A three-year field study on the short-term effects of insecticides used to control cereal aphids on plant-dwelling aphid predators in winter wheat

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Abstract: Short-term effects of six insecticides used to control aphids were assessed in wheat on plant-dwelling aphid predators. Products were applied to small plots of winter wheat in June or at the beginning of July and the densities of predators were estimated three days after treatment using a beating method. Insecticides were tested in 1994, 1995 and 1997 at a single dose, corresponding to their maximum recommended field rate in Belgium. Fluvalinate and esfenvalerate did not significantly reduce catches of syrphid larvae compared to the control but ladybirds were affected by these compounds. Pirimicarb was the only product tested that had no effect on ladybirds. However, syrphid larvae appeared sensitive to this product. Cyfluthrin, deltamethrin and phosalone reduced catches of both syrphids and ladybirds. Populations of lacewing larvae were unaffected by any of the insecticide treatments. Syrphid larvae were the most abundant aphid predator and *Episyrphus balteatus* the most common species. Ladybirds (*Coccinella septempunctata* and *Propylea quatuordecimpunctata*) were less numerous and only a few *Chrysoperla carnea* larvae were recorded. These results indicate that products that are less toxic to syrphid larvae, like esfenvalerate and fluvalinate, may be preferable to other compounds to control cereal aphids in wheat in spring and early summer. However, other criteria, such as the effectiveness of the different aphid-specific predators, cost, efficacy of the treatment and side effects on other aphid antagonists (including parasitic hymenoptera and polyphagous predators) must also be taken into consideration.
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Keywords: insecticides; aphid predators; non-target effects

1 INTRODUCTION

The importance of plant-dwelling predators in the control of cereal aphid populations in wheat in Western Europe has been described by a number of authors.[1–13] Hoverflies, ladybirds and, to a lesser extent, lacewings are able to limit aphid population development and in some years maintain aphids below their economic threshold.

Results of ecotoxicological studies conducted in the laboratory and in the field demonstrated that these predators can be greatly affected by insecticides. Observations of aphid population development in winter wheat fields showed that outbreaks of aphids can sometimes occur after an insecticide application.[14] The reason or one of the reasons for these outbreaks is the elimination of aphid natural enemies by non-selective treatments. Thus, there is a need to select and use insecticides that minimise effects on plant-dwelling aphid predators at recommended application rates.

Several compounds are registered for the control of cereal aphids in summer in Belgium. Only products containing a single active ingredient have been studied. Most were pyrethroids (cyfluthrin, deltamethrin, esfenvalerate and fluvalinate), with one carbamate, pirimicarb, and one organophosphate, phosalone. Results of the Joint Testing Programmes of the IOBC working group 'Pesticides and Beneficial Organisms' showed that phosalone and pirimicarb were moderately harmful to syrphid larvae (*Syrphus vitripiennis* Meigen) and harmless for lacewings larvae (*Chrysoperla carnea* (Stephens)) in laboratory trials; deltamethrin was moderately harmful to *C carnea* and harmful for *S vitripiennis* and ladybird larvae (*Coccinella septempunctata* L).[15,16] Pirimicarb was also found to be harmful to larvae of the hoverfly *Metasyrphus corollae* (F), but this product did not harm *C carnea* larvae nor adults and larvae of *C septempunctata* in the laboratory.[17] The greater sensitivity of hoverflies in comparison with ladybird larvae to pirimicarb has also been observed, with ED_{50} values about 60× higher for *C septempunctata* than for *Syrphus* sp.[18] Esfenvalerate was less toxic than deltamethrin to larvae of *C*

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septempunctata in laboratory tests.[19] Side effects of compounds used in Belgium to control aphids on larvae of the syrphid *Episyrphus balteatus* (Degeer) have recently been studied in the laboratory.[20] Fluvalinate had no effect on syrphid larvae and esfenvalerate and bifenthrin were slightly harmful in a worst-case laboratory test. Other compounds were harmful and needed semi-field or field evaluation for the assessment of their side effects on hoverflies.

There have been few field studies to support these laboratory results. The effects of phosalone and deltamethrin were assessed at recommended field rate in France on the epigeal fauna of winter wheat fields.[21] Neither insecticide affected lacewing larvae. In the same study, no information about the toxicity of the products on coccinellids and syrphids was forthcoming because they were too scarce at the time of the treatment or because the sampling method was not appropriate. Effects of reduced doses of pirimicarb on hoverfly larvae were studied in a wheat field in Germany.[22] Applied at rates of 100 and 50 gAI ha^{-1}, pirimicarb was harmful to syrphids and a certain degree of selectivity appeared only at an application rate of 25 gAI ha^{-1}.

Relative to the range of products that can be used in Belgium to control cereal aphids, there is a lack of information, especially in the field, on the possible side effects of these compounds on plant-dwelling predators in wheat. Thus, specific trials were undertaken to determine the short-term effects of six compounds, four pyrethroids (cyfluthrin, deltamethrin, esfenvalerate, fluvalinate), pirimicarb and phosalone.

2 EXPERIMENTAL METHODS

Trials were carried out in 1994, 1995 and 1997 in winter wheat fields in the area of Gembloux, Belgium. Wheat was cultivated according to the usual agricultural practice for Belgium. Trials planned in 1996 were not undertaken because the populations of aphids and aphid predators were very low, except at the end of the season. The six insecticides were tested as two sets of three products with a control in each set. Each set included three plots per product and three plots left untreated as the control. Experiments were done in a fully randomised block design. The same experimental design was used each year, with a total of 3 × 3 replicates per treatment. Plots were 3 m wide and 10 m long, and were isolated from each other by 2-m buffer zones where plants were cut to the ground one to two weeks before the start of the experiments. Tested products and doses were pirimicarb 500 g kg^{-1} WG (Pirimor; Zeneca) at 125 gAI ha^{-1}, deltamethrin 25 g $litre^{-1}$ EC (Decis 25; Agrevo) at 5 gAI ha^{-1} and esfenvalerate 25 g $litre^{-1}$ EC (Sumi Alpha; Cyanamid Agro) at 5 gAI ha^{-1} in set 1, and phosalone 500 g $litre^{-1}$ EC (Zolone Flo: Rhône-Poulenc Agro) at 750 gAI ha^{-1}, cyfluthrin 50 g $litre^{-1}$ EC (Baythroid 050; Bayer) at 15 gAI ha^{-1} and fluvalinate 240 g $litre^{-1}$ EC (Mavrik 2F; Sandoz) at 36 gAI ha^{-1} in set 2. These products were applied at the maximum recommended field rate for Belgium using a knapsack sprayer connected to a 3-m boom with six Azzo 110° nozzles, at a pressure of 3.5 bar and a spray volume of 300 litre ha^{-1}.

Treatments were made at the end of June or beginning of July, when populations of aphids and predators were high. Details of date of application, growth stages of wheat according to Zadoks scale[23] and climatic conditions during the experiments are given in Table 1. Climatic information was provided by the meteorological station of Ernage, located near Gembloux at a maximum of 5 km from the trials.

In 1994, plant-dwelling predators were sampled using a beating method. Three days after treatment, plastic gutters (1 m long, 12 cm wide) were put on the ground between two rows of wheat and plants were shaken energetically during one min on both side of the gutters. Insects that fell in the gutters were collected in glass vials and brought back to the laboratory in a cooled box for counting and identification. Three samples of three 1-m lengths of gutter placed between four rows of wheat were taken in each plot, avoiding the first and last metre of the plots which were regarded as borders. In 1995 and 1997, insects were sampled with a rectangular sweep net (40 × 15 cm). The nets were pushed along the rows near the bases of the plants for a pre-determined distance (3 m) as the plants between them were shaken to dislodge plant-dwelling predators. Ten samples each of 3 m length were taken from each plot three days after treatments, excluding the first and last metre of the row as in 1994. Insects that fell into the nets were placed in glass vials and brought back to the laboratory in a cooled box. Using the sweep net to collect the insects was preferred to the plastic gutter because it was easier to use, especially when the plants were wet. Comparison of the two sampling techniques in 1995 (Jansen J-P.,

Table 1. Date of insecticide treatment, crop growth stage (Zadoks scale) and climatic conditions during the experiments, from treatment to sampling

		Date of treatment	*Crop growth stage*	*Mean temp (°C)*	*Min-max temp (°C)*	*Rainfall (mm)*
1994	Set 1	1 July	65	22.9	15.0–31.5	0.0
	Set 2	5 July	69	15.0	8.2–19.7	5.8
1995	Set 1	7 July	69	22.5	12.0–31.2	0.0
	Set 2	11 July	71	20.5	15.3–28.5	12.6
1997	Set 1	30 June	65	14.3	10.3–18.7	21.6
	Set 2	4 July	69	15.7	10.0–21.0	8.6

	1994	1995	1997	Three-year mean	Significance[a]
Set 1					
Control	30.3 (±6.4)	14.0 (±0.8)	19.3 (±3.1)	21.2 (±3.0)	
Deltamethrin	28.3 (±3.2)	11.3 (±4.0)	7.7 (±3.8)	15.8 (±6.8)	NS
Esfenvalerate	37.3 (±16.6)	22.7 (±7.8)	25.7 (±5.3)	28.6 (±9.6)	NS
Pirimicarb	6.7 (±3.1)	7.0 (±2.9)	10.3 (±4.8)	8.0 (±4.6)	**
Set 2					
Control	15.7 (±3.2)	7.3 (±2.9)	30.7 (±5.4)	17.9 (±4.8)	
Cyfluthrin	5.3 (±0.6)	3.0 (±2.4)	13.3 (±4.0)	7.2 (±3.9)	**
Fluvalinate	15.3 (±8.1)	3.7 (±2.9)	30.7 (±8.3)	16.6 (±8.7)	NS
Phosalone	4.0 (±2.0)	1.3 (±1.2)	18.7 (±2.9)	8.0 (±5.2)	**

[a] Dunnett test, NS = not significant, $P > 0.05$, * = significant, $P < 0.05$, ** = highly significant, $P < 0.01$.

Table 2. Numbers of syrphid larvae sampled per plot in winter wheat three days after treatment with insecticides. 1994, 1995 and 1997: mean of three replicates (±Sd). Three-year mean: mean of nine replicates (±Sd).

unpublished data) showed no significant differences in the number of syrphid larvae, ladybird adults and larvae and lacewings that were collected (3 × 5 samples taken randomly using each technique from the same field). Furthermore, active arthropods such as earwigs, soldier bugs and spiders that tended to escape from the gutter during sampling were more easily collected with the nets.

In the laboratory, arthropods were identified to species and counted. Ladybirds and lacewings were identified to species directly, whereas syrphid larvae and pupae were reared until adult emergence for a more reliable identification. Statistical analysis of the results was by ANOVA with comparison between treatments and control according to Dunnett test.[24]

3 RESULTS

Numbers of aphid predators collected per plot during the three-year study are listed in Table 2 (syrphid larvae), Table 3 (coccinellid adults and larvae) and Table 4 (lacewing larvae). Results of the Anova test are listed in Table 5. Analysis shows that significant differences in mean predator numbers occurred between insecticide treatments and between years but not between blocks. Other predators that are known to feed on aphids were also collected but there were too few (spiders, adults of Carabidae and Staphylinidae) or numbers were too variable between plots (earwigs, soldier bugs, larvae of Staphylinidae and Carabidae) for an adequate statistical analysis of the results.

Relative abundance and species composition of aphid predators sampled during the three years of the experiment are listed in Table 6. Syrphid larvae clearly appear to be the major specific plant-dwelling aphid predators observed during the study. *E balteatus* was the dominant species, with a minimum of 60% of the total syrphid numbers each year. Other species sometimes reached 10% of the total: *S vitripiennis* and *S ribesii* in 1994 and *Sphaerophoria scripta* (L) in 1997. Coccinellids were numerous in 1994 but scarce in 1995 and 1997. Two species were recorded, *Propylea quatuordecimpunctata* (L), which was present every year, and *C septempunctata*, found only in 1994 and 1995. Larvae of *C carnea* were found every year in relatively low numbers, except in 1995, when they were more numerous. No other lacewing species were recorded.

In the first set of treatments, populations of syrphid larvae were reduced by pirimicarb but not by deltamethrin and esfenvalerate (Table 2). In the second set of treatments, fluvalinate appeared to have no significant effect on syrphid numbers, while populations of this predator were reduced in a highly significant way in plots treated with phosalone and cyfluthrin.

	1994	1995	1997	Three-year mean	Significance[a]
Set 1					
Control	16.7 (±11.1)	4.0 (±1.6)	1.7 (±1.7)	7.4 (±5.3)	
Deltamethrin	2.3 (±1.5)	0.0 (±0.0)	0.0 (±0.0)	0.8 (±1.3)	**
Esfenvalerate	4.3 (±1.5)	1.7 (±1.7)	1.3 (±0.0)	2.3 (±1.6)	NS
Pirimicarb	15.3 (±2.5)	3.0 (±0.8)	2.7 (±0.9)	7.0 (±3.3)	NS
Set 2					
Control	10.7 (±5.1)	3.0 (±2.2)	2.7 (±0.9)	5.4 (±4.6)	
Cyfluthrin	0.7 (±1.2)	0.7 (±0.7)	0.0 (±0.0)	0.6 (±0.8)	**
Fluvalinate	2.7 (±0.6)	0.0 (±0.0)	1.0 (±0.8)	1.2 (±1.2)	**
Phosalone	2.0 (±1.7)	0.0 (±0.0)	0.0 (±0.0)	0.9 (±1.3)	**

[a] Dunnett test, NS = not significant, $P > 0.05$, * = significant, $P < 0.05$, ** = highly significant, $P < 0.01$.

Table 3. Numbers of ladybird larvae and adults sampled per plot in winter wheat three days after treatment with insecticides. 1994, 1995 and 1997: mean of three replicates (±SD). Three-year mean: mean of nine replicates (±SD)

Table 4. Numbers of lacewings larvae sampled per plot in winter wheat three days after treatment with insecticides. 1994, 1995 and 1997: mean of three replicates(±SD). Three-year mean: mean of nine replicates (±SD)

	1994	1995	1997	Three-year mean	Significance[a]
Set 1					
Control	0.7 (±0.5)	4.3 (±0.9)	3.0 (±0.8)	2.7 (±1.2)	
Deltamethrin	0.7 (±0.5)	4.0 (±0.8)	1.3 (±1.2)	2.0 (±1.4)	NS
Esfenvalerate	0.7 (±0.5)	4.3 (±0.5)	1.3 (±1.2)	2.1 (±1.4)	NS
Pirimicarb	0.3 (±0.5)	5.0 (±3.6)	1.7 (±1.2)	2.3 (±2.3)	NS
Set 2					
Control	1.7 (±0.5)	4.3 (±0.5)	3.0 (±2.1)	3.0 (±1.4)	
Cyfluthrin	2.3 (±1.2)	4.3 (±2.6)	1.3 (±1.2)	2.7 (±1.7)	NS
Fluvalinate	1.0 (±0.8)	4.3 (±0.9)	3.3 (±3.4)	2.9 (±2.4)	NS
Phosalone	1.7 (±0.5)	3.7 (±1.2)	5.3 (±2.1)	3.6 (±1.8)	NS

[a] Dunnett test, NS = not significant, $P > 0.05$, * = significant, $P < 0.05$, ** = highly significant, $P < 0.01$.

Compared to syrphids, populations of ladybird larvae and adults were lower but highly significant differences between control and treatments were obtained (Table 3). Deltamethrin in the first set of treatments and cyfluthrin, fluvalinate and phosalone in the second set reduced ladybird populations while pirimicarb had no effect at this application rate. There were no significant differences between populations of ladybirds in untreated plots and in plots treated with esfenvalerate, but results of the Dunnett test showed that the value of $P = 0.05$ was nearly obtained (0.0502).

Populations of lacewing larvae were small but with little variability between replicates (Table 4). No treatment significantly reduced populations of this predator.

4 DISCUSSION

Statistical analysis of the results of the three years of trials clearly shows that the insecticides used in wheat to control aphids in these trials had different short-term effects on plant-dwelling aphid predators. At the application rates tested, none of them can be considered to have impact on populations of the species of hoverflies, ladybirds and lacewings monitored in this study. Pirimicarb had no significant effect on numbers of ladybird adults and larvae, but catches of hoverfly larvae were significantly reduced three days after treatment. Fluvalinate and esfenvalerate were the only two products that did not reduce numbers of syrphid larvae, but populations of ladybirds were affected by these compounds at the application rates used. The other products (cyfluthrin, deltamethrin, phosalone) reduced populations of both predators to different extents. These conclusions are in accordance with those previously published for pirimicarb, deltamethrin and phosalone in the laboratory or in the field.[15–17,22,25] The lack of effect of fluvalinate and esfenvalerate on syrphid larvae in the field parallels the results observed on *E balteatus* larvae on glass plates in the laboratory.[20]

Table 5. Statistical analysis of the results (ANOVA) of the three years of experiment

Object	Source of variation	DF	Mean square	F	P	Significance[a]
Set 1 (control 1, deltamethrin, esfenvalerate, pirimicarb)						
Hoverflies	Year	2	488.69	6.41	0.032	**
	Treatment	3	678.41	13.04	<0.001	**
	Block	6	76.19	1.46	0.232	NS
Ladybirds	Year	2	35.19	0.55	0.605	NS
	Treatment	3	47.40	11.35	<0.001	**
	Block	6	5.81	2.18	0.080	NS
Lacewings	Year	2	45.86	16.19	0.004	**
	Treatment	3	0.78	0.37	0.774	NS
	Block	6	2.83	1.36	0.272	NS
Set 2 (control 2, cyfluthrin, fluvalinate, phosalone)						
Hoverflies	Year	2	1189.75	33.91	0.001	**
	Treatment	3	280.69	10.42	<0.001	**
	Block	6	35.08	1.30	0.294	NS
Ladybirds	Year	2	35.19	6.06	0.036	*
	Treatment	3	47.36	9.34	<0.001	**
	Block	6	5.81	1.15	0.367	NS
Lacewings	Year	2	0.05	0.12	0.892	NS
	Treatment	3	0.16	0.35	0.788	NS
	Block	6	0.40	0.86	0.538	NS

[a] ANOVA test, NS = not significant, $P > 0.05$, * = significant, $P < 0.05$, ** = highly significant, $P < 0.01$.

Table 6. Relative abundance and species composition of larvae of syrphids and lacewings and of ladybird larvae and adults collected in 1994, 1995 and 1997 (2 × 12 plots per year). NF=not found.

	1994	1995	1997	Three years
Total number of syrphids collected:	429	211	469	1111
of which:				
Episyrphus balteatus (%)	66.7	93.7	62.7	70.0
Sphaerophoria scripta (%)	1.0	NF	16.6	7.4
Syrphus vitripiennis (%)	10.4	0.3	4.1	5.8
Scaeva pyrastri (%)	4.7	NF	7.0	4.8
Syrphus ribesii (%)	10.9	NF	NF	4.2
Metasyrphus corollae (%)	3.6	0.9	5.5	3.9
Melanostoma scalare (%)	NF	4.1	1.1	1.3
Baccha sp (%)	NF	0.3	NF	0.1
Platycheirus sp (%)	NF	0.3	NF	0.1
Parasitism (*Diplazon sp.*) (%)	2.7	0.3	3.0	2.4
Total number of ladybirds collected:	170	37	28	235
of which:				
Propylea quatuordecimpunctata(%)	54.7	100.0	100.0	67.2
Coccinella septempunctata (%)	45.3	NF	NF	32.8
Total number of lacewings collected:	27	103	28	158
of which:				
Chrysoperla carnea (%)	100.0	100.0	100.0	100.0

Populations of lacewing larvae were not reduced by the insecticide treatments, indicating that this predator was perhaps more tolerant than ladybirds and hoverflies to these insecticides. However, lacewings are rarely found in great numbers in wheat and their effects on aphid populations are limited. They feed on a wide range of prey, including aphids, leaf-hoppers, thrips, eggs and larvae of lepidoptera, diptera, beetles and sawflies and they are considered more as a polyphagous predator than an aphid-specific predator.[26,27] As such, lacewing larvae are also important in the limitation of wheat pests of secondary economic importance as, such thrips, lepidoptera and cereal leaf beetle. The fact that they are more-or-less tolerant to insecticides applied to control cereal aphids could guarantee that they continue to provide natural control of these secondary pests.

In this study, the measurement of the impact of insecticides on beneficial insects was limited to their short-term effects, three days after treatment. Studies have shown that *E balteatus*, the most numerous aphid predator found in this study, is only able to complete one generation on wheat in the Netherlands under climatic conditions similar to those in Belgium.[28] Furthermore, aphid infestations in wheat occur only for short periods and the critical phase, when a decision of whether or not to apply an aphicide must be made, is very brief. Thus, in this context, the short-term toxicity of a product to aphid predators can be sufficient to cause population reduction, even if its persistence of action is limited in time. In addition, in field tests with insecticides it is difficult to distinguish between the direct effects of products on beneficials and the impact on their populations caused by the reduction of the food available. By sampling three days after treatment, it was assumed that effects that were recorded on hoverfly and ladybird numbers were largely the result of the direct toxicity of the insecticides.

Sampling methods greatly affect the results of field studies. The use of a D-Vac, or plant searching by visual inspection, for the sampling of plant-dwelling predators has been recommended and these two methods are the most commonly used.[29] Nevertheless, both methods have their limitations. In a comparative study of D-vac sampling and visual inspection, it was found that D-vac sampling was not suitable for some taxa, including syrphid larvae.[30] D-vac was also used in an entomofaunic inventory of wheat, but only ladybirds and lacewing larvae were sampled, while adults of syrphids were detected in great numbers by trapping (yellow water traps), indicating that syrphid larvae might also be present on the crop.[21] It was also found that the D-vac could only be used on dry and low vegetation (max 70 cm height). Visual inspection is the easiest method to use for the determination of the aphid population level and, simultaneously, aphid predator density. However, when predator population densities are small, a large number of tillers must be inspected to obtain analysable data. Furthermore, it is not always possible to manipulate tillers without disturbing mobile insects, including ladybirds and lacewings, and because young and small predator larvae, like first-instar larvae of syrphids, ladybirds and lacewings, are not always easily seen, visual inspection of wheat can sometimes lead to an underestimation of aphid predator population levels.

An alternative method was used for sampling aphid predators in plots treated with different insecticides.[25] Pieces of plastic trough were placed on the ground of wheat plots and after treatment, dead insects that fell into the troughs were collected and counted. Low variability in the results permitted the demonstration of statistically significant differences between control and treated plots. However, this method gave information only on numbers of insects killed by insecticides without indicating the numbers of surviving ones, which are the most important, or the initial population level before the treatments were applied. This greatly limits the interest in the results.

For the present study, an original sampling method was developed. It is partly based on the methodology of Hellpap[25] and on the work done by De Proft and Latteur (De Proft M and Latteur G, unpublished data). This method, in which tillers of wheat were shaken and insects collected in length of plastic gutter or in a sweep net placed below the plants, has allowed us to collect large samples of beneficial insects in a limited area and with a minimum of manipulation. Syrphid larvae that are not always active and not easily seen by visual inspection or sampled by D-vac were also collected as well as insects that are highly mobile, like soldier bugs and earwigs. Because counting and determination was done in the laboratory, young and early-instar larvae of predators were detected that would probably have been missed in a visual inspection. This method also allowed the collection of living material that could be reared in laboratory for subsequent identification or determination of parasitism rate. A mean of 21.2 syrphid larvae per plot was found, with a relatively low variability of the data (coefficient of variation of 20.1% for syrphids in control plots, 37.0% in control and treated plots, mean of the three-year study) and analysis showed statistical differences between insecticide treatments, even with only three replicates (yearly analysis). As they were less numerous, variability of data obtained with ladybirds and lacewings was a little higher and differences between means more difficult to confirm statistically. In comparison, an estimated density of up to 20 syrphid larvae per 100 tillers or 50 larvae m^{-2} was found by visual inspection[4,12,22] or by D-vac, [10] but no information on the variability of the data was given.

Relative abundance of predators and species composition are in accordance with results previously published for Belgium and bordering countries.[3,4,12,28,31] As in The Netherlands, France, Germany and the United Kingdom, syrphid larvae were the dominant aphid predator in our study and *E balteatus* the dominant syrphid species. The parasitism level of syrphids was low (less than 3%) and only one genus of parasite (*Diplazon* sp, Ichneumonidae) was found. Numbers of ladybirds were more variable between years and *P quatuordecimpunctata* was the most abundant species. *C septempunctata* was found in 1994 but not in 1995 and 1997.

In conclusion, results obtained in this study indicate that none of the tested products can be considered to have no impact on either ladybird on syrphid populations at the application rates used. Consequently, choice of product may be based on the presence, the relative abundance and the beneficial action of the different groups of aphid predators encountered in the field. As syrphids appear to be the most important aphid predator in wheat in Belgium and bordering countries, these results suggest that the use of esfenvalerate and fluvalinate should be encouraged in these countries and products such as pirimicarb, cyfluthrin, deltamethrin and phosalone avoided if possible. However, other criteria including cost, efficacy of the treatment, effectiveness of the aphid specific predators and side effects on other aphid antagonists such as parasitic hymenoptera and polyphagous predators must also be take into consideration.

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