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Hoverfly (Diptera: Syrphidae) community of a cultivated arable field and the adjacent hedgerow near Debrecen, Hungary

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Abstract: A hoverfly (Syrphidae) community was investigated in a cultivated wheat field and the adjacent hedgerow near Debrecen (Hungary). We monitored the change of species richness and abundance of hoverflies along three transects in the hedgerow and in the wheat field in different distances (10 m, 20 m) from the hedgerow. The effect of sampling methods on the number of hoverfly species and individuals was analyzed. Two sampling methods were used to catch hoverflies: netting and pan traps. The whole sampling period was divided into three subperiods, which are early (22nd April – 2nd June), middle (11th June – 1st August) and late (6th August – 11th September). Altogether 1,214 individuals of 22 species were sampled. Fourteen species with 78% of individuals belonged to the aphidophagous group, feeding on aphids as larvae. Altogether 861 individuals of 22 hoverfly species were sampled by netting and 353 individuals of 10 species by pan traps. The total number of hoverfly species was significant lower in the late period than in the early. The total abundance was higher in the middle period compared to the early. The species richness and abundance of aphidophagous species followed a similar pattern as the total species values. The species richness and abundance of hoverflies were significant higher in 10 m and 20 m distance in the wheat field than along the hedgerow. The results suggest that the pan traps were less efficient in the hedgerow than the netting, but in the wheat field they sampled more hoverflies because of visually alluring effect on hoverflies in the absence of flowers.

Key words: netting; pan trap; pest control agents; pollinators; agricultural landscape; ecosystem services

Introduction

The Diptera family Syrphidae (hoverflies) is one of the largest in the order, with more than 6,000 described species globally. About 1,800 species are known from the Palaearctic region (Thompson & Rotheray 1998), including 800 species in Europe (Ssymank 2001), and about 400 species in Hungary (Tóth 2008). Many species are well known according to their body-colour pattern showing mimicry of wasps and bees. Hoverflies have considerable importance in natural and agricultural ecosystems, providing crucial ecosystem services: on the one hand adult hoverflies feed on pollen, nectar or both (Rossi et al. 2006), pollinating wild flowers and flowering crops, including several fruit trees (Röder 1990; Chacoff 2008; van Rossum 2010). On the other hand more than 30% of Palaearctic syrphid flies are known as aphid predators, i.e. important agents in biological pest control (Tenhumberg & Poehling 1995; Sadeghi & Gilbert 2000; Basky 2005; Pascual-Villalobos et al. 2006; Thomson & Hoffmann 2009; Penvern et al. 2010; Pilkington et al. 2010). Larvae consume even one or two thousands aphids during the 7–10 day developing period (Visnyovszky 1989; Dib et al. 2010; Hogg et al. 2011). However, despite of their important role in the natural and agricultural ecosystems, from Hungary no data are published in international journals about the hoverfly communities.

Several former studies proved that intensive agricultural practices are one of the main driving effects of decreasing diversity of insect pollinators (Meek et al. 2002; Steffan-Dewenter et al. 2005; Biesmeijer et al. 2006; Fitzpatrick et al. 2006; Kuussaari et al. 2011). The hoverflies are good indicators of land use intensity, because the imagoes and larvae are sensitive to agricultural management, e.g., chemical use (Hasken & Poehling 1995; Sommaggio 1999; Burgio & Sommaggio 2007), local food resources and landscape heterogeneity. The lack of wild flowers in homogenous agricultural landscapes, like in intensive cereal fields may reduce hoverfly density through limited nectar and pollen resources, which are essential for flight of hoverflies and egg maturation of females. In monocultures hoverflies cannot overwinter or find protected habitat against hasty weather conditions (Meyer et al. 2009). Therefore, heterogeneous landscape and diverse habitats in agroecosystems are important for hoverflies to provide different habitats available for feeding, mating and overwintering.

Hedgerows are key elements in agricultural landscapes (Sommaggio 1999; Kells et al. 2001; Benton et al. 2003; Vergara & Badano 2009), providing important habitat and foraging resources for many predators and parasitoid arthropods, many of them capable to control pest populations (Maudsley et al. 2002; Peńa et al. 2003; Hannon & Sisk 2009, Krewenka et al. 2011; Veres et al. 2013). The insect-pollinated shrub and herb species in the hedgerows provide pollen and nectar resources for pollinator insects, increasing local biodiversity and enhance crucial ecosystem services such as pollination within the agricultural landscape (Kleijn & Langevelde 2006; Rands & Whitney 2010; Kovács-Hostyánszky et al. 2013). Furthermore, hedgerows are important over-wintering and nesting habitats for hoverflies (MacLeod 1999; Wratten et al. 2003; Sarthou et al. 2005; Garratt et al. 2011).

To better understand the role of hedgerows in the habitat use of hoverflies, we conducted weekly sampling by two different sampling methods along a hedgerow and in the adjacent wheat field. In this paper we studied (i) the change of the species richness and abundance of hoverflies in the hedgerow during a single summer; (ii) the species richness and abundance of hoverflies in increasing distance from the hedgerow in the adjacent crop field; (iii) the effects of sampling method on the number of sampled hoverfly species and individuals.

Material and methods

Samplings were conducted in the vicinity of Debrecen, Hungary (47°33′ N, 21°33′ E), in an intensive wheat field and along the adjacent hedge of 1500 m length. The hedge is orientated in N-S direction. The average width of the hedge was 15 m with a dense shrub layer. The canopy was 70–80% closed and the grass layer was sparsely vegetated. On the contrary there was rich herbaceous vegetation in the grassy margin along the hedge (see Appendix 1). The hedge and the field were separated by a 5 m wide dirt road.

Three 50 m long transects were designated 400 m apart along the hedge. Hoverflies were sampled weekly between 22nd April and 11th September, 2008. The sampling period was divided then to three time periods: "early" (22nd April – 2nd June), "middle" (11th June – 1st August) and "late" (6th August – 11th September).

Hoverflies were sampled by two different sampling methods: netting and coloured pan traps. In the case of netting a modified (thickened textile on the edge) butterfly net was applied. Samples were taken along the hedge in 30 min of 20–25 sweeps in each 50 m long transect, in the morning until 12 a.m., in sunny weather, when hoverflies were most active (Visnyovszky 1989). Specimens were pinned, labelled and identified at species level in the laboratory. A total of 12 white pan traps (17×13×7 cm) were placed out. Two-two pan traps were exposed in the three transects described above, and parallel the hedge in a distance of 10 and 20 m in the cereal field. We placed the traps 1 m high (Bastian 1986; Ssymank 1991), filled with ethylene-glycol, added some drops of detergent to reduce surface tension and enhance the effectiveness of sampling, and emptied them once per week. Captured specimens were washed in 70% ethanol, pinned and identified at species level (Stubbs & Falk 2002; van Veen 2004). Based on the diet of the larvae, hoverflies were classified as aphidophagous and non-aphidophagous species.

Using Malaise trap is also an effective method to collect hoverflies (Burgio & Sommaggio 2002; Petanidou et al. 2011), but in this study area the security of Malaise trap could not be solved.

We used General Linear Mixed Models (GLMM) to analyse the effect of sampling period on the total abundance and species richness of hoverflies from the netting samples and the effects of sampling periods, distance from the hedge and their interaction on the species richness and abundance of hoverflies from the pan trap samples. Similar analyses were conducted on the aphidophagous and non-aphidophagous species groups as well. Response variables were log-transformed, when the distribution of the model residuals was not normal. Since the data from the same transect were spatially not independent, transect was used as random factor in the model. To compare the two sampling methods we used paired *t*-test, pooling together the species richness and abundance of hoverflies over the whole sampling period per transect. The analyses were conducted by the program R (R Development Core Team 2009. version 2.13.1).

Results

During the whole sampling period 1,214 individuals of 22 hoverfly species were collected. Fourteen species including 78% of the individuals were classified as aphidophagous. The most abundant species were *Episyrphus balteatus* (De Geer, 1776), *Sphaerophoria scripta* (L., 1758), *Syritta pipiens* (L., 1758), *Eupeodes corollae* (F., 1794) and *Melanostoma mellinum* (L., 1758) (see Appendix 2).

According to the netting samples the sampling period had significant effect on the total species richness and the abundance of hoverflies (Table 1, Figs 1A, B). The total number of hoverfly species was significantly lower in the late period than in the early (pairwise *t*-test, $P = 0.039$) and middle sampling period (pairwise *t*-test, $P = 0.039$). The total abundance was higher in the middle period compared to the early period (pairwise *t*-test, $P = 0.014$), however did not significantly differ from the late sampling period (pairwise *t*-test, $P = 0.278$). The species richness and abundance of aphidophagous species followed similar pattern as the total species values, showing lower species richness in the late and highest abundance in the middle sampling period (Table 1, Figs 2A, B). We found no difference in the species richness and abundance of the non-aphidophagous species among the sampling periods (Table 1).

Analyzing the data from the pan trap samples there was no interaction between sampling period and distance in the case of the species richness (df = 16, F = 0.28, $P = 0.882$) and abundance (df = 16, F = 0.95, $P = 0.459$) of hoverflies. The species richness (pairwise *t*-test, $P = 0.019$) and abundance (pairwise *t*-test, $P = 0.014$) of hoverflies were significantly higher in 10 m distance in the wheat field than along the hedgerow (Table 2, Figs 3A, B).

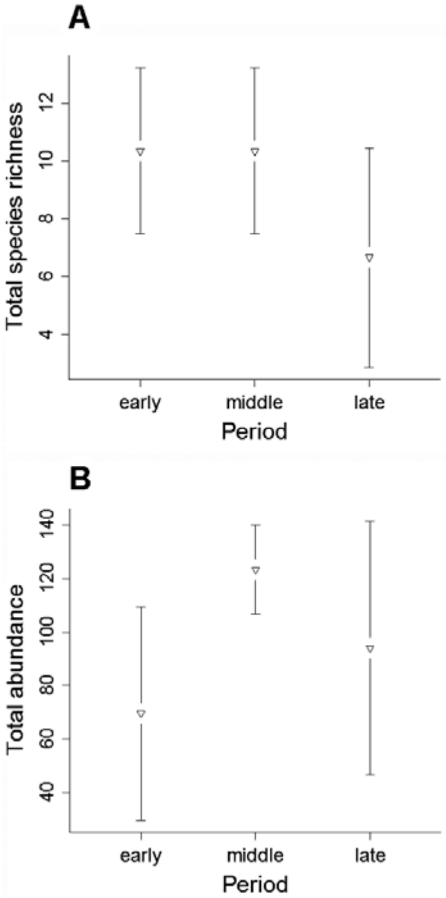

Fig. 1. The total species richness (A) and abundance (B) of hoverflies along the studied hedgerow in the function of sampling period, sampled by netting.

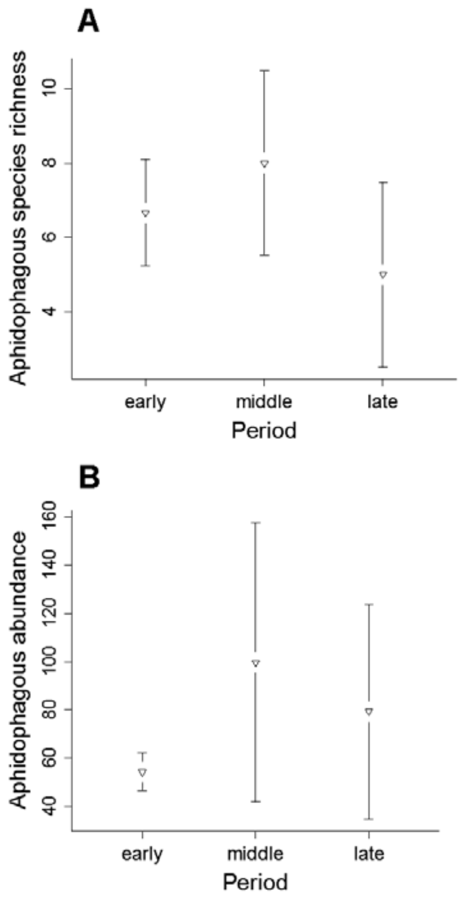

Fig. 2. The species richness (A) and abundance (B) of aphidophagous hoverflies along the studied hedgerow in the function of sampling period, sampled by netting.

Table 1. Effects of sampling period on the species richness and abundance of hoverflies and their functional groups in the netting samples according to the ANOVA of GLMM.

		Period		
		df	F	*P*
Total	Species richness	4	8.06	**0.039**
	Abundance	4	9.74	**0.029**
Aphidophagous	Species richness	4	8.71	**0.034**
	Abundance	4	9.74	**0.029**
Non-aphidophagous	Species richness	4	3.11	0.153
	Abundance	4	0.91	0.47

Explanations: df – Degrees of freedom, F – F-test value, *P* – value of significance. Significant effects are in bold.

Pan traps collected 298 aphidophagous and 55 non-aphidophagous individuals. Aphidophagous species showed no significant difference according to the sampling distance from the hedgerow (df = 16, F = 2.13, $P = 0.15$) and sampling period (df = 16, F = 1.16, $P = 0.337$). Non-aphidophagous hoverflies were present in higher species richness in 10 m from the hedgerow in the field ($P = 0.017$), and in higher abundance in 10 m ($P = 0.018$) and 20 m ($P = 0.02$) distance compared to the hedgerow (Figs 4A, B). The sampling period had no effect on the non-aphidophagous species (df = 16, F = 0.43, $P = 0.654$). We found no interaction between the sampling period and distance (df = 16, F = 0.43, $P = 0.781$).

Altogether 861 individuals of 22 hoverfly species were sampled by netting and 353 individuals of 10 species by pan traps. In pan traps only common species occurred. Comparing the efficiency of the net and pan traps as sampling methods of hoverflies in the hedgerow, we found netting more effective. Both the species richness (df = 1, F = 77.11, $P = 0.012$) and abundance (df = 1, F = 162.45, $P = 0.006$) of hoverflies were significant higher by netting.

Discussion

It is evidence that diverse landscape structure affects positively the insect communities, providing more feeding, mating, overwintering habitats than monocultures (Kleijn & Verbeek 2000; Thomson & Hoffmann 2009). In this study we found a temporal and spatial difference of hoverfly community comparing a hedgerow and the adjacent crop field.

Along the hedgerow, the hoverfly community was most species rich in the spring and early summer, and

Table 2. The effect of periods and distance of pan traps from the hedgerow on the species richness and abundance of hoverflies according to the ANOVA of GLMM.

		Period			Distance		
		df	F	*P*	df	F	*P*
Total	Species richness	20	0.83	0.448	20	5.21	**0.015**
	Abundance	20	1.24	0.3	20	5.74	**0.01**
Aphidophagous	Species richness	20	1.15	0.336	20	1.31	0.289
	Abundance	20	1.6	0.226	20	2.22	0.133
Non-aphidophagous	Species richness	20	0.18	0.828	20	6.67	**0.006**
	Abundance	20	0.74	0.488	20	8.62	**0.002**

For explanations see Table 1.

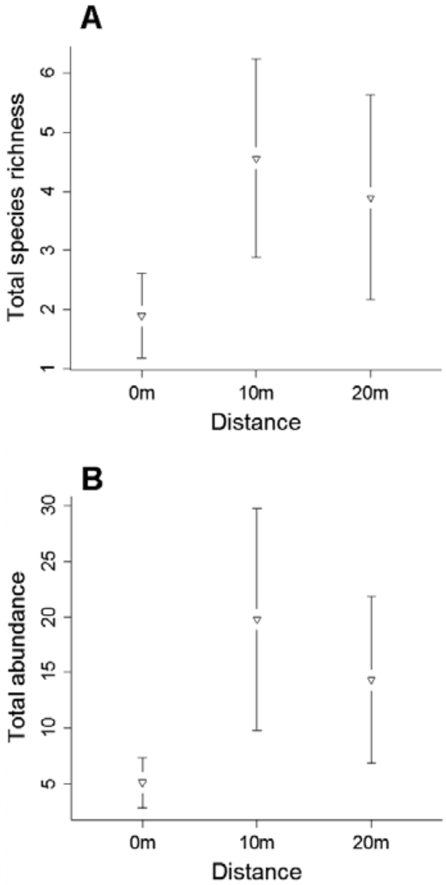

Fig. 3. The effect of distance of pan traps on the total species richness (A) and abundance (B) of hoverflies.

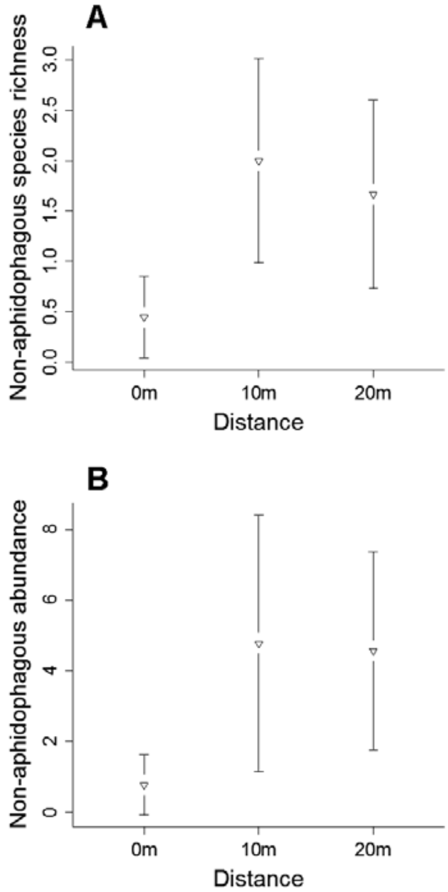

Fig. 4. The effect of distance of pan traps on the species richness (A) and abundance (B) of non-aphidophagous hoverflies.

most abundant in the early summer period. The dominant hoverfly species have two or three generations a year in Hungary, hence they occur in the whole vegetation period (Tóth 2011). Some hoverfly species occur in high numbers only periodically and their abundance is much lower in other years (Ssymank 2001), or the maximum points of their phenology shift. The reasons for these fluctuations are still unknown. Most hoverfly species are present at least four months during the vegetation period, but few species fly only in summer and autumn (Ssymank 2001). The difference in the species richness and abundance that was found here might be explained by the changes in the phenology of the aphidophagous species. The most dominant species in the samples were aphidophagous except for *S. pipiens*. These dominant species (*E. balteatus, S. scripta*, *E. corollae* and *M. mellinum)* overwinter as larvae or pupa, or as imago like *E. balteatus*. *E. balteatus* appears already in the early vegetation season and are present until late summer or autumn, depending on the climatic conditions such as temperature and precipitation (Röder 1990). Imagos of *E. balteatus* are active in the whole vegetation period and they were already sampled in high numbers from the end of May till late August. Females of *E. balteatus* have important role in the predation of aphids. After overwintering the mated females settle in the area and lay eggs next to the early aphid colonies. Larvae are very edacious and are able to destroy more than a hundred aphids a night (Tenhumberg & Poehling 1995). *E. corollae* overwinter as pupa, *S. scripta*, and *M. mellinum* as larvae hence the swarm time of imagos begins later and they disappear in August or early autumn. Since the colonies of aphids appear in spring on the plants and their population increase during summer (Basky 2005), the aphidophagous hoverflies follow this temporal pattern, providing efficient food for their larvae.

The pan traps placed in the hedgerow and in the adjacent wheat field in different distances from the hedge showed higher species richness and abundance of hoverflies in 10 m in the wheat field than along the hedge. White pan traps have visually alluring effect on insects in the wheat field, especially in the absence of flowers (Sobota & Twardowski 2004; Sarthou et al. 2005; Kovács-Hostyánszki et al. 2011). But more probably the shady habitat inside the hedgerow caused by the closed canopy is not preferable for hoverflies (Röder 1990). Less species and individuals in aphidophagous and non-aphidophagous group were in the pan traps in the hedgerow (0 m), but without significant difference from the field. The number of individuals in both groups were the highest at 10 m and 20 m in the wheat field. Hoverflies are capable of flying long distance looking for flower resources however the most hoverfly species are known as non-migrants (Schweiger et al. 2007). They have preference for certain habitats according to the ecological and feeding requirements of larvae (Jauker et al. 2009) and flower availability for adults. Mainly aphidophagous species occurred in the pan traps and some non-aphidophagous species, e.g., *S. pipiens* and *Eristalis* spp. as well.

Trees and shrubs in the hedgerow provide physical protection against wind and rain (Tuzet & Wilson 2007), but they function partly as barrier in the distribution of hoverflies (Wratten et al. 2003). In addition shadow results in poor herbaceous vegetation and less foraging resources for flower-visiting hoverflies (Tóth 2008). Because of the lack of flowers, the interior of the hedgerow is not as suitable as a foraging habitat for hoverflies as their marginal area. The margin of the hedgerow was rich in flowers providing food resources for hoverflies, and as open habitat is more preferred by these insects. However, imagoes might utilize the wheat as food resource as well, because wheat produces high amounts of pollen as wind pollinated plant (Hjelle 1997). Since the wheat field was treated by chemicals, the aphids could survive in high number only in the hedgerow. The herbaceous vegetation in the margin affords suitable habitat for mated hoverfly females to lay their eggs, providing high abundance of aphids for larvae.

Compared to the efficiency of netting and pan traps in the hedge we found that netting was more successful method to sample hoverflies. The efficiency of netting could be the result of the sunny margin of hedgerow, which was rich in flowering vegetation hence provided sufficient habitat for adult hoverflies. From the hoverflies point of view there was a competition between pan traps in the hedgerow and flower rich margin, being more attracted to the flowers. Therefore pan traps in the hedgerow caught only few hoverflies.

Every species caught by pan traps was also sampled by net. Netting did not work well in the wheat field because of the disturbance of vegetation, which made hoverflies to fly away. Sobota & Twardowski (2004) also used pan traps (yellow) and netting in different crop fields and reported more hoverflies sampled by pan traps in the crop than by netting. The attractiveness of such traps to the imagos of hoverflies is mainly due to the strong attraction to yellow or white colour (Hickman et al. 2001). In some cases no difference was found between white and yellow traps in the sampling success of hoverflies (Bastian 1986; Barkemeyer 1984). In our study sampling with white pan traps was successful in the wheat field but not in the shady hedgerow, however we attribute this result not to the trap colour.

According to our results we can conclude that hedgerows play an important role as foraging and breeding habitats of hoverflies. Flower strips on the margin of hedgerows make more heterogeneous the agricultural landscape providing habitat for useful insects. Hoverflies, which are studied in this research, are important pollinators and biological pest control agents, therefore the maintenance of hedgerows and a grassy, flower rich margin along them is suggested from agricultural management point of view. Regarding sampling methodology, application of netting can be more suitable in similar ecological studies for hoverfly sampling in flower rich habitats, while pan traps function more effectively in the case of high and dense vegetation without flowers.

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Appendix 1. Recorded plant species in the three sampled transects along the hedgerow.

Trees and shrubs	Inside the hedgerow	Margin of the hedgerow
Aceraceae	*Acer platanoides* L. – Norway maple	
Corylaceae	*Corylus avellana* L. – common hazel	
Fagaceae	*Quercus robur* L. – English oak	
Oleaceae	*Fraxinus ornus* L. – manna ash	
Rosaceae	*Prunus cerasifera* Ehrh. – cherry plum	*Crataegus monogyna* Jacq. – common hawthorn
Salicaceae		*Salix fragilis* L. – crack willow
Ulmaceae	*Ulmus minor* Mill. – field elm	
Herbs		
Apiaceae		*Conium maculatum* L. – poison hemlock
	Anthriscus cerefolium L. Hoffm. – chervil	*Anthriscus cerefolium* L. Hoffm. – chervil
Asteraceae		*Artemisia vulgaris* L. – common wormwood
		Matricaria maritima L. – sea mayweed
		Ambrosia artemisiifolia L. – common ragweed
		Cichorium intybus L. – common chicory
		Achillea millefolium L. – yarrow
		Taraxacum officinale Weber – common dandelion
		Cirsium arvense L. – creeping thistle
Brassicaceae		*Capsella bursa-pastoris* L. Medicus – shepherd's-purse
		Lepidium draba L. – whitetop
	Alliaria petiolata M.B. Cav. et Gr. – garlic mustard	
Caryophyllaceae	*Stellaria media* L. – common chickweed	
Convolvulaceae		*Convolvulus arvensis* L. – field bindweed
Fabaceae		*Medicago lupulina* L. – black medic
		Trifolium repens L. – white clover
Lamiaceae	*Lamium purpureum* L. – red deadnettle	*Lamium purpureum* L. – red deadnettle
	Ballota nigra L. – black horehound	*Ballota nigra* L. – black horehound
Poaceae		*Bromus sterilis* L. – sterile brome
		Alopecurus pratensis L. – meadow foxtail
		Hordeum murinum L. – wall barley
Polygonaceae	*Rumex obtusifolius* L. – broad-leaved dock	
Rosaceae	*Geum urbanum* L. – wood avens	
Rubiaceae	*Galium aparine* L. – goose grass	
Urticaceae	*Urtica dioica* L. – common nettle	*Urtica dioica* L. – common nettle

Appendix 2. List of the sampled hoverfly species in the hedge and the adjacent arable field by pan traps and insect netting, and their relative abundance. Sign "+" means presence of the species/species was caught, sign "–"means absence of the species/species was not caught.

Hoverfly species	Relative abundance (%)	Diet of larvae	Sampling method	
			Net	Pan trap
Chrysotoxum arcuatum L., 1758	0.08	root aphids	+	–
Dasysyrphus albostriatus (Fallén, 1817)	0.25	aphidophagous	+	–
Epistrophe eligans (Harris, 1780)	0.2	aphidophagous	+	–
Epistrophe nitidicollis (Meigen, 1822)	0.2	aphidophagous	+	–
Episyrphus balteatus (De Geer, 1776)	**42**	aphidophagous	+	+
Eristalinus aeneus (Scopoli, 1763)	0.42	saprophagous	+	+
Eristalis arbustorum (L., 1758)	1.9	saprophagous	+	+
Eristalis pertinax (Scopoli, 1763)	0.25	saprophagous	+	–
Eristalis tenax (L., 1758)	2.7	saprophagous	+	+
Eumerus strigatus (Fallén, 1817)	0.08	phytophagous	+	–
Eupeodes corollae (F., 1794)	**10.2**	aphidophagous	+	+
Eupeodes luniger (Meigen, 1822)	0.34	aphidophagous	+	+
Melanostoma mellinum (L., 1758)	**6.2**	aphidophagous	+	+
Paragus haemorrhous Meigen, 1822	0.08	root aphids	+	–
Pipiza festiva Meigen, 1822	0.2	aphidophagous	+	–
Platycheirus scutatus (Meigen, 1822)	0.51	aphidophagous	+	–
Scaeva pyrastri (L., 1758)	0.6	aphidophagous	+	+
Sphaerophoria scripta (L., 1758)	**16.5**	aphidophagous	+	+
Syritta pipiens (L., 1758)	**15.6**	saprophagous	+	+
Syrphus ribesii (L., 1758)	0.34	aphidophagous	+	–
Syrphus vitripennis Meigen, 1822	1.02	aphidophagous	+	–
Xanthogramma pedissequum (Harris, (1776)	0.08	aphidophagous	+	–