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Original Research

The Impact of the Surrounding Vegetation of Apple Orchards Under Ecological and Integrated Management on the Syrphids (Diptera: Syrphidae)

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Abstract

The study was conducted in south-eastern Poland, in three apple orchards where integrated pest management was applied, and in one ecological orchard and in their surroundings.

In total, 1,677 individuals of Syrphidae belonging to 37 species, 21 genera, and two subfamilies were collected in the yellow traps. The most numerous were zoophagous syrphids – they constituted 94.5% of all the collected specimens and about 70% of the noted species. Among them, one species – *Episyrphus balteatus* (Deg.) – was the eudominant in the orchards and their surroundings.

Comparing the occurrence of Syrphidae in the three IPM apple orchards and in their surroundings, it can be stated that more syrphids were caught in the boundary vegetation than within the orchards, whereas on the ecological site, more hoverflies were collected within the apple orchard than on the neigbouring plants. In most cases, in the orchard under IPM the syrphid species abundant in the surroundings of the orchards also appeared in great numbers in the orchards themselves, which indicated their movement from the boundaries into the orchards.

The study has shown that the surroundings of orchards with species-rich, flowering plants positively influenced the species richness and the abundance of hoverflies occurring in the orchards.

Keywords: hoverflies, orchard boundaries, apple trees, organic management, integrated management

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Introduction

The main recent challenge for agriculture is food production in accordance with the ecological balance. One way to achieve this aim is to maintain biodiversity and ecosystem services. Among the most important factors limiting the yields in crop production are pollination and pests. The Syrphidae family is an important group with a high potential for that service. They play a double role in ecosystems: the adults of all trophic groups use pollen and nectar of flowers as a source of energy for reproduction (pollination of plants), whereas predatory larvae from the subfamily Syrphinae prey on the population of aphids in fields and orchards [1-4].

In apple orchards, intensive chemical pest control is applied. An increasing number of studies related to the identification and characterization of the side effects of the use of fungicides and pesticides on beneficial arthropods (e.g. higher mortality or lower fecundity of insect predators) have been published in the recent years [5-8]; therefore, so important is to find other methods to reduce the occurrence of pests (organic/ecological farming). The main task of ecological and integrated protection is to strengthen pest control by improving the natural resources of their enemies (suitable habitats). In organic orchards due to the non-existent pesticide disruption the increase the number and biodiversity of predators compared to conventional agriculture was observed [5, 9, 10].

Monocultures created by farmers do not provide the food resources for beneficial insects [11]. An important factor promoting the presence of predators and parasites is appropriate arranging of the vegetation surrounding fields and orchards. Trees, bushes and plantings occurring in the vicinity of orchards increase the biodiversity and represent an important source of beneficial insects, which, during the growing season, penetrate neighbouring plots/orchards, pollinating flowers and reducing the numbers of pests [12-16]. The majority of insects in agricultural regions are dependent on the presence of semi-natural habitats. The biodiversity of beneficial insects can be modeled by the features of the habitat. A high level of functional complementarity in the predator community enhances pest control. Refugia not only strengthen the resistance of the environment against pests by increasing the number of entomophagous insects, but are also a place of food resource (alternative prey), sheltering and overwintering for them [12, 17-20].

Knowledge of surrounding vegetation and beneficial insects associated with it allows for the evaluation of the usefulness of these plants in ecological and integrated plant protection in fields and orchards [2]. In practice, it is possible to influence agricultural landscape by planting the appropriate types of plants attractive to adult Syrphidae in the vicinity of orchards, and increase in this way the population of these beneficial insects capable of pollinating flowers and controlling pests such as aphids [4, 15, 18, 21, 22].

The aim of the study was to evaluate the effect of agricultural management systems and vegetation surrounding orchards on the population density and species composition of syrphids – pollinators and biotic agents – occurring in apple orchards under ecological and IPM management systems.

The final objective was to establish the selection of appropriate plants in the orchard surroundings to improve biological pest control through conservation strategies for the syrphid species.

Materials and Methods

Research Sites

The study was conducted in the years 2011-2013 in the south-eastern part of Poland near the town of Przemyśl (49.82°N, 22.79°E), in three apple orchards where integrated pest management (IPM) was applied, and in one ecological apple orchard and in their surroundings.

The study sites included: apple orchards with IPM (Site 1, Site 2, Site 3) and ecological orchard (Site 4 - where no chemicals were used) with 'Szampion', 'Elise' and 'Elstar' cultivars. In the orchards apple trees grew 1.5 x 3 m apart, rows of trees were separated by sward.

Site 1 - of 9 ha surface area, surrounded with: woodlands, shrubs and herbaceous plants (Table 1); Site 2 - of 10 ha surface area surrounded with: a pear orchard (*Pyrus* L.) (with IPM production) and herbaceous plants; Site 3 - of 8.5 ha surface area surrounded with: a pear orchard with IPM production, woodlands and herbaceous plants; Site 4 - ecological - of 9 ha surface area surrounded with: a walnut orchard (*Juglans regia* L.) (ecological) and herbaceous plants. The surroundings adjacent to the orchard were 7-8 m wide. The vegetation were determined by manually assigning.

No chemical pesticides were used in the ecological orchard as well as in surrounding walnut orchard, while in the orchards under IPM, the integrated fruit production policy was implemented. In each orchard, depends on year of study, 5-7 procedures against diseases and 6-7 against pests were performed.

Method of Sampling

Syrphid adults were collected using a common method of trapping imagines – the yellow Moericke trap [23] – a yellow plastic pan, 17 cm in diameter and 20 cm in deep, filled with water and glycol. The traps were situated 1.5-2 m above the ground, 10 pans in each orchard and 10 pans in its surroundings. The traps were placed up to 10 m apart from each other in rows in the middle of the respective areas – no traps were placed at the edge of the orchard or its surroundings to avoid marginal effects. Syrphid adults were collected, counted and removed every 2 weeks from the end of April to the end of September. The syrphids collected in one pan during 14 days constituted one sample.

The identification of the collected syrphids was based on the van Veen [24] key, using the terminology proposed by Soszyński [25].

Statistical Analysis

The collected Syrphidae were analyzed with respect to the species composition, abundance, dominance structure, frequency, and species richness.

The dominance coefficient was adopted as comprising five dominance classes [26]: >10% eudominants, 5.1-10% dominants, 2.1-5% subdominants, 1.1-2% recedents, and <1% subrecedents.

Similarity of syrphid associations was calculated using the Jaccard classic index [27].

$$J_{class} = A/A + B + C$$

J_{class}- Jaccard similarity index, A- number of shared species, B - number of species unique to the first assemblage, C -number of species unique to the second assemblage.

The similarity was also studied with cluster analysis and the results were presented as a dendrogram. The structure of the syrphid community collected from each site was examined by applying principal components analysis (PCA) (Statistica 13.3).

Results

During the 3 years of observations, a total of 1,677 Syrphidae individuals belonging to 37 species, 21 genera, and two subfamilies were collected in the yellow traps in the two types of habitat. Overall, more species were recorded in the surroundings of the orchards (32 species) than in the orchards themselves (28 species). Similar abundance of the collected Syrphidae was noted in each year of the study.

Comparing the occurrence of Syrphidae in the IPM apple orchards (Sites 1, 2, 3) and in their surroundings (Table 2), it can be stated that more syrphids were caught in the boundary vegetation than within the orchards (possibly due to the use of chemicals in these orchards), whereas on Site 4 (ecological), more hoverflies were collected in the apple orchard than on the neigbouring plants,

The presence of flowering plants and aphids feeding on the vegetation surrounding the orchards, e.g. *Aphis grossulariae* Kalt., *Aphis podagrariae* Schrank, *Aphis sambuci* L., *Aphis urticata* Gmelin, *Dysaphis crataegi* Kalt., *Liosomaphis berberidis* Kalt., *Myzus cerasi* F., *Myzocallis coryli* Goetze, and *Myzus ligustri* Mosley, provided an ideal living place for syrphids. The plants (pollen) attracted the adults and provided alternative food (aphids) for the larvae of predatory species. Among the syrphids, one species – *Episyrphus balteatus* (Deg.) – was the definite eudominant on all the sites. In the apple orchard, its average percentage share was 37.4 % while in the surroundings 39.3%. Overall, *E. balteatus*

Table 1. The plants habitat in surroundings of apple orchards.

	Trees	Shrubs	Herbaceous plants
Site 1	*Cerasus vulgaris* Mill., *Juglans regia* L., *Picea abies* (L.), *Prunus* L., *Rhus typhina* L.	Berberis vulgaris L., *Corylus avellana* L., *Crataegus monogyna* Jacq., *Ligustrum vulgare* L., *Photinia melanocarpa* Michx., *Ribes uva-crispa* L., *Rosa canina* L., *Rubus* L., *Sambucus nigra* L., *Syringa vulgaris* L.	*Achillea millefolium* L., *Aegopodium podagraria* L., *Artemisia absinthium* L.; *Capsella bursa-pastoris* L., *Daucus carota* L., *Galinsoga parviflora* Cav., *Galium aparine* L., *Lamium album* L., *Matricaria discoidea* DC., *Plantago lanceolata* L., *Ranunculus acris* L., *Rhamnus cathartica* L., *Rumex acetosa* L., *Stellaria media* (L.) Vill., *Solidago virgaurea* L., *Taraxacum officinale* Web., *Trifolium repens* L., *Urtica dioica* L., *Veronica chamaedrys* L.
Site 2	pear orchard (*Pyrus* L.)		*Achillea millefolium* L., *Aegopodium podagraria* L., *Capsella bursa-pastoris* L., *Daucus carota* L., *Galinsoga parviflora* Cav., *Galium aparine* L., *Lamium album* L., *Matricaria discoidea* DC., *Plantago lanceolata* L., *Ranunculus acris* L., *Rumex acetosa* L., *Stellaria media* (L.) Vill., *Solidago virgaurea* L., *Taraxacum officinale* Web., *Trifolium repens* L., *Urtica dioica* L., *Veronica chamaedrys* L.
Site 3	pear orchard (*Pyrus* L.) *Cerasus vulgaris* Mill., *Picea abies* (L.), *Prunus* L., *Rhus typhina* L.	Berberis vulgaris L. *Corylus avellana L. Ligustrum vulgare L.*	*Aegopodium podagraria* L., *Daucus carota* L., *Lamium album* L., *Plantago lanceolata* L., *Ranunculus acris* L., *Rhamnus cathartica* L;, *Stellaria media* (L.), *Taraxacum officinale* Web., *Trifolium repens* L., *Urtica dioica* L., *Veronica chamaedrys* L.
Site 4	walnut orchard (*Juglans regia*)		*Aegopodium podagraria* L., *Matricaria discoidea* DC., *Plantago lanceolata* L., *Poa annua* L., *Stellaria media* (L.) Vill., *Solidago virgaurea* L., *Trifolium repens* L., *Urtica dioica* L., *Veronica chamaedrys* L.

Table 2. Species composition, domination and frequency of syrphids collected to the yellow traps in orchards and their surroundings 2011-2013.

Species	Site 1						Site 2						Site 3						Site 4						Total no
	Orchard			Surrounding			Orchard			Surrounding			Orchard			Surrounding			Orchard			Surrounding			
	no	%	f	no	%	f	no	%	f	no	%	f	no	%	f	no	%	f	no	%	f	no	%	f	
Subfamily Eristaline –saprophagous species																									
Brachyopa testacea (Fallén)	1	1.2 R	2.8	1	0.6 Sr	2.8																			2
Ceriana conopsoides (L.)	3	3.5 Sd	8.3	4	2.4 Sd	8.3	2	1.2 R	5.6	1	0.4 Sr	2.8	6	3.7 Sd	11.1	11	4.3 Sd	13.9	2	0.4 Sr	8.3	16	14.8 Eu	20.8	45
Eristalis arbustorum (L.)							1	0.6 Sr	2.8	1	0.4 Sr	2.8	1	0.6 Sr	2.8	1	0.4 Sr	2.8	4	0.8 Sr	16.7	2	1.9 R	8.3	10
Eristalis interrupta (Poda)							1	0.6 Sr	2.8																1
Eristalis intricaria (L.)										1	0.4 Sr	2.8													1
Eristalis pertinax (Scop.)										1	0.4 Sr	2.8													1
Helophilus pendulus (L.)				1	0.6 Sr	2.8				1	0.4 Sr	2.8													2
Helophilus trivittatus (Fabr.)										1	0.4 Sr	2.8													1
Neoascia podagrica (Fabr.)																			1	0.2 Sr	4.2				1
Syritta pipiens (L.)							1	0.6 Sr	2.8	1	0.4 Sr	2.8				2	0.8 Sr	2.8	22	4.5 Sd	41.7				26
Subfamily Eristaline -phytophagous species																									
Cheilosia pagana (Meig.)	1	1.2 R	2.8										2	1.3 R	2.8										3
Subfamily Syrphinae – zoophagous species																									
Chrysotoxum vernale Loew	3	3.5 Sd	5.6				1	0.6 Sr	2.8	1	0.4 Sr	2.8	1	0.6 Sr	2.8	1	0.4 Sr	2.8							7
Dasysyrphus venustus (Meig.)																2	0.8 Sr	2.8							2
Didea fasciata Macq.																1	0.4 Sr	2.8							1

Table 2. Continued.

Didea intermedia Loew							1	0.6 Sr	2.8																1
Epistrophe eligans (Harr.)										6	2.5 Sd	2.8							7	1.4 R	16.7	3	2.8 Sd	2.8	16
Epistrophe melanostoma (Zett.)				2	1.2 R	5.6				31	13.0 Eu	8.3	1	0.6 Sr	2.8	6	2.3 Sd	2.8	8	1.6 R	8.3				48
Episyrphus balteatus (Deg.)	44	51.1 Eu	38.9	81	47.9 Eu	36.1	39	23.9 Eu	36.1	43	18.1 Eu	25	88	54.7 Eu	33.3	125	48.4 Eu	50	167	33.8 Eu	75	55	50.9 Eu	45.8	642
Eupeodes corollae (Fabr.)	13	15.1 Eu	22.2	26	15.4 Eu	22.2	29	17.8 Eu	33.3	20	8.4 D	25	27	16.8 Eu	8.3	22	8.5 D	33.3	47	9.5 D	70.8				184
Eupeodes lapponicus (Zett.)	3	3.5 Sd	5.6	1	0.6 Sr	2.8	12	7.4 D	11.1	2	0.8 Sr	5.6				1	0.4 Sr	2.8	9	1.8 R	12.5				28
Eupeodes latifasciatus (Macq.)	1	1.2 R	2.8	2	1.2 R	2.8	8	4.9 Sd	8.3	14	5.9 D	19.4	2	1.2 R	5.6	11	4.3 Sd	13.8	16	3.2 Sd	8.3				54
Eupeodes luniger (Meig.)	2	2.3 Sd	2.8	1	0.6 Sr	2.8	9	5.5 D	8.3							1	0.4 Sr	2.8	4	0.8 Sr	8.3				17
Melangyna lasiophthalma (Zett.)				8	4.7 Sd	2.8										1	0.4 Sr	2.8							9
Melanostoma mellinum (L.)	2	2.3 Sd	5.6	6	3.6 Sd	11.1	20	12.3 Eu	16.7	3	1.3 R		2	1.2 R	5.6	2	0.8 Sr	5.6	15	3.0 Sd	33.3	2	1.9 R	4.2	52
Parasyrphus annulatus (Zett.)				1	0.6 Sr	2.8				30	12.6 Eu	2.8				12	4.7 Sd	5.6							43
Platycheirus discimanus Loew										1	0.4 Sr	2.8							2	0.4 Sr	4.2				3
Platycheirus melanopsis Loew	1	1.2 R	2.8	1	0.6 Sr	2.8	1	0.6 Sr	2.8							1	0.4 Sr		2	0.4 Sr	4.2				6
Platycheirus scutatus (Meig.)				2	1.2 R	5.6	3	1.8 R	2.8							2	0.8 Sr	5.6	4	0.8 Sr	8.3				11
Scaeva pyrastri (L.)	1	1.2 R	2.8				2	1.2 R	5.6	2	0.8 Sr	5.6				2	0.8 Sr	5.6	3	0.6 Sr	8.3				10
Scaeva selenitica (Meig.)	1	1.2 R	2.8	1	0.6 Sr	2.8																			2
Sphaerophoria menthastri (L.)				1	0.6 Sr	2.8										1	1.6 R	11.1							2
Sphaerophoria scripta (L.)	6	6.9 D	5.6	15	8.9 D	27.8	17	10.4 Eu	22.2	4	1.7 R	8.3				8	1.9 R	13.9	117	23.7 Eu	58.3	12	11.1 Eu	8.3	179

Table 2. Continued.

Syrphus ribesii (L.)							2	1.2 R	5.6	10	4.2 Sd	5.6				3	1.2 R	2.8	9	1.8 R	8.3				24
Syrphus torvus O.-S.	1	1.2 R	2.8	5	3.0 Sd	11.1	6	3.7 Sd	5.6	27	11.3 Eu	5.6	4	2.5 Sd	5.6	24	9.3 D	16.7	20	4.0 Sd	37.5	5	4.6 Sd	12.5	92
Syrphus vitripennis Meig.	2	2.3 Sd	5.6	10	5.9 D	16.7	7	4.3 Sd	13.9	37	15.5 Eu	8.3	27	16.8 Eu	16.7	17	6.6 D	16.7	35	7.1 D	45.8	13	12.0 Eu	12.5	148
Xanthandrus comtus (Harr.)	1	1.2 R	2.8				1	0.6 Sr	2.8																2
Xanthogramma pedissequum Harr.																1	0.4 Sr	2.8							1
Total number of specimens	86			169			163			238			161			258			494			108			1677
Mean number specimens/sample	2.4			4.7			4.5			6.6			4.5			7.2			21.5			4.7			

Eudominants > 10%, Dominants 5,1-10%, Subdominants 2,1-5%, Recedents 1,1-2%, Subrecedents <1%
n-number, %-percentage, f- frequency

accounted for more than 38% of all the collected hoverflies (Table 2).

The frequency of this species ranged from 25% (in surroundings Site 2) to 75% (in the ecological orchard, Site 4), which means that this species was found in one-quarter (¼) to three-quarters (¾) of all the samples collected (Table 2).

Species that were also quite numerous included: *Eupeodes corollae* (Fabr.) in Orchard 4 (frequency 70.8), but surprisingly, it was not noted in the surroundings of this orchard; *Sphaerophoria scripta* (L.) – very numerous in Orchard 4 (frequency 58.3), not registered in Orchard 3, and *Syrphus vitripennis* Meig.– present on all the sites. The percentage share of these three species was more than 30% of all the Syrphidae caught (Table 2). Other species appeared in smaller numbers; however, predatory *Syrphus torvus* O.-S., *Melanostoma mellinum* (L.), *Parasyrphus annulatus* (Zett.), *Eupeodes latifasciatus* (Masq.), *Epistrophe melanostoma* (Zett.), and saprophagous *Ceriana conopsoides* (L.) were quite numerous (more than 40 specimens). Species such as: *Cheilosia pagana* (Meig.), *Eristalis interrupta* (Poda), *Neoascia podagrica* (Fabr.) and *Xanthandrus comtus* (Harr.) were recorded only in the orchards, while *Parasyrphus annulatus* (Zett.) only in the boundaries (Table 2).

An analysis showed that the highest mean number of collected Syrphidae per one sample was noted in the surroundings of Orchard 3, with abundant and diverse vegetation and in the ecological orchard, where no chemicals were used (Table 2).

In the present study, syrphids belonging to three trophic groups were collected. The most numerous were zoophagous syrphids from the subfamily Syrphinae – particularly important as their predatory larvae feed mostly on aphids – represented by 26 species (1,584 specimens); they constituted 94.5% of all the collected specimens and about 70% of the noted species, followed by saprophagous syrphids (10 species, 90 specimens) – 5.4%. The largest numbers of predatory species were noted in Orchard 2 (IPM) and Orchard 4 (ecological) (18 and 16, respectively), and in the surroundings of Orchard 3 (21 species). The saprophagous *C. conopsoides* was one of the few species found to be quite numerous in the surroundings of the ecological orchard (Table 2).

In most cases, the syrphid species abundant in the surroundings of the orchards also appeared in great numbers in the orchards themselves, which indicated their movement from the boundaries into the orchards, although there were a few exceptions, for example, *E. melanostoma* and *P. annulatus* – numerous in the boundaries of Orchard 2 – were not found within Orchard 2 (Table 2).

The species richness varied between the habitats. The smallest number of species and the lowest species richness (3.5) were noted in the surroundings of Orchard 4 – the place with the least diverse vegetation (nut trees and few species of herbaceous plants), while

Table 3. Species richness of Syrphidae on different sites during 2011-2013.

	Site 1		Site 2		Site 3		Site 4	
	Orchard	Surrounding	Orchard	Surrounding	Orchard	Surrounding	Orchard	Surrounding
Number of species	17	19	21	22	11	24	20	8
Species richness	8.3	8.2	9.1	8.8	5.6	9.6	7.0	3.5

Table 4. Similarity of syrphid associations collected into yellow traps calculated from Jaccard classic index.

	Site 1 orchard	Site 1 surrounding	Site 2 orchard	Site 2 surrounding	Site 3 orchard	Site 3 surrounding	Site 4 orchard	Site 4 surrounding
Site 1 orchard	x	0.565	0.583	0.393	0.474	0.464	0.480	0.316
Site 1 surrounding	0.565	x	0.429	0.414	0.364	0.593	0.500	0.286
Site 2 orchard	0.583	0.429	x	0.483	0.391	0.607	0.640	0.318
Site 2 surrounding	0.393	0.414	0.483	x	0.435	0.533	0.615	0.364
Site 3 orchard	0.474	0.364	0.391	0.435	x	0.400	0.409	0.462
Site 3 surrounding	0.464	0.593	0.607	0.533	0.400	x	0.629	0.304
Site 4 orchard	0.480	0.500	0.640	0.615	0.409	0.629	x	0.400
Site 4 surrounding	0.316	0.286	0.318	0.364	0.462	0.304	0.40.0	x

the surroundings of Orchard 3, with varied vegetation, were characterized by the highest indicator of species richness (9.6) (Table 3).

The structure of syrphid communities differed between the sites. On Site 1 and 2, the same 13 species were found in both the orchard and its surroundings, this suggested a species migration from the environment into the orchards under IPM.

The communities of Syrphidae collected in the apple orchards and their surroundings were compared in terms of quantity using the Jaccard index [27] (Table 4). The highest similarity between the orchard and its surroundings was noted on Site 1 – 0.565, whereas the lowest was for Site 3 and 4 (Table 4).

Low similarity in species composition was observed between the ecological orchard (Site 4) and orchards with IPM (with the exception of Orchard 2).

When all the orchards and their surroundings were taken into account, the highest similarity was observed between the syrphid community collected in Orchard 4 and those in the surroundings of Site 2 and 3, which proved that the ecological orchard, not affected by the use of chemicals, had the same rich hoverfly community as the vegetation diverse surroundings of the IPM orchards (Table 4).

The syrphids collected in the apple orchards and their surroundings were also compared using order grouping with the cluster method (Fig. 1). This analysis confirmed that the community of syrphids found in the ecological orchard (Site 4) was the most similar to that found in surroundings of orchards with diverse vegetation (Fig. 1).

The analysis of the similarities in the quantity and quality structures of the Syrphidae communities found on the different sites was completed by comparing their structures using the principal component analysis method (PCA). The results showed similarities between the same communities as those determined with the cluster method, and the different from other orchards character of the community found in the ecological orchard 4 (Fig. 2).

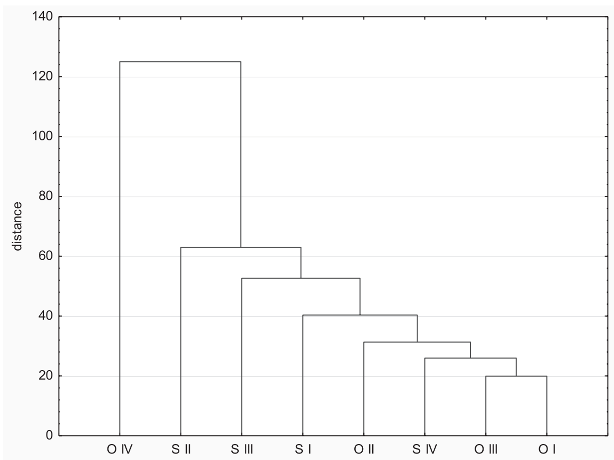

Fig. 1. Cluster analysis of habitats with group single linking as the clustering method(OI – Orchard 1 IPM, OII- Orchard 2 IPM, OIII- Orchard 3 IPM, OIV – Orchard 4 – ecological, SI- Surrounding 1 , SII – Surrounding 2, SIII – Surrounding 3, SIV – Surrounding 4).

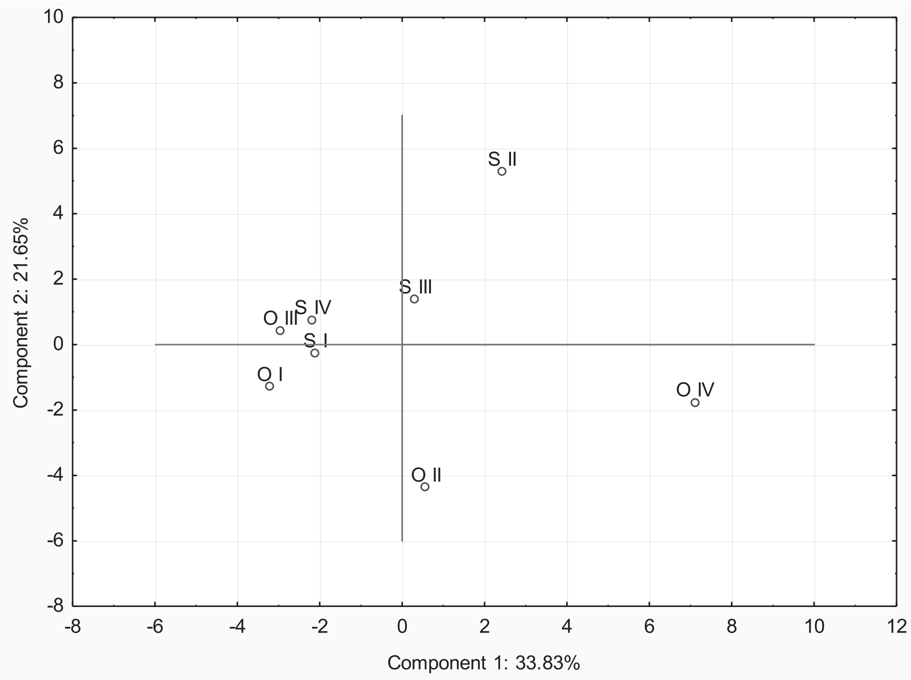

Fig. 2. Plot of principal components analysis of habitats (OI – Orchard 1 IPM, OII- Orchard 2 IPM, OIII- Orchard 3 IPM, OIV – Orchard 4 – ecological, SI- Surrounding 1 , SII – Surrounding 2, SIII – Surrounding 3, SIV – Surrounding 4).

Discussion

Based on the results obtained, it can be concluded that the surroundings of IPM orchards consisting of species-rich and well-developed vegetation (trees, shrubs, and herbaceous plants) were the place where a greater diversity of syrphid species and their greater abundance were noted in comparison with the orchards. The results showed that abundant vegetation of orchard boundaries constituted a more attractive habitat for syrphids than the orchard biocenosis. This was probably related to the use of plant protection chemicals in the orchards under integrated production, which in the negative way influence some beneficial insects. In natural habitats, large numbers of species occurring as recedents and subrecedents are noted, and such a situation was observed in the surroundings of the orchards, especially those characterized by rich vegetation. The research confirmed a positive influence of varied wild vegetation in the boundaries of orchards on increasing the species richness and abundance of Syrphidae. It was found that the presence of taller vegetation, i.e. trees and shrubs (and not only herbaceous plants), creates better conditions for the thriving of hoverflies.

According to Lindgren et al. [28] and Albrecht et al. [22], natural habitats, e.g. forest edges, hedgerows, and the surrounding landscape, have been shown to be important to maintain species richness and as an important factor determining pollination and pest control. Piekarska- Boniecka et al. [29] reported that orchard surroundings with diverse blooming plants were the element which attracted syrphids more strongly than orchards and might determine the migration of these beneficial insects into orchards. Albert et al. [2] noted that flower strips increased the natural enemies abundance in the vicinity of the orchards and thus played an important role in the biological control of *D. plantaginea*.

The attractiveness of orchard edges was also influenced by the presence of alternative host plants for aphids (not infesting apple trees), on which *Aphis grossulariae* Kalt., *Aphis podagrariae* Schrank, *Aphis sambuci* L., *Aphis urticata* Gmelin, *Dysaphis crataegi* Kalt., *Liosomaphis berberidis* Kalt., *Myzus cerasi* F., *Myzocallis coryli* Goetze, and *Myzus ligustri* Mosley were feeding. They constituted a supplementary food for predatory syrphid larvae, whereas flowering plants were the source of nectar and pollen for the imagines, attracting them to forage in the vicinity of orchards.

Taking into account the similarity between individual environments, it should be emphasized that the syrphid community caught in the ecological orchard was very similar to that collected in the surroundings of IPM orchards. This proves that the ecological orchard, where no pesticides were used, had the same species richness of hoverflies as the surroundings of orchards with rich and varied vegetation. The least attractive environment was the nut orchard and herbaceous vegetation, which indicated that surroundings with least diverse vegetation were not a favourable environment for syrphids and the selection of the appropriate flora affects the occurrence of beneficial insects. Many authors have emphasized the role of flowering plants, especially from the families Asteraceae, Apiaceae, Lamiaceae, Ranunculaceae and Rosaceae, in attracting adult Syrphidae [3, 4, 15, 22].

The Syrphinae subfamily, which includes the species feeding on aphids, constituted more than 70% of all the noted species and 94.5% of all the specimens found. This information was important from a plant protection point of view because syrphid adults attracted near orchards by flowering wild plants could then lay eggs in aphid colonies infesting apple trees, thus limiting their numbers [15, 18, 21].

It is also worth emphasizing the important role of adults of all the trophic groups of syrphids in pollinating plants, including apple trees, which has a positive effect on the fruit crop [15, 22].

A recent study showed the dominance of *E. balteatus, E. corollae, S. scripta* and *S. vitripennis* in apple orchards and their surroundings. The results of other authors [4, 29, 30] indicated their dominant role in orchard habitats. Rossi et al. [30] collected 17 species of syrphids in an ecological apple orchard in north-western Italy. The dominant species were *S. scripta* and *E. corollae* – they constituted more than 80% of all the collected syrphids. Trzciński and Piekarska-Boniecka [31] recorded 20 species of Syrphidae in apple orchards and the neighbouring shrubberies – dominated by *E. balteatus*. Piekarska-Boniecka et. al. [29] noted 38 syrphid species in apple orchards and 49 species along their edges. All the habitats were dominated by two zoophagous species – *E. balteatus* and *E. corollae*.

The dominance of these species, both in orchards and their surroundings, suggested their migration between adjacent environments, and in effect the control of aphid colonies feeding on apple trees. *E. balteatus* is known as an effective predator of *Aphis pomi* and *Dysaphis plantaginea* and other species occurring in orchards [32-35].

During all the years of the study, the impact of the orchard management system on the occurrence of syrphids was evident. The non-use of chemical treatments in the ecological orchard probably increased the numbers of Syrphidae.

The relationship between orchard management and the occurrence of natural pest enemies has been observed by Porcel et al. [10]. The authors observed that an ecological system resulted in more diverse and abundant predators in the orchard and noted their earlier occurrence in aphid colonies than in the conventional orchard.

According to Simon et al. [5] and Rusch et al. [9, 11], conventional agriculture decreased populations of beneficial insects, whereas organic apple production increased the number and biodiversity of predators due to the non-existent pesticide disruption. Khan and Riyaz [36] observed poor species diversity and less widespread distribution of syrphids in orchards prayed with insecticides, compared to the unsprayed orchards.

Conclusions

The study has shown that the surroundings of orchards with species-rich, flowering plants positively influenced the species richness and the abundance of hoverflies occurring in orchards. Orchard margins significantly increased the density and species biodiversity of predators, then it could be hypothesized that the pest management benefits of habitat diversification. Habitats providing floral resources, trees and shrubs have been shown to be beneficial for natural enemies, however, the contribution of each surroundings will depend on its vegetation composition and structure, abundance in the landscape and spatial arrangement. The results of this work could help farmers to limit the use of chemicals in orchards with integrated production by introducing appropriate plants in the boundaries surrounding orchards, thus enriching biodiversity and providing food for beneficial insects, and in this way increasing the number and effectiveness of pollinators and predators able to reduce the populations of pests.

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Author Contributions

Both authors contributed to this work.

Conflicts of Interest

Authors declare no conflicts of interest.

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