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ORIGINAL ARTICLE

Effect of stinging nettle habitats on aphidophagous predators and parasitoids in wheat and green pea fields with special attention to the invader *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae)

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Abstract

The relative occurrence and seasonal abundance of aphids and their natural enemies were visually assessed between May and July 2005–2006 in four types of habitats located in Gembloux (Namur province, Belgium): green pea, wheat and stinging nettle either planted in or naturally growing in woodland adjacent to these crops. Results showed that: (i) *Acyrthosiphon pisum* Harris, *Sitobion avenae* F. and *Microlophium carnosum* Buckton were the most common aphid species, respectively, on green pea, wheat and stinging nettle either in or near field crops; (ii) stinging nettle and field crops shared several important aphidophagous insect species such as the ladybird *Coccinella septempunctata* L., hoverfly *Episyrphus balteatus* De Geer and braconid wasp *Aphidius ervi* Haliday; (iii) the shared beneficial species were typically recorded earlier on stinging nettles than on crops; and (iv) the spatial occurrence of the invasive ladybird *Harmonia axyridis* Pallas was distinctly associated with stinging nettles, particularly in 2005. Stinging nettles and field crops partially coincide in time, enabling the movement of natural enemies among them. These findings suggest that the presence of stinging nettles in landscapes seems to enhance the local density of aphidophagous insect communities necessary for aphid biocontrol in field crops.

Key words: Aphidae, Braconidae, Coccinellidae, diversity, Syrphidae, *Urtica dioica*.

INTRODUCTION

The impact of a natural enemy on a prey species can depend on the availability of alternative prey (Holt & Lawton 1994). Semi-natural habitats in agricultural landscapes can provide a wide range of ecological services including alternative preys. It is increasingly recognized that these habitats can help in sustaining beneficial arthropod species (Marshall & Moonen 2002; Frank & Reichhart 2004; Gurr *et al.* 2005). Among semi-natural habitats, the perennial and cosmopolitan stinging nettle *Urtica dioica* L. is well known as a source of food for a great diversity of insects (Greig-Smith 1948). According to Perrin (1975), the stinging nettle aphid *Microlophium carnosum* Buckton is attacked by a wide range of beneficial insects such as *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) and *Platycheirus scutatus* Meigen (Diptera: Syrphidae). Many studies have demonstrated that cultural practices affect natural enemy abundance, including crop rotation (Xia 1994), creation of hedgerows (Wratten & Thomas 1990; Dennis *et al.* 2000) and manipulation of non-crop habitat (Perrin 1975; Schellhorn & Sork 1997; Landis *et al.* 2000). Thomas *et al.* (1992) showed that grass banks provide overwintering refuge sites and that predator numbers increase with the age of these habitats. These last authors found also that the use of non-crop habitats within crops could successfully promote the movement of natural enemies into fields.

For ladybirds and hoverflies, the presence of non-crop habitats can influence abundance and dispersal in spring by providing a source of non-crop aphids (Wratten & Thomas 1990). The importance of ladybirds in biological control of aphids was clearly demonstrated by Hodek and Honěk (1996) and Iperti (1999). The exotic ladybird *Harmonia axyridis* Pallas is a polyphagous

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species originating from the Far East (Iablokoff-Khnzorian 1982) that prefers to feed on aphids (Hukusima & Kamei 1970; Iablokoff-Khnzorian 1982; Osawa 1992). In Belgium, while *H. axyridis* was first released for aphid biocontrol in 1997, its first feral population was recorded in Ghent in 2001, and it has now colonized the whole country (Adriaens *et al.* 2008).

Preliminary observations of *H. axyridis* in different types of habitats were conducted in Gembloux in 2005 (Alhmedi *et al.* 2007). While the 2005 assessments revealed that *H. axyridis* was largely present on stinging nettles and absent on field crops, we sought to know whether all the common representatives of the aphidophagous guild were also differentially distributed and associated with stinging nettle habitats. This paper determines the relative occurrence and seasonal abundance of predators (ladybirds, hoverflies) and parasitoids (braconid wasps) associated with aphids in green pea, wheat and stinging nettle either planted in or growing naturally in woodland adjacent to these crops. Data obtained through two growing seasons (2005, 2006) could be used in developing and subsequently evaluating integrated management strategies for aphid pests.

MATERIALS AND METHODS

The present study was carried out during the 2005 and 2006 growing seasons in 3–5 ha fields of wheat *Triticum aestivum* L. and green pea *Pisum sativum* L. located at the experimental farm of Gembloux Agricultural University (Gembloux, Belgium). Positioned within either wheat or green pea crops were two distinct patches (10 m × 20 m each) of planted stinging nettles (Fig. 1). Two stinging nettle patches of similar size were also delimited in rape crops in order to use them when the wheat crop replaces rape following the cropping rotation established at the experimental site. A two-year cropping rotation was established as follows: field 1 contained green pea in 2005 and rape *Brassica napus* L. in 2006, field 2 contained rape in 2005 and wheat in 2006 and field 3 contained wheat in 2005 and green pea in 2006. Two sampling areas (10 m × 20 m each) of wheat and two others of green pea were, respectively, selected each year in wheat and green pea crops (Fig. 1). Regarding the planted stinging nettle in field 3, the two patches established in the wheat crop in 2005 were maintained in 2006 within the green pea field. Stinging nettles in patches delimited within the experimental crops were planted on November 2004, at 200 plants per patch. Two stinging nettle patches of similar size, placed 100 m away from each another, were also selected within a natural nettle area (≈1000 m^2) located on 3 ha of woodland to study the effects of the natural nettle area size and age on aphidophagous populations; these patches were monitored during the 2005 and 2006 growing seasons. For each type of habitat, the two patches were established 100 m apart (Fig. 1). Thus, there were, in total, 10 insecticide-free patches sampled each year (Fig. 1). No insecticide treatment was applied to field crops (Table 1).

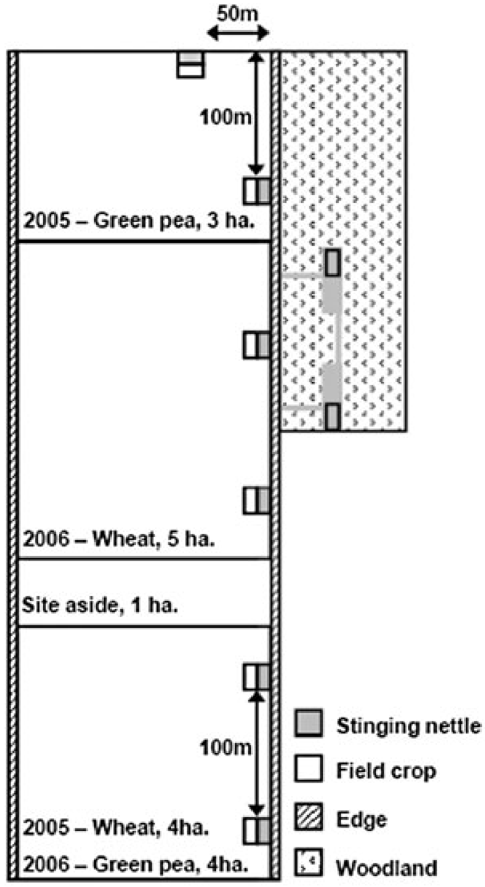

Figure 1 Layout of experimental site.

Field observations were conducted from early May to late July in 2005 and 2006 (12 weeks in total per year), until the field crops were harvested. Meteorological observations were provided by a permanent official station adjacent to the experimental site, located at Walloon Agronomic Research Center of Gembloux. Mean temperatures and rainfalls were higher in 2006 than in 2005 (22.2°C and 2.7 mm/day, 20.8°C and 1.4 mm/day, respectively). Once a week during the study period, aphids and their natural enemies were counted on 10 plants randomly sampled in each experimental patch. Aphid samples were returned to the laboratory and transferred to 70% ethanol in labeled tubes.

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Table 1 Herbicides, fungicides and fertilizers applied throughout green pea and wheat growing seasons in 2005 and 2006

Year	Treatment	Application date
Green pea crop		
2005	Challenge (Aclonifen)	4 April 2005
2006	Challenge (Aclonifen)	4 April 2006
Wheat crop		
2005	Nitrogen solution 39	4 April 2005
	Allie express (Metsulfuron-methyl and Carfentrazone)	22 April 2005
	Cycofix 720	5 May 2005
	Ammonitrate 27	11 May 2005
	Amistar (Azoxystrobine)	27 May 2005
	Opus (Epoxiconazole)	27 May 2005
2006	Nitrogen solution 39	13 April 2006
	Lexus Xpe (Metsulfuron-methyl and Flupyrsulfuro)	18 April 2006
	Platform (Carfentrazone and Mecoprop-P)	18 April 2006
	Cycofix 720 G (Chlormequat)	4 May 2006
	Nitrogen solution 39	5 May 2006
	Ammonitrate 27	1 June 2006
	Bravo (Chlorothalonil)	2 June 2006
	Opus (Epoxiconazole)	2 June 2006

Collected insects were identified to the species level. Hoverflies, ladybirds, lacewing larvae and mummified aphids were reared in the laboratory and identified at adult emergence.

Statistical analysis

To normalize the data, a $\log_{10}(n + 1)$ transformation was applied to the data prior to conducting one-way ANOVA and Tukey's test ($P < 0.05$).

RESULTS

Seasonal occurrence and abundance of aphid populations

Aphid population levels were higher in 2005 than in 2006, particularly in stinging nettle patches (Table 2). Among the aphid species recorded in the different habitats and listed in Table 2, *M. carnosum*, *A. pisum* Harris and *S. avenae* F. were, respectively, the predominant species on stinging nettle, green pea and wheat. Aphids occurred in significantly higher numbers on stinging nettles growing in the woodland than in the other patches ($F_{4,1195} = 68.91$, $P < 0.001$). Aphid populations began rising in early May (particularly in the natural area) and mid-June on stinging nettles and field crops, respectively (Fig. 2).

In the 2006 growing season, aphid populations showed similar distributions in the different habitats compared to the previous year. The green pea crop was significantly more infested by aphids compared to the other habitats ($F_{4,1195} = 48.71$, $P < 0.001$). From mid-May, aphids were observed on both stinging nettles and green pea crops, while aphid colonies were not seen on wheat until the third week of June. As in 2005, *M. carnosum* and *A. pisum* were the most common species, while *Metopolophium dirhodum* Walker was the dominant species in wheat patches.

Seasonal occurrence and abundance of aphidophagous populations

Ladybirds, hoverflies and braconid wasps were the main aphidophagous groups recorded in the different habitats (Table 2). Overall, they occurred in significantly higher numbers in 2005 compared to 2006 season (ladybirds $F_{1,2398} = 157.08$, $P < 0.001$, hoverflies $F_{1,2398} = 8.28$, $P = 0.004$, braconid wasps $F_{1,2398} = 47.59$, $P < 0.001$). They were typically observed earlier on stinging nettles then on field crops (Fig. 3).

In 2005, the main beneficial groups were significantly more abundant on stinging nettles growing in the woodland than in other habitats (ladybirds $F_{4,1195} = 35.76$, $P < 0.001$, hoverflies $F_{4,1195} = 6.33$, $P < 0.001$, braconid wasps $F_{4,1195} = 8.65$, $P < 0.001$).

In 2006, the aphidophagous population abundance was larger overall on green pea crops compared to other habitats (ladybirds $F_{4,1195} = 6.93$, $P < 0.001$, hoverflies $F_{4,1195} = 13.12$, $P < 0.001$, braconid wasps $F_{4,1195} = 20.46$, $P < 0.001$).

Because aphidophagous anthocorid, mirid and chrysopid species were only recorded on stinging nettles in 2005, their relative occurrence is not presented.

Ladybirds

Ladybirds constituted 53.7 and 34.9% of the total aphidophagous insects observed in 2005 and 2006, respectively (Table 2). *Harmonia axyridis* and *C. septempunctata* were the commonest constituting more than 95% of the total numbers of ladybirds, whereas the other four species were recorded at less than 5%.

In 2005, six ladybird species were recorded attacking aphid colonies in experimental patches, mainly *H. axyridis* and *C. septempunctata*. A particular occurrence of *H. axyridis*, *Adalia bipunctata* L. and *C. septempunctata* was observed in the experimental site in 2005. The first two species occurred mainly in stinging nettle patches throughout the observation season, whereas the

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Table 2 Total numbers of aphids and their natural enemies recorded in different habitats throughout 2005 and 2006 growing seasons

Species	Treatment											
	2005†						2006					
Aphids	Ns	Pg	Np	W	Nw	%‡	Ns	Pg	Np	W	Nw	%‡
Microlophium carnosum Buckton	7725	0	935	0	1355	63.8	405	0	90	0	685	35.7
Aphis urticata Gmelin	0	0	685	0	320	6.4	10	0	5	0	5	0.6
Acyrthosiphon pisum Harris	0	2745	0	0	0	17.5	0	1775	0	0	0	53.6
Macrosiphon euphorbiae Thomas	0	15	0	0	0	0.1	0	0	0	0	0	0.0
Sitobion avenae F.	0	0	0	1425	0	9.1	0	0	0	115	0	3.5
Metopolophium dirhodum Walker	0	0	0	505	0	3.2	0	0	0	220	0	6.7
Ladybirds			53.7%§						34.9%§			
Coccinella septempunctata L.	19	91	82	2	22	54.0	2	21	4	1	10	74.5
Harmonia axyridis Pallas	153	1	8	0	5	41.8	2	3	3	0	2	19.6
Propylea quatuordecimpunctata L.	3	0	0	3	1	1.8	0	1	0	1	0	3.9
Adalia bipunctata L.	6	0	1	0	1	2.0	0	0	0	0	1	2.0
Adalia decempunctata L.	1	0	0	0	0	0.3	0	0	0	0	0	0.0
Anatis ocellata L.	1	0	0	0	0	0.3	0	0	0	0	0	0.0
Hoverflies			4.6%§						13.0%§			
Episyrphus balteatus De Geer	10	7	2	9	0	82.4	0	10	0	2	1	68.4
Melanostoma mellinum L.	0	0	0	1	0	2.9	0	3	0	0	0	15.8
Platycheirus scutatus Meigen	1	0	0	0	0	2.9	0	0	0	0	0	0.0
Eupeodes nitens Zetterstedt	1	0	0	0	0	2.9	0	1	0	0	0	5.3
E. latilunulatus Collin	0	1	0	0	0	2.9	0	0	0	0	0	0.0
E. luniger Meigen	1	0	0	0	0	2.9	0	0	0	0	0	0.0
Sphaerophoria scripta L.	0	1	0	0	0	2.9	0	0	0	0	0	0.0
Scaeva pyrastri L.	0	0	0	0	0	0.0	0	2	0	0	0	10.5
Anthocorids			15.2%§						27.4%§			
Orius minutus L.	61	0	25	0	14	88.5	1	3	4	0	28	90.0
Anthocoris nemorum L.	4	0	4	0	0	7.1	3	0	0	0	1	10.0
Anthocoris nemoralis F.	3	0	2	0	0	4.4	0	0	0	0	0	0.0
Mirids			9.7%§						5.5%§			
Deraeocoris ruber L.	44	0	6	0	8	80.6	3	0	0	0	2	62.5
Heterotoma meriopterum Scop.	12	0	1	0	1	19.4	2	0	0	0	1	37.5
Chrysopids			0.4%§						1.4%§			
Chrysoperla carnea Stephens	0	0	1	0	2	100.0	1	1	0	0	0	100.0
Braconid wasps			16.5%§						19.2%§			
Aphidius ervi Haliday	26	7	0	8	1	34.2	0	8	1	0	1	35.7
A. rhopalosiphi De St. Perez	0	0	0	5	0	4.1	0	0	0	0	0	0.0
A. urticae Haliday	6	4	0	0	1	8.9	0	3	0	0	1	14.3
A. smithi Sharma et Subba Rao	1	6	0	0	0	5.7	0	12	0	0	0	42.9
A. picipes Nees	15	8	1	0	2	21.1	0	2	0	0	0	7.1
Praon volucre Hal.	0	0	0	2	0	1.6	0	0	0	0	0	0.0
Lysiphlebus fabarum Marshall	0	0	30	0	0	24.4	0	0	0	0	0	0.0
Total aphidophagous species	19	9	12	7	11		7	13	4	3	10	
%¶	32.8	15.5	20.7	12.1	19.0		18.9	35.1	10.8	8.1	27.0	

†First set of abundance results according to Alhmedi *et al.* (2007).
‡Proportional representation of each species by family.
§Relative occurrence of each family in aphidophagous populations.
¶Relative rate of overall aphidophagous species according to plant type. Np, Nw, stinging nettle planted within green pea and wheat crop respectively; Ns, stinging nettle growing naturally in woodland; Pg, green pea crop; W, wheat crop.

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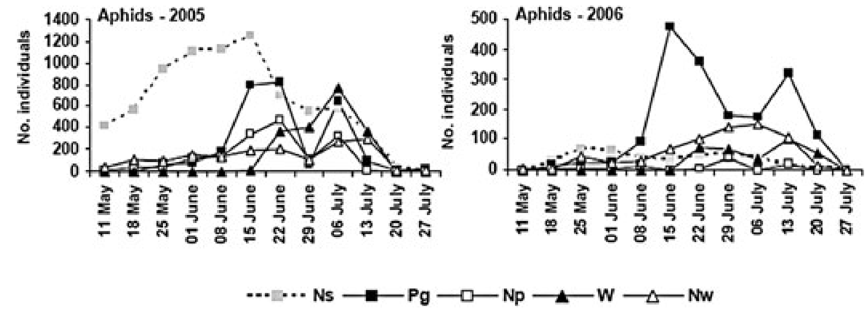

Figure 2 Seasonal occurrence and abundance of aphids recorded in the different habitats investigated in the 2005 and 2006 growing seasons. Ns, stinging nettles growing in natural area in the woodland; Np, Nw stinging nettles planted in green pea and wheat fields, respectively; Pg, green pea crop; W, wheat crop.

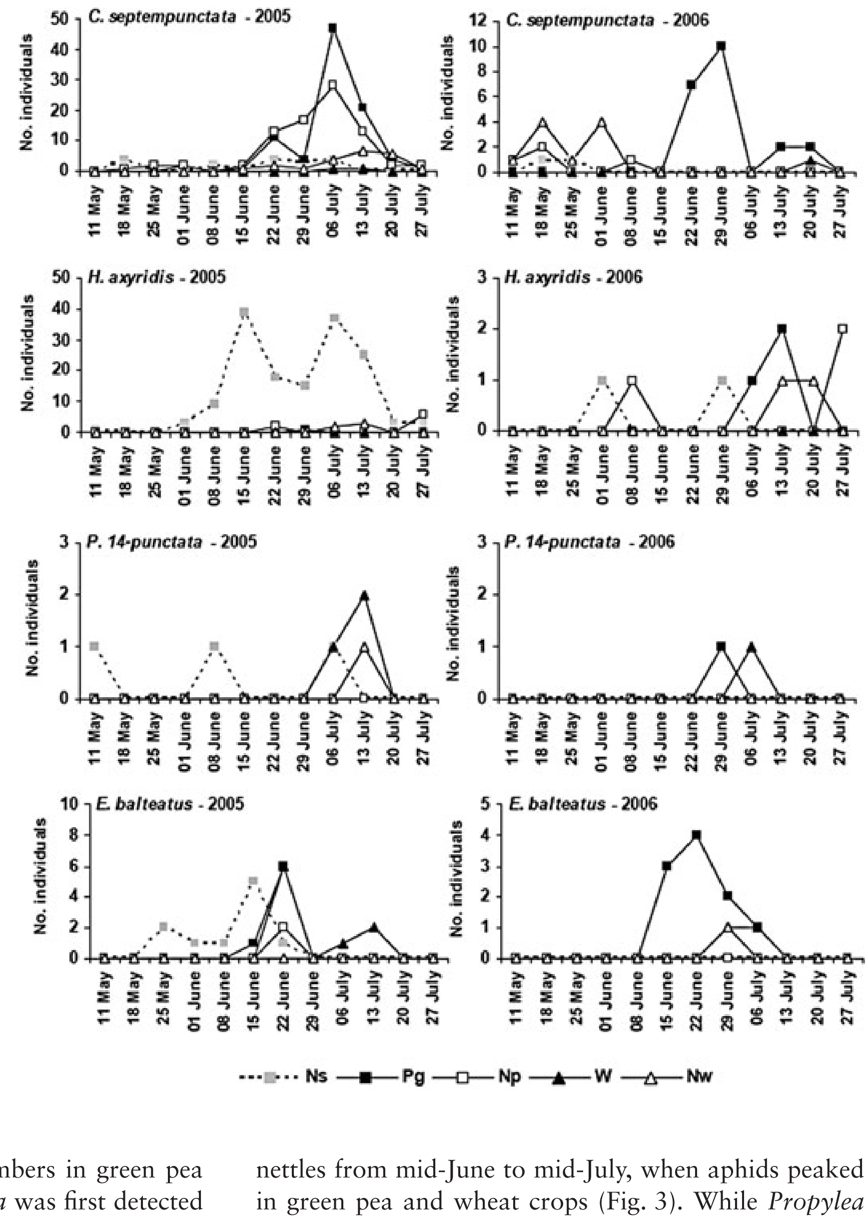

Figure 3 Seasonal occurrence and abundance of the main predatory species that preyed on aphids in stinging nettle, green pea and wheat patches through 2005 and 2006 seasons. Ns, stinging nettles growing in natural area in the woodland; Np, Nw, stinging nettles planted in green pea and wheat fields, respectively; *P. 14-punctata*, *Propylea quatuordecimpunctata*; Pg, green pea crop; W, wheat crop.

latter species occurred in higher numbers in green pea patches. However, *C. septempunctata* was first detected in early May on stinging nettles growing naturally in the woodland and later on field crops (early June, Fig. 3). The greatest numbers of ladybirds occurred on stinging nettles from mid-June to mid-July, when aphids peaked in green pea and wheat crops (Fig. 3). While *Propylea quatuordecimpunctata* L. was observed in lower numbers, it occurred earlier on stinging nettles growing in the woodland in the beginning of May. It was

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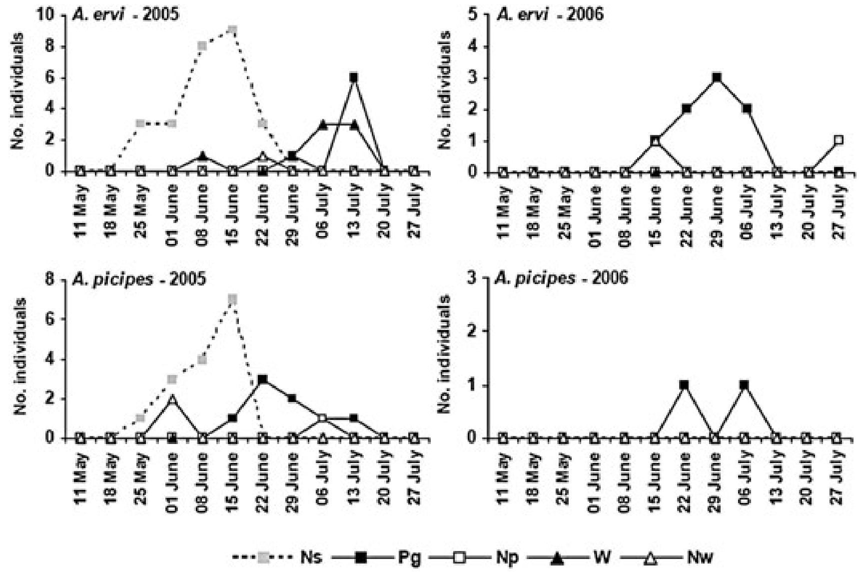

Figure 4 Seasonal occurrence and abundance of the main parasitoid species recorded parasitizing aphids on stinging nettles, green pea and wheat in the 2005 and 2006 seasons. Ns, stinging nettles growing in natural area in the woodland; Np, Nw, stinging nettles planted in green pea and wheat fields, respectively; Pg, green pea crop; W, wheat crop.

recorded later on field crops, particularly when wheat aphids peaked in early July (Fig. 3).

In 2006, among four ladybird species recorded in study sites *C. septempunctata* was the predominant species. Although this species occurred in high numbers on the green pea crop, it was first recorded in early May in stinging nettle patches before its arrival in field crops six weeks later (Fig. 3).

Hoverflies

Seven and four hoverfly species were recorded during 2005 and 2006 growing seasons, respectively. *Episyrphus balteatus* De Geer was the commonest hoverfly (82.4% of hoverflies in 2005, 68.4% in 2006) and it occurred in different habitats. During the 2005 growing season, *E. balteatus* occurred earlier, in late May, on stinging nettles growing in the woodland, 3–4 weeks before occurring on field crops (Fig. 3). However, this species was detected first on the green pea crop in 2006, and then two weeks later it was recorded attacking nettle (planted within wheat crop) and wheat aphids (Fig. 3).

Regarding the other species recorded during the two growing seasons, they occurred in lower densities constituting 15.7 and 35.3% of total hoverflies in 2005 and 2006, respectively. While *Eupeodes luniger* Meigen and *Platycheirus scutatus* Meigen occurred on stinging nettles only, *Melanostoma mellinum* L., *Eupeodes latilunulatus* Collin, *Sphaerophoria scripta* L. and *Scaeva pyrastri* L. were recorded attacking only crop aphids.

Braconid wasps

Among 278 mummified aphids observed during investigation years, 88.1% of the mummies were recorded in the 2005 growing season. All aphidophagous parasitoids that emerged from these mummies belonged to Braconidae family (Table 2). However, 44.4% of total adults that emerged were hyperparasitoids that belonged to three families: Magaspilidae, Pteromalidae and Figitidae.

In 2005, seven braconid species were recorded parasitizing aphids in the different habitats. *Aphidius ervi* Haliday was the commonest species with 34.2% of total parasitoids. It attacked *M. carnosum* colonies on stinging nettles growing in the woodland in the third week of May. However, the first mummies of *A. ervi* recorded on green pea and wheat crops were, respectively, in early and late June (Fig. 4). Densities of *A. ervi* started to increase and peaked on stinging nettles growing in the woodland before they did in field crops (Fig. 4). While *Lysiphlebus fabarum* Marshall was the second-most abundant species with 24.4% of the parasitoids, it attacked only *Aphis urticata* Gmelin on stinging nettles planted within green pea crop in the later half of June. *Aphidius picipes* Nees von Esenbeck (21.1% of the parasitoids) was the third commonest recorded through this season. Of *A. picipes* specimens, 57.7% were found earlier (late May) parasitizing *M. carnosum* in stinging nettle patches located in the woodland, 3–4 weeks before parasitizing (30.77% of *A. picipes* specimens) *A. pisum* on green pea crop (Fig. 4). Low numbers of *Aphidius rhopalosiphi* De Stefani Perez and *Praon volucre* Haliday (respectively, 4.1 and 1.6% of total parasitoids) were recorded parasitizing wheat aphids only.

In 2006, in response to aphid densities recorded in the different habitats through this season, 96.2% of mum-

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mified aphids were detected on the green pea crop. Among the four parasitoid species observed, *Aphidius smithi* Sharma et Subba Rao and *A. ervi* were the predominant species constituting, respectively, 42.9 and 35.7% of parasitoids. *Aphidius urticae* Haliday and *A. picipes* recorded in low numbers (respectively 14.3 and 7.1% of total parasitoids) through this season were found parasitizing mainly *A. pisum* on the green pea crop in early July and the third week of June, respectively.

DISCUSSION

The present field observations provide evidence that stinging nettles support aphidophagous insects and it is likely they contribute to the regulation of aphid populations in field crops. Regarding the impact of area size and age of stinging nettles on natural enemy populations, the patches delimited within the natural area of stinging nettle, especially in 2005, significantly supplied the field crops with higher densities of aphidophagous insects, mainly *C. septempunctata*, *E. balteatus*, *A. ervi* and *A. picipes*, compared to those located in green pea and wheat fields. Zabel and Tscharntke (1998) found that the small-scale habitat fragmentation of *U. dioica* caused a significant decrease in the diversity and population densities of associated insects; this finding can help us to understand the significant differences between stinging nettle patches. Small and isolated nettle habitats showed a reduced aphidophagous insect density and diversity compared to stinging nettle patches located in the woodland. In the present study, aphidophagous insects tended to occur first on natural stinging nettles growing in the woodland, before appearing in the small nettle habitats (delimited within field crops). The main result of this study is the differential susceptibility of aphids and their natural enemies to habitat type and fragmentation. Several interactions between crop and non-crop areas are important for many taxa (Thomas *et al.* 2001). Clear understanding of these interactions can support the design of field and margin arrangements that improve biological pest control in farmland and conserve the landscape scale benefits. However, the impact of a natural enemy on a focal prey species can depend on the availability of alternative prey (Holt & Lawton 1994).

Several biotic and abiotic factors can play an important role influencing the seasonal abundance and occurrence of aphids and their natural enemies. The variability in the climatic conditions between 2005 and 2006 may be among the factors influencing the demography of insect populations (both pest and beneficial). Higher temperatures and rainfall averages were recorded in 2006 than 2005. The temperature is well known as a key abiotic factor that regulates insect population dynamics, developmental rates and seasonal occurrence (Campbell *et al.* 1974; Logan *et al.* 1976; Schowalter 2000). Moreover, the intrinsic rate of increase in aphid populations, upper and lower developmental thresholds, fecundity and survivorship schedules are already found to be strongly influenced by temperature (Walgenbach *et al.* 1988; Aldyhim & Khalil 1993; Asin & Pons 2001). The decline observed in *H. axyridis* populations through the 2006 season may be explained by the evidence that the climatic changes often highly influence the density, stability and persistence of introduced species like *H. axyridis*, more than native species like *C. septempunctata* (McClure 1986; Myers 1990). However, this decline in *H. axyridis* likely caused the low densities of aphids recorded on stinging nettles through 2006 season.

In the present work, biotic factors such as fungus may also play an important role in the decline observed in aphid populations in 2006. According to Marti and Olson (2006), 60 and 90% of cotton aphid *Aphis gossypii* Glover populations were killed following attack by the fungus *Neozygites fresenii* Nowakowski in late June and early July, respectively. In our study, fungus attack seems to contribute greatly to the recorded decline, especially in *M. carnosum* populations through 2006 season, where its mainly apterous individuals were highly infected by fungus, unidentified in this work, particularly in late June and early July in 2005.

The occurrence of aphidophagous insects on stinging nettles was strongly related to nettle aphid *M. carnosum* population dynamics; this aphid is known as specific to the stinging nettle. For the successful biological control of aphids, there is a need to increase aphid natural enemy numbers in the spring prior to the early summer propagative phase of aphids (Powell 1986). While several aphidophagous species, such as *C. septempunctata*, *E. balteatus*, *A. ervi* and *A. picipes*, occurred earlier on stinging nettles before attacking later crop aphids, this study may support the strategy aimed to exploit this marginal plant in crop aphid biocontrol (Banks 1955; Perrin 1975; Honěk 1981).

A high occurrence of ladybirds was observed in both stinging nettle and crop habitats mainly when aphid populations peaked, suggesting that these predators can play a strong role in keeping aphid densities under economic thresholds in the study area (Hodek & Honěk 1996). Moreover, the early occurrence of aphidophagous populations on stinging nettles through 2005 and 2006 seasons compared to field crops may explain the presumed movement of these beneficial

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species from stinging nettle areas to adjacent crops. According to Hodek (1973) and Zhou and Carter (1992), *C. septempunctata* adults often crossed field boundaries during their dispersal from semi-natural to crop plant habitats.

The importance of the ladybird *H. axyridis* as a biocontrol against aphids has long been stressed (Osawa 2000; With *et al.* 2002). This polyphagous predator is known to have the ability to exploit resources in a wide range of habitats such as conifer woodland (McClure 1986), forage crops (LaMana & Miller 1996; Buntin & Bouton 1997), corn, soybean and wheat (Colunga-Garcia & Gage 1998), but the habitat associations observed for *H. axyridis* in this study were unexpected. Due to the spatial occurrence observed for *H. axyridis*, which was strongly linked to stinging nettle habitats as demonstrated in the present work, there is reluctance for this species to move toward fields when there are sufficient quantities of its host prey, *M. carnosum*, colonizing stinging nettles. *Harmonia axyridis* was detected in laboratory conditions to display preferential predation and oviposition for the stinging nettle–*M. carnosum* complex (Alhmedi *et al.* 2008). Therefore, *H. axyridis* is likely to be an unsuitable candidate for biological control via establishment of stinging nettle strips surrounding crop fields. Thus, we should be able to make predictions about how to implement effective cultural practices to manage pest insects by increasing our knowledge of natural enemies and pests in relation to habitat use. Future research is needed to determine how the process of cutting stinging nettle plants can be important for migration of the beneficial predators, particularly *H. axyridis*, to the adjacent crops. Moreover, the use of chemical attractants may be useful in orienting the beneficial movements towards field crops. (*E*)-β-farnesene, the well-known aphid alarm pheromone (Francis *et al.* 2005b) shows an attractive kairomonal effect on *C. septempunctata* (Al Abassi *et al.* 2000), *A. bipunctata* (Francis *et al.* 2001) and *E. balteatus* (Francis *et al.* 2005a). β-caryophyllene also has an attractive effect for *H. axyridis* (Verheggen *et al.* 2007). Further work is also needed to test these chemical substances in field conditions to assess their efficacy in attracting aphidophagous insects from semi-natural habitats towards field crops.

In conclusion, stinging nettle patches may be particularly important as reservoirs of natural enemies in agroecosystems (Perrin 1975) as long as they are not small and isolated. Habitat connectivity appears to be important for increasing aphidophagous insect populations in the agricultural landscape for possible biocontrol of actual or potential pests.

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