 298 individuals, the abundances over three times as high as those in agricultural areas (A1), where only 93 individuals were caught. The most even distribution of species was reported for the shrubberies and on the road, as J' index for those communities assumed the highest values, i.e. 0.78 and 0.72. In agricultural areas the species abundance distribution was the least even and J' index was the lowest.

An analysis of the qualitative and quantitative structure of the Pimplinae communities in particular habitats of orchard environment led to the following conclusions:

The highest species diversity of entomophages was on the orchard edge which was a road lined with trees and shrubs (C2), and the lowest in agricultural areas (A2),

The highest abundance of entomophages was reported for orchard C1 neighbouring on the road and the lowest for agricultural areas (A2),

The most even distribution of species abundance was found in shrubberies (B2), and the least even in agricultural areas (A2).

A species diversity of the Pimplinae communities caught in particular habitats and together in the apple orchards and on their edges was analysed with ACE, Chao1 and Jack1 estimators (Table 2). For most parasitoid communities the species diversity indicated by estimators was higher than the one found during studies. It was established that the estimator ACE evaluated a species diversity the closest to the diversity found in most habitats and the total found in the orchards with well-developed plant life on edges. The estimator indicated only from 2 to 4 Pimplinae species more in communities than the number found during studies. ACE estimator evaluated a definitely higher species diversity than the result obtained during studies only for orchard A1 and the orchard and the edge A1-A2 together.

The dominance structure of the Pimplinae communities caught in all the orchard habitats was the following (Table 3):

One eudominant was reported from all the apple orchards and their edges (A1-C2), namely *Itoplectis maculator* with the share of 18.2-72.4.%, All the apple orchards (A1, B1, C1) yielded only one eudominant, namely *Liotryphon crassiseta* with the share 21.57-35.03%,

Edges with well-developed plant life (B2, C2) had one eudominant, also *Liotryphon crassiseta* with the share 12.18-31.54%,

One dominant was found in the orchards with well-developed plant communities on the edge (B1, C2), namely *Endromopoda detrita* with share 5.11-5.51%,

The dominants in the apple orchard bordering on shrubberies (B1) included *Endromopoda detrita* (5.11%) and *Itoplectis alternans* (5.89%),

In agricultural areas (A2) another dominant was *Itoplectis alternans* (5.37%),

The dominants in shrubberies (B2) were *Pimpla rufipes* (6.26%) and *Pimpla contemplator* (5.16%).

Other Pimplinae species were found to be less abundant in particular habitats; they also belonged mainly to recedents and subrecedents.

Table 2. Species numbers per study region showing numbers of species. The estimated numbers of species (ACE, Chao1 and Jack1) were calculated based on the number of species in the orchard environment near Czempiń.

Habitat	Number of species (S)	ACE	Chao1	Jack1
Głuchowo - orchard (A1)	33	43	57	50
Głuchowo - field (A2)	14	19	26	21
Gorzyczki - orchard I (B1)	28	32	35	37
Gorzyczki - shrubberies (B2)	30	32	36	37
Gorzyczki - orchard II (C1)	29	33	54	39
Gorzyczki - road (C2)	35	40	63	48
Głuchowo - (A1, A2)	35	45	67	53
Gorzyczki - (B1, B2)	39	42	49	49
Gorzyczki - (C1, C2)	39	41	46	48

The species of the *Itoplectis* genus are polyphagous endoparasitoids of pupae. The species of the *Pimpla* genus are mainly endoparasitoids of Lepidoptera, however, they can parasitize also Hymenoptera and Coleoptera pupae. *Liotryphon* species are ectoparasitoids of Lepidoptera and Coleoptera larvae. The species *Endromopoda detrita* is an ectoparasitoid of Lepidoptera, Coleoptera, Hymenoptera and Diptera larvae.

Out of 47 Pimplinae species (Table 3) reported from all the orchard environments 32 species (68.1%) can control the abundance of pests infesting orchards. They constitute the most numerous trophic group of parasitoids, which includes the species of the following genera: *Apechthis, Dolichomitus, Itoplectis, Liotryphon, Pimpla* and *Scambus* as well as the species *Acropimpla pictipes, Delomerista mandibularis, Endromopoda detrita, Ephialtes manifestator, Gregopimpla inquisitor, Iseropus stercorator* and *Theronia atalantae.* Another abundant trophic group is made up by 13 species (27.5%) which parasitize the representatives of Arachnida and belong to the genera *Clistopyga, Polysphinca,Tromatobia, Zaglyptus* and *Zatypota* and the species *Acrodactyla degener* and *Sinarachna nigricornis.* The third trophic group comprises parasitoids of Aculeata, namely 2 species (4.4%) of the *Perithous* genus.

Table 3. The list of species, the number of specimens (N) and the dominance index (D) of Pimplinae communities in the orchard environment near Czempiń in 2008-2010.

Species		Habitats											
	Głuchowo				Gorzyczki I				Gorzyczki II				
	Orchard (A1)		Field (A2)		Orchard (B1)		Shrubberies (B2)		Orchard (C1)		Road (C2)		
	N	D	N	D	N	D	N	D	N	D	N	D	
S1	*Acrodactyla degener* (Haliday, 1838)	2	0.75%			1	0.39%			5	1.10%	2	0.67%
S2	*Acropimpla pictipes* (Gravenhorst, 1829)	1	0.37 %					3	1.11%			3	1.01%
S3	*Apechthis compunctor* (Linnaeus, 1758)	2	0.75%	1	1.08%	4	1.57%	9	3.31%	3	0.66%	5	1.68%
S4	*Apechthis quadridentata* (Thomson, 1877)	1	0.37%					1	0.37%				
S5	*Apechthis rufata* (Gmelin, 1790)	1	0.37%			1	0.39%	1	0.37%	1	0.22%	1	0.34%
S6	*Clistopyga incitator* (Fabricius, 1793)	1	0.37%	1	1.08%			2	0.74%	1	0.22%	4	1.33%
S7	*Clistopyga rufator* Holmgren, 1856	1	0.37%					1	0.37%			1	0.34%
S8	*Clistopyga sauberi* Brauns, 1898											1	0.34%
S9	*Delomerista mandibularis* (Gravenhorst, 1829)											1	0.34%
S10	*Dolichomitus mesocentrus* (Gravenhorst, 1829)							1	0.37%	1	0.22%	1	0.34%
S11	*Dolichomitus populneus* (Ratzeburg, 1848)	1	0.37%										
S12	*Dolichomitus* sp.									1	0.22%	1	0.34%
S13	*Endromopoda detrita* (Holmgren, 1860)	4	1.50%	3	3.22%	13	5.11%	21	7.75%	25	5.51%	10	3.36%
S14	*Ephialtes manifestator* (Linnaeus, 1758)	2	0.75%			1	0.39%			1	0.22%	1	0.34%
S15	*Gregopimpla inquisitor* (Scopoli, 1763)	1	0.37%			6	2.35%	7	2.58%	4	0.88%	4	1.33%
S16	*Iseropus stercorator* (Fabricius, 1793)									1	0.22%		
S17	*Itoplectis alternans* (Gravenhorst, 1829)	12	4.48%	5	5.37%	15	5.89%	9	3.31%	7	1.54%	13	4.36%
S18	*Itoplectis maculator* (Fabricius, 1775)	117	43.66%	67	72.04%	102	40.00%	66	24.35%	181	39.88%	54	18.12%
S19	*Liotryphon crassiseta* (Thomson, 1877)	71	26.50%	3	3.22%	55	21.57%	33	12.18%	159	35.03%	94	31.54%
S20	*Liotryphon punctulatus* (Ratzeburg, 1848)	1	0.37%			8	3.15%			6	1.32%	2	0.67%
S21	*Perithous divinator* (Rossi, 1790)	1	0.37%			1	0.39%	2	0.74%			1	0.34%
S22	*Perithous scurra* (Panzer, 1804)							2	0.74%				
S23	*Pimpla contemplator* (Mueller, 1776)	2	0.75%	1	1.08%	2	0.78%	14	5.16%	6	1.32%	8	2.68%
S24	*Pimpla flavicoxis* Thomson, 1877							7	2.58%			8	2.68%
S25	*Pimpla insignatoria* (Gravenhorst, 1807)					1	0.39%					1	0.34%
S26	*Pimpla melanacrias* Perkins, 1941					1	0.39%	4	1.48%	4	0.88%	6	2.01%
S27	*Pimpla rufipes* (Miller, 1759)	4	1.50%			10	3.93%	17	6.26%	12	2.64%	12	4.03%
S28	*Pimpla spuria* Gravenhorst, 1829	10	3.72%	4	4.29%	5	1.96%	5	1.85%	10	2.20%	23	7,72%
S29	*Pimpla turionellae* (Linnaeus, 1758)	9	3.35%	1	1.08%	5	1.96%	1	0.37%	3	0.66%	3	1.01%
S30	*Polysphincta boops* Tschek, 1869	1	0.37%			1	0.39%			3	0.66%	1	0.34%
S31	*Polysphincta tuberosa* Gravenhorst, 1829	1	0.37%			3	1.18%						
S32	*Scambus brevicornis* (Gravenhorst, 1829)	4	1.50%	2	2.15%	1	0.39%						
S33	*Scambus calobatus* (Gravenhorst, 1829)	4	1.50%	2	2.15%	2	0.78%			2	0.44%		
S34	*Scambus inanis* (Schrank, 1802)					4	1.57%	3	1.11%				
S35	*Scambus nigricans* (Thomson, 1877)	2	0.75%					8	2.95%	2	0.44%	7	2.34%
S36	*Scambus planatus* (Hartig, 1838)	4	1.50%	1	1.08%	1	0.39%					1	0.34%
S37	*Scambus pomorum* (Ratzeburg, 1848)	2	0.75%			2	0.78%	1	0.37%	1	0.22%	4	1.33%
S38	*Scambus vesicarius* (Ratzeburg, 1844)			1	1.08%			1	0.37%				

Table 3. Continued.

Species		Habitats											
	Głuchowo				Gorzyczki I				Gorzyczki II				
	Orchard (A1)		Field (A2)		Orchard (B1)		Shrubberies (B2)		Orchard (C1)		Road (C2)		
	N	D	N	D	N	D	N	D	N	D	N	D	
S39	*Sinarachna nigricornis* (Holmgren, 1860)	1	0.37%										
S40	*Theronia atalantae* (Poda, 1761)	1	0.37%					2	0.74%			3	1.01%
S41	*Tromatobia lineatoria* (Villers, 1789)	1	0.37%			2	0.78%	5	1.85%	3	0.66%		
S42	*Tromatobia ovivora* (Boheman, 1821)	1	0.37%			4	1.57%	3	1.11%	1	0.22%	1	0.34%
S43	*Tromatobia variabilis* (Holmgren, 1856)			1	1.08%					1	0.22%		
S44	*Zaglyptus multicolor* (Gravenhorst, 1829)	1	0.37%			2	0.78%	35	12.92%	1	0.22%	14	4.70%
S45	*Zaglyptus varipes* (Gravenhorst, 1829)					2	0.78%	3	1.11%	4	0.88%	2	0.67%
S46	*Zatypota discolor* (Holmgren, 1860)											1	0.34%
S47	*Zatypota percontatoria* (Mueller, 1776)	1	0.37%					4	1.48%	5	1.10%	4	1.33%
Total number of specimens		268	100%	93	100%	255	100%	271	100%	454	100%	298	100%
	361				526				752				
Total number of species		33		14		28		30		29		35	
	35				39				39				

A quality similarity of the Pimplinae communities in particular habitats of the orchard environment was analysed with Sørensen (So) index (Table 4). Most communities yielded a high quality similarity, as So index reached high values from 0.71 to 0.79. Those communities inhabited all the apple orchards (A1, B1, C1) and edges with well-developed greenery (B2, C2) except the communities in orchard C1, Gorzyczki and shrubberies (B2), which showed slightly lower quality similarity (So=0.66). A lower similarity was found between entomophages communities in agricultural areas (A2) and other habitats (A1, B1, B2, C1, C2), for which So index was from 0.41 to 0.52. Analysing the quality similarity of Pimplinae communities in particular orchards and on their edges it was found that the highest similarity was between the comm-nities in the orchards and on the road lined with trees and shrubberies (C1-C2).

Table 4. Sørensen and Renkonen similarity of Pimplinae communities in the orchard environment near Czempiń in 2008-2010 (A1 Głuchowo, orchard; A2 Głuchowo, field; B1 Gorzyczki, orchard I; B2 Gorzyczki, shrubberies; C1 Gorzyczki, orchard II; C2 Gorzyczki, road).

Habitat A1		Sørensen index (So)					
		A2	B1	B2	C1	C2	
Renkonen index (Re)	A1		0.51	0.79	0.73	0.74	0.76
	A2	0.64		0.52	0.45	0.51	0.41
	B1	0.81	0.58		0.66	0.77	0.73
	B2	0.52	0.40	0.62		0.71	0.77
	C1	0.80	0.53	0.81	0.57		0.78
	C2	0.65	0.38	0.64	0.67	0.69	

A qualitative similarity of the Pimplinae communities in particular habitats of orchard environment was analysed with Renkonen index (Re) (Table 4). It took slightly different values than qualitative structure similarity of the communities. Only the communities of entomophages inhabiting apple orchards (A1, B1, C1) showed a high similarity of qualitative structures and their Re index took high values, i.e. 0.81, 0.8 and 0.81. A low quantitative similarity was found between the communities of agricultural areas (A2) and the communities inhabiting the edges with well-developed plant life (B2, C2), with Re index taking the lowest values, namely 0.38 and 0.40. The average qualitative similarity was reported for the entomophage communities in the other compared habitats, where Re index was between 0.52 and 0.67.

After an analysis of quantitative similarity of the Pimplinae communities in particular orchards and on their edges it was found that the highest similarity was between the communities in the orchard and on the road with trees and shrubs (C1-C2).

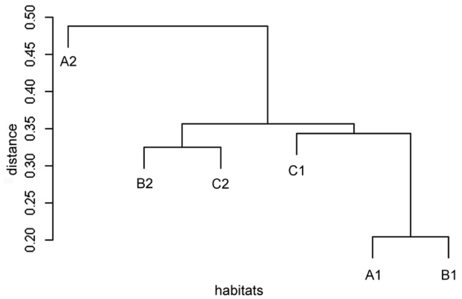

Fig. 3. Dendrogram of habitats with group single linking as the cluster method (A1 Głuchowo, orchard; A2 Głuchowo, field; B1 Gorzyczki, orchard I; B2 Gorzyczki, shrubberies; C1 Gorzyczki, orchard II; C2 Gorzyczki, road).

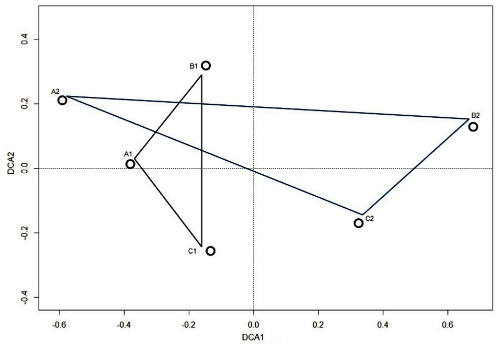

Fig. 4. Position of six locations along the first two axes of detrended correspondence analysis (DCA). (A1 Głuchowo, orchard; A2 Głuchowo, field; B1 Gorzyczki, orchard I; B2 Gorzyczki, shrubberies; C1 Gorzyczki, orchard II; C2 Gorzyczki, road).

A quantitative-qualitative structure of the Pimplinae communities in particular habitats of the orchard environment was analysed with a hierarchical grouping with the cluster method (Fig. 3), detrended correspondence analysis (Fig. 4) and redundancy analysis (Fig. 5). The entomophage communities of agricultural areas (A2) were proved to differ definitely in their qualitative and quantitative structures from the other

Pimplinae communities. Two entomophage groups were similar in terms of qualitative and quantitative structures, namely:

The communities of apple orchards A1 and B1 and orchard C1,

The communities of edges with well-developed plant life, i.e. B2 and C2.

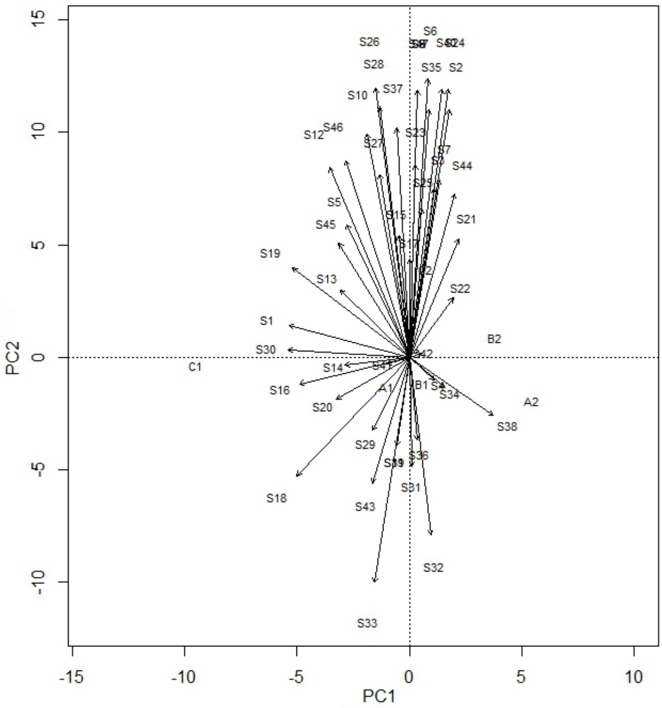

Fig. 5. Redundancy analysis (RDA) biplot showing distribution 47 species (S1, S2, ..., S47) in relation to the habitats (A1 Głuchowo, orchard; A2 Głuchowo, field; B1 Gorzyczki, orchard I; B2 Gorzyczki, shrubberies; C1 Gorzyczki, orchard II; C2 Gorzyczki, road).

DISCUSSION

The studies conducted in the years 2008-2010 in the vicinity of Czempiń clearly proved that in the orchard environment made up of an apple orchard and well-developed edge plant life, i.e. shrubberies and a road lined with trees and shrubs, a species diversity of parasitoids of the Pimplinae subfamily and their abundances were higher than those reported for the orchard environment made up of an orchard and the adjacent agricultural areas. The obtained results corroborated a positive impact of wild plant life growing in the vicinity of orchards on species diversity and increased abundance of entomophages of the Pimplinae subfamily in the orchard environment. Earlier studies by Euler *et al.* (2006) indicated that the more diverse the edge plant life was, the more parasitoids in that habitat occurred. Also Miliczky and Horton (2005) found that diversified species of wild plants around the orchard created a good habitat for useful entomofauna and positively influenced its occurrence in agrocenoses. A similar conclusion was drawn by Debras *et al.* (2006), who established that there is a positive effect of diversified hedge plant life growing in the vicinity of pear orchards on the entomophages which inhabit those orchards. Also Dib *et al.* (2012) found a positive influence of blooming plant belts in the vicinity of apple orchards onto the parasitoids which control the abundance of diapausing larvae of *Cydia pomonella* in the orchards. Sarvary *et al.* (2007) found that plant communities around an apple orchard caused an increase in the abundance and species diversity of entomophages which paratisized Torticidae in the orchard. Also Łabanowska-Bury *et al.* (2009), as well as Twardowski *et al.* (2009) established that blooming plants increase the abundance of entomophages in agricultural environment. Miquel *et al.* (1986) and Dewenter *et al.* (2002) found that adjacent environments form a consistent and open area with a constant interaction between plants and the inhabiting entomofauna. A similar conclusion was drawn by Dennis *et al.* (2000), Kruess and Tscharntke (2000) and Piekarska-Boniecka *et al.* (2015), who established that parasitoids migrate between adjacent habitats. The plants in these habitats may constitute a dispersion route for entomophages of the adjacent habitats.

Studies proved that the plants of an apple orchard constitute a more attractive habitat for the parasitoids of the Pimplinae subfamily than agricultural areas, as definitely more species and more individuals were caught in the orchard. This results from the fact that the orchard environment is definitely a better place for development of parasitoid hosts, the blooming plants in the orchard are a better source of food and shelter for parasitoid imagines than agricultural areas. This was corroborated in the studies by Colignon *et al.* 2002, which indicated that more entomophages inhabited the wood plant belt adjacent to agricultural areas than these areas.

According to study results the edges with well-developed plant life yielded a slightly higher species diversity of parasitoids of the Pimplinae subfamily than their adjacent apple orchards. A road lined with trees and shrubs was the most attractive habitat for entomophages, as it had the highest species richness. It probably results from the fact that numerous species of blooming trees and shrubs, i.e. maple trees, dogwood, hawthorn, rosehip, elder lured entomophages to that habitat. Dąbrowski *et al.* 2008 and Olszak *et al.* 2009 presented a list of plant species which favour the occurrence of useful entomophauna which included the following shrubs: *Crataegus monogyma, Sambucus nigra, Viburnum opulus, Caragana arborescens, Evonymus europea,* and trees: *Alnus* spp., *Carpinus betulus, Ulmus* spp., *Acer* spp. and *Fraxinus excelsior.* Olszak *et al.* 2009 found that among shrubs most abundantly inhabited by entomophages were *Crataegus* sp**.**, *Sambucus nigra* and *Viburnum* sp.. Blooming plants provide food for parasitoid imagines, as they supply pollen, honeydew and nectar (Carreck and Williams, 2002; Fitzgerald and Solomon, 2004; Lavandero *et al.*,2005; Wäckers *et al*., 2006; Badenes-Pérez and Márques, 2012; Dąbrowski *et al*., 2013).

Studies established that the abundance of parasitoids in the shrubberies bordering on the orchard was higher than in the orchard. It also proves that entomophages are attracted to this habitat by wild plants. Earlier studies by Piekarska-Boniecka and

Suder-Bytner (2002) also confirmed a higher abundance of Pimplinae in the shrubberies than in the apple orchard. The same conclusions were drawn by Debras *et al.* (2006).

The community of parasitoids inhabiting shrubberies were characterised by the most even distribution of species abundance.

Studies showed that higher numbers of parasitoids from the Pimplinae subfamily were caught in the apple orchard adjacent to the road than on its edge. This can be explained by the fact that more potential hosts of parasitoids fed in the orchard than on the road lined with trees and shrubs. *Synanthedon myopaeformis*, parasitised by *Liotryphon crassiseta* (Bąkowski *et al.* 2013), occurred massively in this orchard. This parasitoid obtained the highest share (35.03%) in the community of the orchard.

Study results proved a lower species diversity of the Pimplinae communities in particular habitats than those indicated by the estimators ACE, Chao1, Jack1. Previous studies by Sääksjärvi *et al.,* (2004) concerning the Pimplinae and Rhyssinae communities of the Amazon forests also proved that the species diversity evaluated by estimators was higher than the one established during studies. Also Veijalainen *et al.* (2012) found that the estimated species diversity of the Orthocentrinae communities in tropical forests was higher than the obtained one. This trend in establishing species diversity was corroborated in the studies of the Pimplinae in agrocenoses of central Wielkopolska conducted by Piekarska *et al.* (2015).

The studies established a definite dominance of the species *Itoplectis maculator* in all the apple orchards and on their edges and the species *Liotryphon crassiseta,*, except agricultural areas. Current studies confirmed the abundance of these species in the orchard environment, as they were more often proved as dominant in this environment by Kadłubowski and Piekarska (1984), Piekarska-Boniecka H. and Suder-Byttner (2002) and Kot (2007). Also Mills (2005) indicated a numerous share of parasitoids of the genus *Liotryphon* in parasitizing larvae of the *Cydia pomonella* in apple orchards. The parasitoids *Itoplectis maculator* and *Liotryphon crassiseta* control the abundance of economically significant pests of apple orchards, which include species of the genera *Archips, Cydia, Hedya, Tortrix, Pandemis, Adoxophyes, Malacosoma, Lymantria, Operophtera, Phyllonorycter, Yponomeuta, Synanthedon* (Lepidoptera) and *Anthonomus* (Coleoptera) (Yu *et al.,* 2012). The studies established that the most similar in their qualitative and quantitative structures were the communities inhabiting apple orchards and the communities occurring on the edges with well-developed plant life. This results from a similar structure of these biocenoses, i.e. plants and phytophages which feed there. However, then the qualitative and quantitative similarity of parasitoids in a given orchard and on its edge was analysed and the communities in the orchard and on the road with trees and bushes were found to be the most similar in terms of quality and quantity.

Study results clearly indicated that the edge of the apple orchard which was characterised by the highest species diversity of plants, i.e. the road with trees and shrubs, had the strongest influence on the qualitative and quantitative structure of parasitoid communities of the Pimplinae subfamily which occurred in the orchard. The influence concerned first of all the qualitative structure. The abundance of parasitoids in the orchard was mainly determined by two factors, namely: the abundance of hosts and blooming flowers of the habitat and the plants of orchard edge. The road with trees and shrubs constituted the most attractive habitat for those entomophages.

CONCLUSIONS

The occurrence of well-developed and diversified species of plants on the edges of apple orchards positively influences species richness and abundance of parasitoids of the subfamily Pimplinae occurring in the orchard environment. It leads to an increased abundance and higher species diversity of those insects, thus providing a natural regulatory mechanism of the abundance of phytophages feeding in the orchards by those entomophages. Rich plant life of orchard edges is an important element of an ecological structure, the fact which should be used in designing orchard environments.

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