INTER- AND INTRA-GUILD INTERACTIONS RELATED TO APHIDS IN NETTLE (*URTICA DIOICA* L.) STRIPS CLOSED TO FIELD CROPS

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SUMMARY

A field experiment designed to assess the biodiversity related to nettle strips closed to crops, and more particularly the aphid and related beneficial populations, was established in experimental farm located in Gembloux (Belgium). Margin strips of nettle (*Urtica dioica*) closed to wheat (*Triticum aestivum*), green pea (*Pisum sativum*) and rape (*Brassicae napus*) fields were investigated. The diversity, abundance of aphids and related predators were analysed according to the plant crop species and the differential pesticide application (treated plot and control). Insects were visually observed every week during all the cultivation season. Two main families of aphidophagous predators were found in all field crops and nettle, the Coccinellidae and Syrphidae. The diversity of the aphidophagous predators was shown to be higher on nettle than in field crops, particularly the Chrysopidae, the Anthocoridae and the Miridae. However, a striking difference of ladybird abundance was observed according to the aphid host plant. In one side, *Coccinella septempunctata* was much more abundant on *Acyrthosiphon pisum* infested green pea than on the other host plant species. At the opposite, higher occurrence of *Harmonia axyridis* was observed on the aphid infested nettle plants than on the crop plants. In particular, none of *H. axyridis* was found in wheat crop. Also, more than only a significant positive correlation between predator and aphid abundance, specialised relations between particular aphid species and some so-called generalist predators was determined in the fields. Finally, intraguild interactions between the aphidophagous predators was assessed and shown that only a significant negative correlation between *Episyrphus balteatus* and *H. axyridis* related to the nettle aphid, *Micrlophium carnosum*, was observed. The relative distribution of the ladybirds, namely *C. septempunctata* and *H. axyridis* according to the host plant, nettle strips and crop plots was discussed in relation to integrated pest management approach.

Key words: Intraguild relations, Aphid, Beneficial, Insect, Diversity, Nettle, Arable margin strips.

INTRODUCTION

Insecticide applications in agricultural practices provide large environmental disturbances leading to the reductions of natural enemy populations and of species diversity richness (Los and Allen 1983; Booij and Noorlander 1988; Croft 1990). According to Marshall (1988), field margins are currently a key feature of agricultural landscapes, present in some forms at the edges of all agricultural fields.

The definitions of field margins varied and the etymology of the structures of field edges is equally diverse. Here, the term field margin is adapted from Greaves and Marshall (1987) and defined as the whole of the crop edge, any margin strip present and the semi-natural habitat associated with the boundary.

Therefore, habitat management can be considered as a subset of conserva-
tive biological control methods that improve availability of the resources
required by natural enemies for optimal performance. Among the margin
plants, the common nettle (*U. dioica* L.) is a common marginal, perennial and
cosmopolitan plant species and is known to be the source of food for a great
diversity of insects (Greig-Smith, 1948). According to Perrin (1975), the nettle
provides a significant and relatively sure habitat for beneficial insects, for
examples, aphidophagous predators such as *C. septempunctata, H. axyridis*
(Coccinellidae: Coleoptera), *Platycheirus albimanus* and *E. balteatus* (Syrphi-
dae: Diptera).
As previously, conservation biological control involves manipulation of the
environment to enhance developmental and reproductive parameters but
also the behaviour of natural enemies to increase their effectiveness. There-
fore, conservation practices can be further categorized as those that focus on
reducing mortality, providing supplementary resources, controlling secon-
dary enemies, or manipulating host plant attributes to the benefit of natural
enemies (Rabb *et al.*, 1976; van den Bosch and Telford, 1964). Because of its
importance in enhancing natural enemy performance, conservation biologi-
cal control should be a keystone of all biological control efforts (Gurr and
Wratten, 1999).
Studies investigating the importance of biodiversity for ecosystem functio-
ning have become widespread due to the currently rate of biodiversity loss
(Loreau *et al.* 2001). Many studies in this area have focused specifically on
the role of producer diversity (Tilman *et al.* 2002), whereas the consequences
of biodiversity loss at higher trophic levels have been often underlooked
(Duffy 2003; Naeem and Li 1998; Norberg 2000; Paine 2002; Duffy *et al.*
2003; Hillebrand and Cardinale 2004; Downing 2005).
Little is known about the impact of trophic interactions, particularly preda-
tor–predator and predator–prey interactions, on the relationship between
biodiversity and ecosystem functioning in natural systems (Morin 1995;
Wilby & Thomas 2002; Cardinale *et al.* 2003; Montoya *et al.* 2003; Finke &
Denno 2004; Snyder *et al.* 2005). Consequently, a multi-trophic perspective
will necessitate the consideration of additional mechanisms by which
changes in biodiversity might influence ecosystem functioning, including the
occurrence of intraguild predation (Ives *et al.* 2005).
The importance of diversity within higher trophic levels for prey suppression
and trophic cascades has been explored only recently and evidence is emer-
ging that changes in natural enemy diversity can, in fact, influence the func-
tioning of ecosystems (Morin 1995; Cardinale *et al.* 2003; Finke and Denno
2004).
Predator–prey studies leading to herbivore suppression by multiple predator
species suggest that there is a variety of mechanisms by which changes in
predator diversity could influence the occurrence of trophic levels (Sih *et al.*
1998; Snyder *et al.* 2005). Increasing predator diversity could promote tro-
phic cascades if predator species act additively (Snyder and Ives 2003) or
synergistically (Losey and Denno 1998; Cardinale *et al.* 2003), trophic
mechanisms that are analogous to resource use partitioning and facilitation
among producers (Fridley 2001), or hinder trophic cascades if these species
engage in intraguild predation (Polis *et al.* 1989; Rosenheim *et al.* 1993;
Finke and Denno 2002, 2003).

Intraguild predation is a widespread phenomenon in a variety of ecosystems (Polis *et al.* 1989; Rosenheim 1998; Arim & Marquet 2004) and its potential role in inhibiting trophic cascades has been documented, both empirically (Finke and Denno 2004) and theoretically (McCann *et al.* 1998; Hart 2002). Despite this fact, the importance of intraguild predation in mediating relationships between biodiversity and ecosystem function has been rarely addressed.

The study of the entomological biodiversity in wheat, green pea and rape agro-ecosystem, and the assessment of the closed environment effect on the entomological biodiversity was the objective of this work. We aimed to evaluate and use the aphidophagous predators occurring in the field crops and in closed nettle areas (marginal plant).

The study covered two aspects:

1. The abundance and diversity of aphids and their predatory aphidophagous in the experimental plots of nettle and field crops over season 2005.
2. Study of inter- and antra-guild interactions related to nettle strips crops, aphidophagous predators and their preys by visual observations.

MATERIALS AND METHODS

In 2005, three field crops (3-5 ha.) and a large natural marginal plant area were selected in the experimental farm located in Gembloux (Belgium). The field crops selected were wheat (*T. aestivum*), green pea (*P. sativum*) and rape (*B. napus*). Nettle (*U. dioica*), as marginal plant, was used to assess its effect on diversity of aphidophagous beneficials and the distribution in closed field crops. Nettle areas were planted in November 2004 (200 plants per 200 m²/plot).

Studies were performed between 4th May and 10th August 2005. Two replicates were realised for each field crop species and each was consisted of three designed plots (nettle, insecticide untreated and treated); all plots investigated were 10×20 m.

The assessments were weekly carried out; ten plants per plot were taken randomly to count and identify the number of aphids and aphidophagous predators present on each plant. Larvae of hoverflies and ladybirds were reared out in laboratory and the emerged adults identified.

The software SAS was used in statistic analyses. All data were summarised per plot, one-way analyses of variance and Student & Newman Keuls test were performed for treatment comparison. A correlation analysis was performed to study the coefficient signification between aphids and theirs predators.

RESULTS

Diversity and abundance of aphids and aphidophagous predators
Aphids

No significant difference in aphid abundance between treated and untreated plot in wheat and green pea was observed (Table 1). In particular, no aphids' infestation was recorded in rape. Two major aphid species were observed on wheat and pea crop as well on nettle (Table 2). The main observed species were *M. carnosum*, *A. pisum* and *S. avenae* on nettle, green pea and wheat respectively.

Table 1. Aphid abundance related to green pea and wheat plots observed between 04.05 and 10.08.2005

Plot	Average number of aphids ± SE	F	P
Green pea untreated	733.3±1617.9[a]	0.48	0.49
Green pea treated	644.0±1531.9[a]		
Rape untreated	0.1±1.7[a]	1.00	0.45
Rape treated	0.0±0.0[a]		
Wheat untreated	1041.3±2303.5[a]	0.04	0.83
Wheat treated	1003.3±2104.5[a]		

M. carnosum (specific species on nettle) was observed in the first week of the study and before the other species such as *A. urticata* that had very low abundance noticed late in the fourth week of June. In green pea plots, *A. pisum* was occurred on the fourth week of observation at the same time of *M. euphorbiae*. These two last species were observed at the beginning of the observation only with very low abundance. The wheat aphid species, *M. dirhodum* was observed first on wheat. Whether, *S. avenae* occurred later in the fourth week of June, it was globally more abundant on wheat than *M. dirhodum* (Table, 2).

Table 2. Abundance and diversity (total individual number/m²/week) of aphids and related predators assessed by visual observations between 04.05 and 10.08.2005

	Nettle in green pea	Green pea un-treated	Green pea trea-ted	Nettle in wheat	Wheat untreated	Wheat treated	Nettle in rape	Rape untreated	Rape treated	Nettle in natural reserve	%*	
Aphididae												
Microlophium carnosum	174.3	-	-	266.0	-	-	587.0	-	-	5256.7	47.4	
Aphis urticata	132.0	-	-	54.0	-	-	3.0	-	-	-	1.4	
Acyrtosiphon pisum	-	1466.7	1264.0	-	-	-	-	-	-	-	20.6	
Macrosiphon euphorbiae	-	-	16.0	-	-	-	-	1.0	-	-	0.1	
Metopolophium dirhodum	-	-	-	-	437.5	513.3	-	-	-	-	7.2	
Sitobion avenae	-	-	-	-	1645.0	1446.7	-	-	-	-	23.3	%**
Coccinellidae												
Coccinella septempunctata	14.6	48.5	22.4	3.8	2.3	7.0	5.2	-	-	15.3	50.5	
Harmonia axyridis	2.0	-	1.1	1.4	-	-	5.4	-	-	92.0	43.2	
Adalia 2-punctata	0.2	-	-	0.2	-	-	-	-	-	4.7	2.1	64.7
Propylea 14-punctata	-	-	-	0.2	3.5	1.2	1.0	-	-	2.7	3.6	
Adalia 10-punctata	-	-	-	-	-	-	-	-	-	0.7	0.3	
Anatis ocellata	-	-	-	-	-	-	-	-	-	0.7	0.3	
Syrphidae												
Episyrphus balteatus	0.4	3.7	3.2	-	11.7	5.9	0.8	-	-	6.7	89.0	
Metasyrphus latilunulatus	-	0.5	-	-	-	-	-	-	-	-	1.4	
Sphaerophoria scripta	-	0.5	-	-	-	-	-	-	-	-	1.4	
Metosyrphus nitens	-	-	-	-	-	-	-	-	-	0.7	1.8	10.1
Metasyrphus luniger	-	-	-	-	-	-	-	-	-	0.7	1.8	
Platycheirus scutatus	-	-	-	-	1.2	-	-	-	-	-	3.3	
Melanostoma mellinum	-	-	-	-	-	-	0.2	-	-	0.7	2.4	
Anthocoridae												
Orius minutus	6.0	-	-	3.4	-	-	10.0	-	-	38.0	88.7	
Anthocoris nemorum	0.6	-	-	-	-	-	0.4	-	-	2.7	5.7	17.7
Anthocoris nemoralis	0.4	-	-	-	-	-	0.6	-	-	2.7	5.7	
Miridae												
Deraeocoris ruber	1.2	-	-	2.8	-	-	3.0	-	-	15.0	83.8	7.0
Heterotoma meriopterum	0.2	-	-	0.2	-	-	0.2	-	-	3.7	16.2	
Chrysopidae												
Chrysoperla carnea	0.2	-	-	0.4	-	-	0.6	-	-	-	100.0	0.3

* Relative proportion of each species in family.
** Relative proportion of each family in aphidophagous predators.

Aphidophagous predators

No significant difference was observed for aphidophagous predator abundance between the treated and untreated plots in wheat and green pea. In contrast, highly significant differences were found in predatory beneficials in nettle and field crop plots (Table 3).
Among aphidophagous predators, ladybird beetles were the most abundant group and have a broad distribution compared with other observed predators, on different plots (Table 2). The occurrence of predatory anthocorids, mirids and green lacewings species were restricted on nettle only (Table 2). Anthocorid predators were noticed in the first week, O. minutus represented

the main observed species (88.7%). Mirid predators were observed later (second week of June) and were represented by a main species, *D. ruber* (83.8%). The only chrysope species that had very low abundance, *C. carnea*, was observed also late in the first week of June.

**Table 3**. Abundance (average number ± SE) of predators observed between the 04.05 and the 10.08.2005

Plot	All predators	Ladybird	Hoverfly
Wheat untreated	19.3±61.9[b*]	3.5±24.5[c]	6.4±41.2[a]
Wheat treated	19.8±70.2[b]	5.8±40.1[c]	2.9±26.6[ab]
Nettle in wheat	6.6±14.7[c]	3.1±10.4[c]	0.0±0.0[b]
Rape untreated	0.0±0.0[c]	0.0±0.0[d]	0.0±0.0[b]
Rape treated	0.0±0.0[c]	0.0±0.0[d]	0.0±0.0[b]
Nettle in rape	14.3±22.8[b]	6.7±21.1[c]	0.7±6.2[c]
Nettle in green pea	11.3±20.6[b]	9.1±20.8[c]	0.2±2.5[c]
Green pea untreated	19.2±46.0[b]	24.8±74.9[c]	3.5±22.9[ab]
Green pea treated	14.7±34.9[b]	12.5±33.9[c]	2.4±16.5[ab]
Nettle in natural reserve	88.7±107.9[a]	62.0±139.4[a]	6.7±27.5[a]
	F = 67.35	F = 32.28	F =4.08
	P<0.001	P<0.001	P<0.001

* Mean values within a column followed by the same letter are not significantly different, P<0.05.

Ladybird beetles

Ladybirds diversity was higher in nettle than in field crops (Table 3). Whether six ladybird species were observed in the different plots, *C. septempunctata* and *H. axyridis* were the most abundant (50.5% and 43.2% respectively). The beetle diversity was higher in nettle than in field crops: *A. 2-punctata*, *A. 10-punctata* and *A. ocellata* were only collected in nettle (Table 2).

The relative proportions of ladybird species observed were largely dependent on the plant species. We found a specific frequency of *C. septempunctata* and *H. axyridis*. Therefore, *C. septempunctata* was more frequent in field crops, while *H. axyridis* was more abundant in nettle (Figure 1)
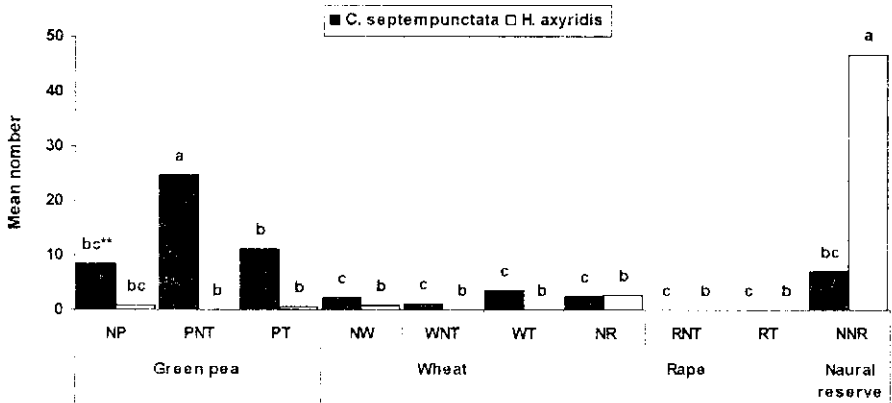
Figure 1. Abundance of *C. septempunctata* and *H. axyridis* according to the host plant (NP, NW, NR and NNR: nettle at green pea, wheat, rape and natural reserve areas respectively; PNT, PT, WNT, WT, RNT and RT: insecticide untreated and treated green pea, wheat and rape plots respectively.
** Mean values within a column followed by the same letter are not significantly different, P<0.05.

Hoverflies

The frequency of hoverfly species was higher on untreated wheat than on nettle (F=2.55 et P=0.01). Hoverflies species were weakly present on all plots observed through season 2005. In spite of that, seven hoverfly species were recorded; *E. balteatus* was the main species (89%) (Table 2).

Correlation analysis

In general, the coefficient of correlation between aphid species and their aphidophagous predators was significant (R=0.518 and P<0.001).
In nettle, a significant correlation was found between *C. septempunctata* and *A. urticata* (R=0.363 and P<0.001), but also a weak correlation with *M. carnosum* (R=0.058 and P=0.045). *H. axyridis* and *E. balteatus* have only an average correlation with *M. carnosum* (R=0.328 and P<0.001; R=0.336 and P<0.001 respectively). No significant correlation between the occurrence of *M. carnosum* and *A. urticata* was observed (R=-0.038 and P=0.185). Concerning aphidophagous predators, the correlation between *E. balteatus* and *H. axyridis* was significant (R=0.121 and P<0.001). In contrast, no significant correlation was found between combinations of both *E. balteatus* and *C. septempunctata* (R=0.055 and P=0.058) or of *H. axyridis* and *C. septempunctata* (R=-0.001 and P=0.966).
In green pea, the correlation coefficient between *A. pisum* with both *E. balteatus* and *C. septempunctata* was significant (R=0.43 and P<0.001; R=0.286 and P<0.001 respectively); while it was not significant with *H. axyridis* (R=0.001 and P=0.987). Also, statistic analyse is showed no significant correlation between combinations of both *E. balteatus* and *C. septempunctata* (R=-

0.020 and P=0.736), of *E. baleatus* and *H. axyridis* (R=-0.013 and P=0.823) or of *H. axyridis* and *C. septempunctata* (R=-0.032 and P=0.576).

In wheat, a significant correlation was showed between *S. avenae* and *C. septempunctata* (R=0.214 and P<0.001), but no significant correlation was found between *M. dirhodum* and *C. septempunctata* (R=0.043 and P=0.461). Whereas, the correlation coefficient was significant between *E. balteatus* and those aphids' species (R=0.206 and P<0.001; R=0.140 and P=0.001 respectively). A similar observation was noticed between wheat aphid species observed *S. avenae* and *M. dirhodum* (R=0.225 and P<0.001). At the aphidophagous predator level, there was not significant correlation between *C. septempunctata* and *E. balteatus* (R=0.212 and P<0.001).

DISCUSSION

An increasing number of studies suggested that species diversity within a trophic level can have effects on resource capture and on a food web (Root 1973, Russell 1989, Andow 1991, Sih *et al.* 1998, Tilman 1999, Naeem 2002). Our results showed that the trophic composition of the predator assemblage can play an important role in determining the nature of the relationship between predator diversity and ecosystem function. We found that increasing predator species richness influenced the occurrence of trophic cascades, but the magnitude and the direction of the effect depended on the trophic composition of the present predators. Several studies have suggested that the effect of diversity at one trophic level may depend on diversity in another trophic level (van der Heijden *et al.* 1998, Klironomos *et al.* 2000, Naeem *et al.* 2000). This has led to the prediction that trophic interactions will generate nonadditive effects of diversity among trophic levels (Holt and Loreau 2002). An increase in the predator species number was already shown to promote antagonistic intraguild interactions and resulted in lower prey consumption and in a higher density of herbivores. The plant productivity was the lowest at the highest level of predator species richness.

In our works, *A. urticata* was rare and due to the presence of *M. carnosum* on nettle. Also, a specific distribution was found for the aphidophagous predators and was related to the aphid species on host plant. Previous work already showed that *M. carnosum* could experience apparent competition with grass aphids (*Rhopalosiphum padi*) and the resident predators may be largely responsible for the local rarity of two aphid species (Müller and Godfray, 1999). It might be expected therefore that the local rarity of *A. urticata* could be due to present enemy-mediated competition with *M. carnosum* (Kean *et al.*, 2004). This phenomenon was noticed also in case of pea aphid species observed, *A. pisum* and *M. euphorbiae*. Similar observation was found with *H. axyridis* and *C. septempunctata* ladybirds. The frequency of *H. axyridis* on nettle was much higher than *C. septempunctata*. In contrast, *C. septempunctata* was much more abundant on green pea than *H. axyridis*.

The frequency of coccinellid species was higher than other aphidophagous predators. The specific distributions at plots observed for *C. septempunctata* and *H. axyridis* may be explained by inter- and intraguild interaction, host-plant and trophic prey.

As previously, habitat manipulations in agro-ecosystems could be attractive strategy of biological control (van Edmen, 1990). It is however rather cheap

and quite simple to increase the diversity of plants within or without crops to provide shelter or alternative sources of food to predators and parasitoïds. As *M. carnosum* is specific to nettle and the aphidophagous ladybirds observed were generalists, nettle presence is able to provide natural enemies reservoirs in the field crops. According to Perrin (1975), *C. septempunctata* and *Platcheirus albimanus* were the predatory main species in nettle in France. In this study realized in Belgium, *H. axyridis* and *E. balteatus* were the most abundant predatory species in nettle. The presence of specific aphid of nettle from May, before aphid occurrence in field crops allowed providing beneficials early for an effective control of aphid pests in field crops.

These results suggest that, under some circumstances, the simultaneous loss of diversity from two different trophic levels might not lead to any noTable change in the energy fluxes or matter through a food web. Reductions in plant and related natural enemy diversity are often concurrent particularly in highly simplified agricultural systems (Andow 1991, Benton *et al.* 2003).

Particularly, intraguild predation is likely to be a common mechanism mediating the impact of changes in predator diversity on the consequent of trophic cascade changes in a wide diversity of systems (Polis *et al.* 1989; Rosenheim 1998; Arim and Marquet 2004).

In conclusion, insect diversity and abundance can be increased by raising the diversity and area of non-crop vegetation. The specific management of particular insect species requires more detailed knowledge of their habitat requirement. However, the introduction of margin nettle into the agroecosystems is an important tool in this process. Therefore, further work is needed to determine the inter-specific interaction between *H. axyridis* and *E. balteatus* in the field and laboratory to be able to enhance biological control of aphids.

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