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The influence of agricultural landscape structure on the flora and communities of parasitoids in statistical terms

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ABSTRACT. The agricultural landscape structure in relations between spatial units (forest edge, shrubberies, field borders and roadsides), its green cover and animal communities is studied. The share of parasitoid *Hymenoptera* of the *Pimplinae* subfamily in structural elements of agricultural landscape is presented. The relationships between species diversity and the abundance of *Pimplinae* communities and the complexity level of agricultural landscape are considered. For examining these dependences, multivariate statistical analysis, eg. principal component analysis is used.

INTRODUCTION

In the recent decades one of research problems undertaken by various scientific centres is the landscape structure considered in the aspect of natural determinants and anthropogenic transformations. Most frequently the studies cover ecomorphological variety and the diversity of green cover, while the relations between spatial units and animal communities are researched much less often.

The term of landscape has many definitions, as it is used by scientists of many fields. This study adopts the definition by FORMAN and GODRON (1986), highlighting that landscape is a heterogeneous land area composed of interacting ecosystems. Landscapes occur

repeatedly throughout an area in a similar form, and their most important features are: their structure, functioning and diversity. Their basic structural elements are vast, homogenous patches, criss-crossing corridors and small environmental islands.

Landscape is studied not only for the sake of knowledge itself, but also for practical reasons. In Europe the predominating landscape type is fields, therefore most studies deal with their structure (e.g. seminar materials edited by JONGMAN (1996), or many sessions within IALE). Traditional agriculture forms many various types of spatial units (RINGLER & HEINZELMANN 1986), and the intensification of production creates vast, monotonous, separated areas. A mosaic structure of agricultural landscape plays an important role in preserving not only natural elements of green cover, but also accompanying animal communities, which is vital for maintaining the habitat's buffer features and its sustainable development.

The study presents the share of parasitoid *Hymenoptera* of the *Pimplinae* (*Hymenoptera, Ichneumonidae*) subfamily in structural elements of agricultural landscape of various complexity. Those species are vital components of biocenotic and economic value, as they constitute some of the main biotic factors controlling the abundance of phytophages in biocenoses. Those are ecto- or endoparasitoids, parasitising the larvae and pupae of *Lepidoptera, Coleoptera, Hymenoptera* and *Diptera* species (PIEKARSKA-BONIECKA 2005).
The study was aimed at verifying the following hypotheses:
- whether the share of non-cultivated habitats (refugia for the flora and entomofauna) determines the structure of agricultural landscape,
- whether landscape's structural units defined on geobotanical basis are similar to one another,
- whether the existing differences (similarities) in the landscape structure are reflected in the animal world on the example of parasitoids of the *Ichneumonidae*,
- whether there is a similarity between the flora and parasitoid communities depending on the level of landscape structure heterogeneity.

MATERIAL AND METHODS

The study was conducted in the agricultural landscape of central Wielkopolska (Poland), a flat area in the basin of the Warta river. In physical geography terms it is Wielkopolska Lakeland, mesoregion: Poznań Lakeland (KONDRACKI 1994). The analysed areas are located in the vicinity of Łęczyca (UTM: XT29) and Trzebaw (UTM: XY29) villages, which in turn are situated in the grounds of the Wielkopolska National Park, as well as near Strzeszyn (UTM: XU21) located on the Poznań Plain, an urbanized part of a morainic plateau, in the suburbs of Poznań.

The basis for the study was identification and delimitation of the following spatial units that occur in every environment: forest edge, shrubberies, field borders and roadsides. The share of the above refugia in the landscape structure was presented on the basis of an analy-

sis of a 1 km^2 area. On each site, homogenous as to its potential fauna and management, a symphytosociological picture was taken in high vegetation season (TÜXEN 1973, SOLON 1983), then an inventory of phytocenons and vascular plants was made and their share in the area was defined.

The potential natural fauna was defined on the basis of the study by WOJTERSKI et al. (1981) and authors' own results. The systematics of plant communities in general terms was quoted according to WOJTERSKI et al. (1981). Phytocenons' reactions to anthropogenic influences followed the classification by FALIŃSKI (1969). While analysing the flora some of the basic criteria are the origin of plants and the level of their naturalization – geographical and historical classification and the spectrum of live forms by RAUNKIAER (1934). The classification into groups was adopted after JACKOWIAK (1990). The sociological classification was based on the studies by MATUSZKIEWICZ (2001) and RATYŃSKA (2003).

The faunistic description of parasitoid Hymenoptera of the *Pimplinae* (*Hymenoptera, Ichneumonidae*) subfamily was created in the years 1996-1998. The parasitoids were caught from May to October into yellow MOERICKE traps (MOERICKE 1953). 5 traps were laid out on each site, placed 0.5 to 1.5 m above the ground. The insects were taken out of traps at 10-day intervals. Individuals caught in one trap within 10 days were adopted as one sample (PIEKARSKA-BONIECKA 2005).

Multivariate results were statistically processed with a multidimensional method called the principal component analysis (PCA) (MARDIA et al. 1979). The calculations were made using the R package (R Development Core Team, 2005).

RESULTS

Landscape structure

In the analysed agricultural landscape types, i.e. the vicinity of Łęczyca, Strzeszyn and Trzebaw, the same structural units appeared repeatedly. However, their quantity relations were different, which results from the area's management and history. The simplest structure was found in the landscape near Trzebaw (non-cultivated habitats, i.e. shrubberies, forests and uncultivated land took up 3.3% of the area, while line elements, i.e. field borders and roadsides – 5.6 km), while the highest level of mosaic structure was reported from the area of Strzeszyn (33.4% and 4.5 km respectively). In the agricultural landscape of medium mosaic structure around Łęczyca the share of non-cultivated habitats was 7.6%, and line elements took up 7.9 km.

Flora and greenery

The total flora of the studied habitats included 190 species of vascular plants. The refugia of low and high-level mosaic structure landscape near Trzebaw and Strzeszyn were the richest in flora (Table 1). The richest flora was found on the roadside near Strzeszyn (82), while the fewest species were reported from the shrubberies around Łęczyca (31) and the forest edge in Strzeszyn (32). In all the sites domestic species were predominant (Table 2), while the share of non-synanthropic spontaneophites, related mainly to forest edges, was low. Among life forms hemicryptophytes were predominant. Terophytes were the most abundant on roadsides, and they reached the highest share in shrubberies around Łęczyca. In all the units the most abundant were *Artemisietea vulgaris* edificators, mostly ruderal species, *Stellarietea mediae* – mainly field taxa and shrubbery species with *Rhamno-Prunetea*. Typical forest species (*Querco-Fagetea*, *Vaccinio-Piceetea* and *Epilobietea angustifoliae*) occurred mainly on forest edges. Most of them were reported from the vicinity of Trzebaw, and the fewest from the Strzeszyn area. Field species occurred in all the units, most abundantly on roadsides. Sward termophile edge species were mainly concentrated on field borders.

Table 1. The number of plant species and plant communities of the studied habitats (Fe – forest edge, Sh – shrubberies, Fb – field border, Ro – roadside)

Nr of species and plant communities	Simple mosaic landscape Trzebaw				Middle mosaic landscape Łęczyca				High mosaic landscape Strzeszyn			
	Fe	Sh	Fb	Ro	Fe	Sh	Fb	Ro	Fe	Sh	Fb	Ro
Nr of species	42	48	50	61	44	31	45	53	32	76	51	82
Nr of species in landscape	121				103				124			
Nr of plant communities	5	13	5	15	9	10	9	10	6	10	7	12
Nr of plant communities in landscape	27				19				22			

The greenery of the studied areas included 41 communities in total. Most of them were reported from the area of Trzebaw, in the simplest, but the least transformed landscape in the vicinity of the National Park. The richest were roadsides and shrubberies (form 10 to 15 communities), while the poorest were forest edges and field borders. In all sites anthropogenic – ruderal communities prevailed.

Parasitoids

3,037 samples in total were collected in the refugia of agricultural landscape. 57 species of *Pimplinae* were found, which constitutes 42.8% of the national fauna of this subfamily and 75% species reported from Wielkopolska (Table 3). The highest species diversity was reported from the landscape of medium mosaic structure (50) around Łęczyca, while in other landscape types fewer species were found with the same species diversity reported (44 in each case).

Species diversity of parasitoids reported in particular habitats of agricultural landscape with medium (Łęczyca) and high (Strzeszyn) mosaic level was very similar. It fluctuated between 28 species on forest edge and 35 on field border and roadside in the landscape of medium mosaic structure and from 27 on the field border to 32 in shrubberies in the landscape of high mosaic structure. On the other hand, in the landscape of low mosaic structure (Trzebaw) clear species diversity was reported from the refugia. The number of species was between 18 on roadside to 33 in shrubberies.

The highest diversity was reported from the field border and roadside in the landscape of medium mosaic structure (Łęczyca), while the lowest was on the roadside in the landscape of simple structure (Trzebaw).

In the refugia of agricultural landscape the total of 4,387 *Pimplinae* species were caught (Table 3). The highest numbers were reported from the landscape of high (Strzeszyn) (1,599) and medium (Łęczyca) mosaic structure (1,493), while lower values occurred in the landscape of low (Trzebaw) mosaic structure (1,295). The abundances of parasitoids in the refugia of medium and high mosaic structure were similar (from 216 to 494), except for the forest edge in the landscape of medium mosaic structure, where a higher abundance was reported (677) in comparison with the other habitats. In the landscape of low mosaic structure clear fluctuations in parasitoid abundance were reported in particular refugia: the lowest abundance was found on roadside (83), while the highest it was on the forest edge (754) when compared with the other habitats in all the three types of landscape.

Comparisons

In statistical flora-based analyses the most similar turned out to be forest edges – the units of most natural character (Fig. 1). The habitats within every one of all three types of agricultural landscape were quite similar. The simple-structure and medium mosaic structure landscapes, both located in the vicinity of Wielkopolska National Park, were similar to each other.

Table 2. Chosen characteristics of the distinguished agricultural landscapes components (Fe – forest edge, Sh – shrubberies, Fb – field border, Ro – roadside).

Landscape component \ Type of landscape		Simple landscape Trzebaw				Middle mosaic landscape-Łęczyca				High mosaic landscape-Strzeszyn			
		Fe	Sh	Fb	Ro	Fe	Sh	Fb	Ro	Fe	Sh	Fb	Ro
Vegetation syngenesis	Natural communities	4	4	1	5	4	4	3	4	4	4	1	3
		40,0	30,8	20,0	33,3	44,6	40,0	33,3	40,0	66,6	40,0	14,3	25,0
	Seminatural communities	1	3		3	3	1	1	1	1	2		
		10,0	23,1		20,0	33,5	10,0	11,1	10,0	16,7	20,0		
	Xenospontanic communities				1							1	2
					6,7							14,3	16,7
	Segetal communities				1			1					
					6,7			11,1					
	Ruderal communities	1	6	4	5	2	5	4	5	1	4	5	7
		40,0	46,2	80,0	33,3	22,2	50,0	44,5	50,0	16,7	40,0	71,4	58,3
Geographical-historical groups of plants	Nonsynanthropic spontaneophytes	6	3	1	4	5			2	2	3		1
		14,3	6,2	2,0	6,5	11,4			3,8	6,2	3,9		1,2
	Apophytes	29	41	34	45	34	24	39	38	24	54	44	55
		69,1	85,5	68,0	73,8	77,3	77,4	86,7	71,7	75,0	71,1	86,2	67,1
	Archeophytes	3	3	9	9	2	4	5	9	4	11	6	17
		7,1	6,2	18,0	14,8	4,5	12,9	11,1	17,0	12,5	14,5	11,8	25,8
	Kenophytes	4	1	3	3	3	2	1	4	2	5	1	9
		9,5	2,1	6,0	4,9	6,8	6,5	2,2	7,5	6,2	6,6	2,0	10,9
	Diaphytes			3			1				3		
				6,0			3,2				3,9		
Life forms of plants	Megafanerophytes	10	6	7	7	9	3	2	9	3	7	3	10
		23,8	12,5	14,0	11,5	23,9	9,7	4,4	17,0	9,4	9,2	5,9	12,2
	Nanofanerophytes	6	8	3	6	8	4	5	5	3	6	2	3
		14,3	16,7	6,0	9,8	14,4	12,9	11,1	9,4	9,4	7,9	3,9	3,6
	Chamephytes	3	5	6	3	4	3	5	4	1	7	6	6
		7,2	10,4	12,0	4,9	9,2	9,7	11,1	6,6	3,1	9,2	11,7	7,3
	Hemikryptophytes	13	16	19	25	13	10	21	17	16	32	28	35
		30,9	33,3	38,0	41,0	29,5	32,2	46,7	32,1	50,0	42,1	54,9	42,7
	Geophytes	4	7	6	6	5	2	3	5	4	7	5	9
		9,5	14,6	12,0	9,8	11,5	6,5	6,7	9,4	12,5	9,2	9,9	11,0
	Therophytes	6	6	9	14	5	9	9	13	5	17	7	19
		14,3	12,5	18,0	23,0	11,5	29,0	20,0	24,5	15,6	22,4	13,7	23,2

Table 3. Quality-quantity structure of *Pimplinae* communities caught in refugium habitats in the three types of agricultural landscape in 1996-98.

Landscape type	Environment	Number of samples (*n*)	Number of species (*S*)	Number of specimens (*N*)
Simple landscape Trzebaw	Shrubberies	240	33	357
	Field border	240	22	101
	Roadside	246	18	83
	Forest edge	255	28	754
	Total	981	44	1295
Meddle mosaic landscape Łęczyca	Shrubberies	252	32	266
	Field border	251	35	334
	Roadside	250	35	216
	Forest edge	254	28	677
	Total	1007	50	1493
High mosaic land-scape Strzeszyn	Shrubberies	263	32	470
	Field border	263	27	494
	Roadside	259	31	377
	Forest edge	264	30	258
	Total	1049	44	1599
Total		3037	4387	57

Within the simple-structure landscape the forest edge and the roadside proved to be the most similar. In the landscape of medium mosaic structure the roadside and shrubberies were the closest, while in the most heterogeneous landscape (Strzeszyn) a similarity was found between the roadside and shrubberies and between the shrubberies and field borders. While defining the similarity of *Pimplinae* communities in quality and quantity terms with the PCA method it was found that the communities on the forest edge in the landscape of low (Trzebaw) and medium (Łęczyca) mosaic structure differed from the others and at the same time they constituted one similarity group (Fig. 2).

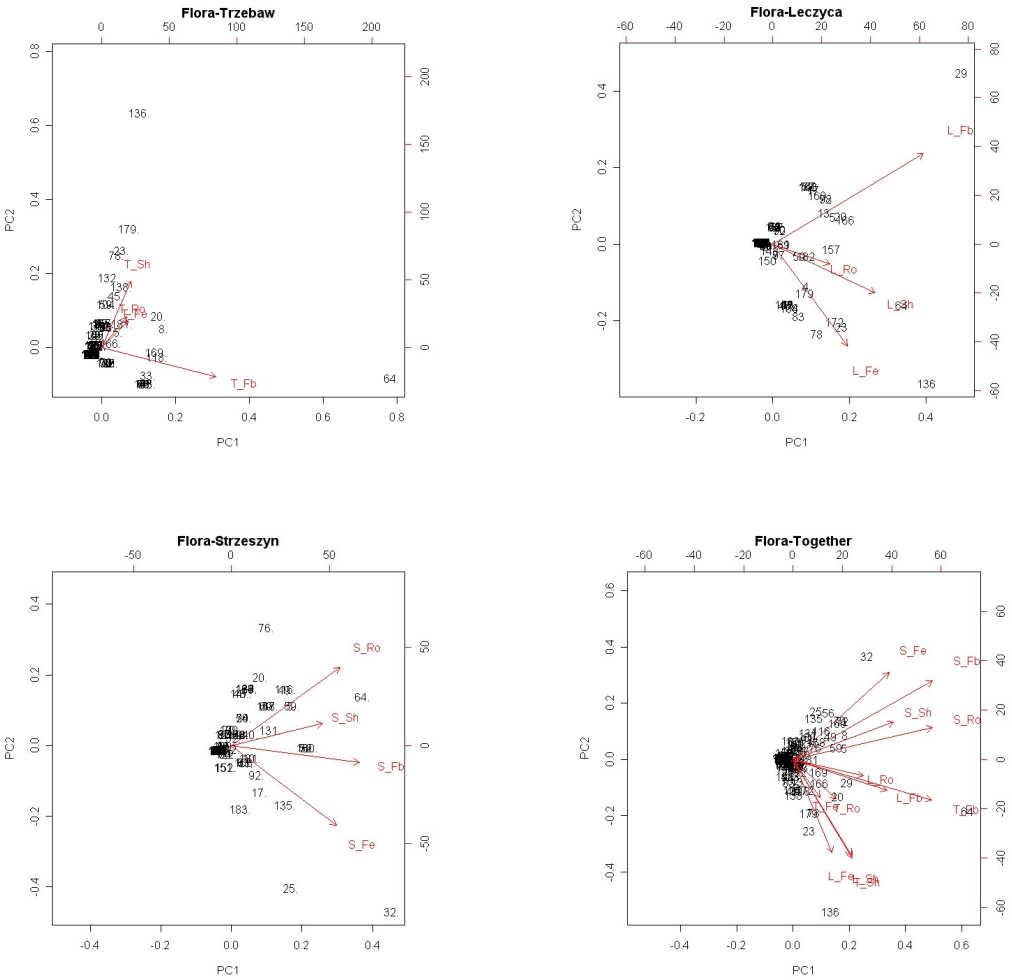

Fig.1. The principal component analysis for flora (T – Trzebaw, L – Łęczyca, S – Strzeszyn in four habitats: Fe – forest edge, Sh – shrubberies, Fb – field border, Ro – roadside).

After analysing the similarity of communities in particular refugia in particular landscape types it was found that parasitoid communities that proved to be similar occurred on field borders, roadsides and in shrubberies, while they were not found on forest edge. In the landscape of low mosaic structure (Trzebaw) the communities on the field border and roadside were similar, while those in the shrubberies and on forest edge were definitely different from the others. In the landscape of medium mosaic structure (Łęczyca) the communities

on the field border and in shrubberies were similar, while those on the forest edge were clearly different from the others. In the landscape of high mosaic structure (Strzeszyn) the communities on the roadside and in shrubberies were similar, while on the roadside and forest edge they were different.

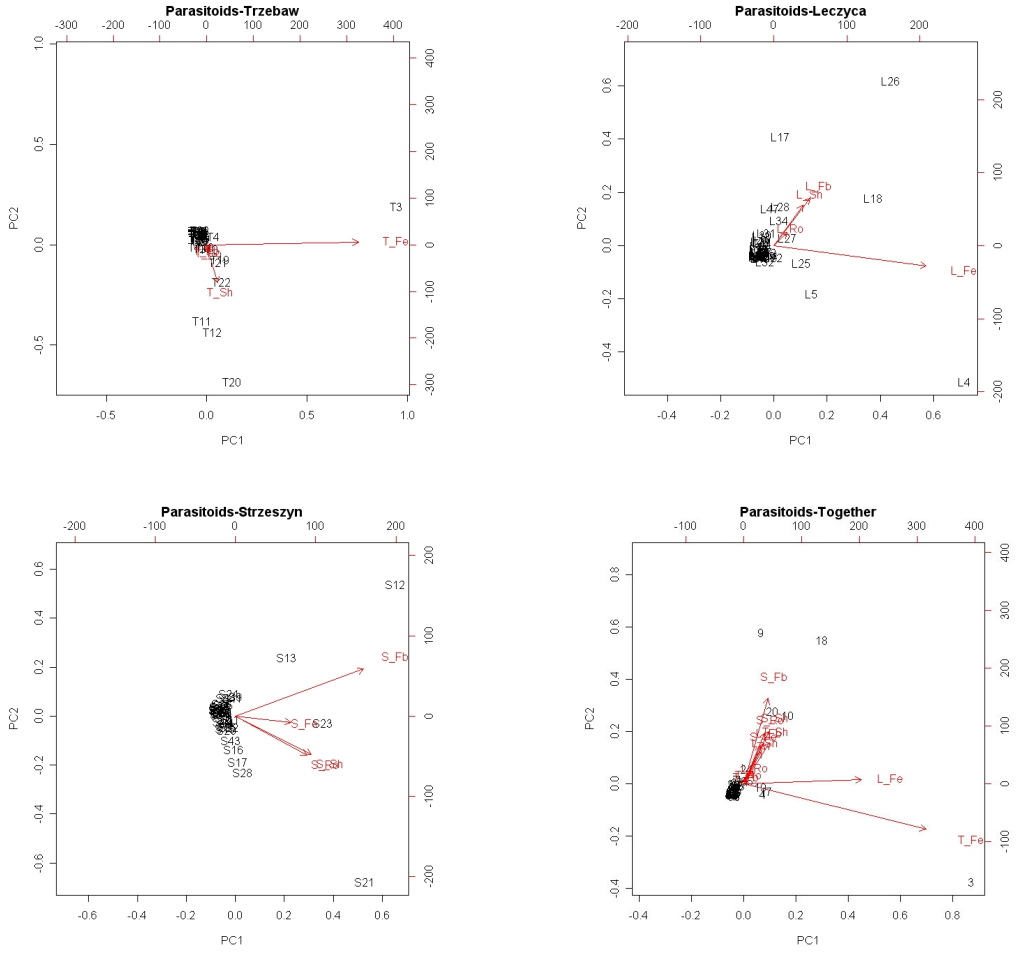

Fig. 2. The principal component analysis for parasitoids (T – Trzebaw, L – Łęczyca, S – Strzeszyn in four habitats: Fe – forest edge, Sh – shrubberies, Fb – field border, Ro – roadside).

When comparing simultaneously the similarity of flora and parasitoid communities in the refugia of particular landscape types it was found that habitats with similar flora and

entomofauna occurred only in the landscape of high mosaic structure (Strzeszyn), Those included the roadside and shrubberies.

DISCUSSION

The structure of the analysed agricultural landscape was similar, the differences occurred on the level of spatial units' share in the area and their level of transformation. The landscape types were defined as simple structure or medium and high mosaic structure. The criteria adopted in the study comply with the opinions expressed by FORMAN and GORDON (1986), according to whom the structure of agricultural landscape is made up by three groups of elements, such as matrices, patches and corridors, and their spatial layout defines the so-called patchiness of the landscape. According to PIETRZAK (1998) the share of patches and corridors in agricultural landscape determines its diversity and mosaic structure. Although the refugia of the agricultural landscape in question were of anthropogenic origin, as is the case in other regions of Europe (AGGER & BRANDT 1984, 1988), their biocenotic significance in the dominant agrocenoces is very high. Landscape structural units defined on the basis of geobotanic showed similarity, but statistical analyses proved higher similarity between particular types of agricultural landscape (Fig. 1).

The flora of the analysed areas was quite poor, which results from the potential of the habitats and homogenous forms of cultivation. Both in terms of flora and greenery the richest units were usually those most influenced by medium-scale anthropopressure: roadsides and shrubberies (eg, RATYŃSKA 2003). The richest flora was reported from the landscape of the highest mosaic structure. This results on the one hand from a significant share of refugia in the area and on the other from the volume of anthropopressure in the suburban zone of greater Poznań – secondary eutrophisizing of roadsides and shrubberies with garbage. At the same time, due to its young age and strong human penetration, apart from roadsides (trees and bushes) no typical forest species were found in the area and after statistical analyses this type of landscape proved to stand out most strongly (Fig. 1). The most natural character expressed in the share of non-synanthropic spontaneophites and the domination (both in terms of the area taken and the number of communities) of natural greenery could be seen on forest edges, next came shrubberies (Table 1). This was corroborated particularly in respect to forest edges by the results concerning the similarity of *Pimplinae* communities reported there (Fig. 2). Field borders and roadsides had the most changed green cover.

The study confirmed a positive influence of the variety of agricultural landscape structure on its entomofauna's species diversity on the example of *Pimplinae*. Those are relationships reported previously by many authors conducting research on parasitic and predatory entomofauna in refugia of agricultural landscape (KARG & SZEFLIŃSKA 1996, BILEWICZ-PAWIŃSKA 1987a, 1987b, BILEWICZ-PAWIŃSKA et al. 1987c, BARCZAK et al. 2000, 2002). The highest species diversity of the *Pimplinae* was reported from the field border

and roadside in the landscape with medium share of non-cultivated land. The significance of field borders and roadsides as habitats for entomophages was presented by GRABARKIEWICZ and TROJANOWSKI (1998). A positive relationship between spontaneic greenery of field edges and parasitoids of the *Hymenoptera* and *Diptera* genera was presented by EMDEN (1963), POWELL (1986), JERVIS et al. (1993), LEIUS (1967), FOSTER & RUESINK (1984), LANDRIS & HAAS (1992), IDRIS & GRAFIUS (1995) and DYER & LANDRIS (1997).

Also a positive relationship between the level of agricultural landscape variety and the abundance of parasitoids in agrocenoses was proven. Similar conclusion had been previously reached by eg. EMDEN (1993), MARINO and LANDIS (1996, 2000) and RYSZKOWSKI et al. (2001).

Regardless of the level of landscape structure diversity, refugia of similar entomofauna occurred in the area. The study results also indicated a relationship between a landscape structure and a similarity of flora and entomofauna of the same refugium habitat (Fig. 2). Similarities in flora and entomofauna analyses were seen only in the landscape of the highest mosaic structure. This is probably related to particularly rich greenery, which consequently makes those habitats more attractive for beneficial entomofauna.

The study showed the relationships between structural elements of the landscape, its green cover and parasitoid entomofauna. Such research conducted on various levels of nature organisation and various trophic levels contribute to broadening the knowledge on agroecosystems.

CONCLUSIONS

1. Within agricultural landscape the share of refugia differentiates its structure and results in creating a specific green cover and entomofauna.
2. Structural units of landscape based on geobotanical assumptions show similarities.
3. There is a positive relationship between species diversity and the abundance of *Pimplinae* communities and the complexity level of agricultural landscape.
4. The quality and quantity structure of *Pimplinae* communities in refugia depend on the level of agricultural landscape complexity.
5. A quality and quantity similarity of *Pimplinae* communities in most refugia in agricultural landscape was found regardless of its structure complexity.
6. The similarities of quality and quantity structure between *Pimplinae* communities in refugia do not depend on the level of agricultural landscape complexity.
7. There is a positive relationship between the complexity of landscape structure and the similarity of flora and entomofauna in refugia.
8. The similarity of flora and entomofauna of agricultural landscape refugia depends on the level of complexity of agricultural landscape structure.

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