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SELECTIVITY OF PLANT PROTECTION PRODUCTS USED IN WHEAT IN SUMMER ON THE MAJOR CEREAL APHID NATURAL ENEMIES

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ABSTRACT

The effects of a range of insecticides and fungicides commonly used in wheat in Belgium were assessed on the three major group of aphid natural enemies: parasitic hymenoptera, aphid-specific predators and entomopathogenic fungi.
Insecticides used to control cereal aphids were highly toxic in the laboratory on glass plate and leaf tests for adults of the parasitic hymenoptera *Aphidius rhopalosiphi*, but the last larval and the nymphal growth stage of the parasite were protected from insecticides inside the mummified aphid. Results of field studies showed that the insecticides tested had no effects or time-limited effects on Aphidiidae populations. Fungicides were in general less toxic than insecticides for *A. rhopalosiphi* in glass plate tests but many compounds commonly used were still harmful. The toxicity of these fungicides was reduced when they were tested on wheat plants, but some of them exhibited a marked repellent effect, so that the wasps spent less time on the plants and fewer aphids were parasitised. A field study showed that the parasitism rate of aphids in the field can be reduced by some fungicides, but the effect was short-lived and without consequence on the development of aphid populations.
20 fungicides were also tested at their maximum field rate on the entomopathogenic fungi *Erynia neoaphidis*. Most of the products reduced the infectivity of conidia of this fungi, sometimes greatly.
The effects of insecticides on aphid specific predators were assessed in the laboratory (syrphids) and on winter wheat in the field (syrphids, ladybirds and lacewings). Some products were harmless or slightly harmful for syrphids in the laboratory, but the majority of them were toxic. These results were confirmed by field-testing. None of the products can be considered as safe for both syrphids and ladybirds in the field. Lacewings were unaffected by the insecticides tested.
Overall analysis of the results obtained since 1993 show that all insecticides currently used on wheat in Belgium will affect the major aphid natural enemies to a greater or lesser degree. Tests on parasitic hymenoptera and entomopathogenic fungi also indicate that the selection of fungicides used to protect wheat against diseases should be based not only on their efficacy and cost but also on their possible side-effects on aphid natural enemies.

INTRODUCTION

In many countries, aphids have become a major pest in cereal crops. However, as aphid population levels vary greatly from year to year, systematic application of insecticides is not always necessary. Observations of aphid population dynamics in Belgium in 90 winter wheat fields between 1971 and 1989 showed that economic threshold values were reached in only 7 years out of 18 (Latteur et Moens, 1990). Variation in aphid populations can be attributed to various factors but the presence and activity of aphid natural enemies seems to be the major one. Large numbers of aphid natural enemies are usually correlated with low aphid numbers. Syrphid larvae, Aphidiid wasps and Entomopathogenic fungi (Entomophthorales) are the most important natural enemies of aphid in wheat at the end of spring and beginning of summer in Belgium. They can prevent the aphids proliferating and render insecticide applications unnecessary (Latteur & Oger, 1991).

Several studies have shown that natural control of pests and the use of pesticides are not always compatible. Following the elimination of natural enemies with non-selective pesticides, outbreak of pests, especially aphids may occur (Ripper, 1956, Pimentel, 1961, Horn, 1983, Borgemeister & Poehling, 1989). Secondary pests may also become important (Bartlett, 1958, Bacon, 1960, Eveleens *et al.*, 1973, Naïbo & Foulgocq, 1983). Thus, the determination of the selectivity of pesticides for aphid natural enemies is an integral part of the development of aphid IPM strategies. At the initiative of the Ministry of Agriculture (Collaboration between «Fonds des Matières Premières» and Department of Biological Control and Phytogenic Resources), a research program was initiated in 1993 to select pesticides for use in wheat in spring and early summer that are compatible with the most important aphids natural enemies occurring in Belgium: Aphidiids wasps, syrphids larvae and Entomophthorales. Several studies were initiated both in the laboratory and in the field, using standard characteristic and testing scheme developed by the IOBC working group «Pesticides and Beneficial Organisms» (Hassan, 1992). Insecticides and fungicides selected in this programme are all used in wheat in Belgium between May and July, when populations of aphids and aphid natural enemies are present in the field. The effects of fungicides were assessed on Aphidiidae and on Entomophthorales and those of insecticides on Aphidiidae and on aphid specific predators. This paper presents the most important results obtained since 1993. Some of them have been published previously (Jansen, 1996, 1998, 1999, in press, Latteur & Jansen, in press) and are only given in outline. The others have not been published and are given here in more details.

MATERIAL AND METHODS

Aphidiidae

Laboratory trials

In initial toxicity tests, *Aphidius rhopalosiphi* (Destefani-Perez) (Hym.: aphidiidae) adults were exposed for 24h to pesticide residues applied at their recommended field rate on glass plates. The fecundity of the surviving wasps was assessed and the reduction in their beneficial capacity (E) was calculated on the basis of the mortality and fecundity rates. According to the results obtained, pesticides were classified as harmless (class 1, $E<30\%$), slightly harmful (class 2, $30<E<75\%$), moderately harmful (class 3, $75<E<99$) or harmful (class 4, $E>99\%$). This method fulfils the requirements of the «Standards characteristic for initial toxicity tests» developed by the IOBC working group «Pesticides and Beneficial Organisms» (Hassan, 1992). Insecticides that shown to be toxic by this method were also tested on adults on maize leaves and on mummies. For fungicides, an original test design was developed to test the effect of the products on the parasitoids on plants with aphids. Details of these methods and the results are given in Jansen (1996) for insecticides and Jansen (1999) for fungicides.

Field tests

In 1998, a field study was carried out to test the side effects of deltamethrin and esfenvalerate on aphid parasitic hymenoptera. A winter wheat field of about 2 ha was divided into 9 plots of 40x40 m. Three plots were left untreated for control and the others received an insecticide application (3 plots/product) at GS 65 (Zadoks *et al.*, 1974). Sampling was done before and during the 20 days period after treatment using a D-vac apparatus, yellow water traps and visual counting. One yellow water trap was placed at the centre of each plot. 5 D-vac samples (0.408 m² for 30s) were taken and 40 tillers were inspected for aphids and aphid mummies in the 30x30m central area of each plot on each sampling date. Results were compared each other using a Student t-test (Dagnelie, 1970). In another field test in 1997, the effects on aphid parasitism of two fungicides were compared. Sportak® (prochloraz, 450 g a.i./ha) which was non toxic in the laboratory trials for *A. rhopalosiphi*, and the most toxic one in the laboratory, Bufalo® (tebuconazole + fenpropidin, 250 g + 375 g a.i./ha), were each applied on three 40x40 m plots of winter wheat at earing (GS 59, Zadoks *et al.*, 1974). Populations of aphids were counted on 50 tillers/plot before and after treatment and at least 100 aphids/plot were brought back to the laboratory and reared on wheat plants for 10 days for the determination of percentage parasitism. Results were compared using a Student t-test (Dagnelie, 1970).

Entomopathogenic fungi

Laboratory trials

The effects of 20 fungicides on the infectivity of conidia of *Erynia neoaphidis* (Zygomycetes, Entomophthorales) were assessed in a laboratory trial. Conidia of *E. neoaphidis* were projected on broad bean leaves. Leaves and conidia were then treated with fungicides applied at their recommended field rate. After treatment, the infectivity of the conidia was measured using living aphids (*Acyrthosiphon pisum* (Harris)). Mortalities of aphids confined with fungicide-treated conidia was compared with those of aphids confined with water-treated conidia. According to the reduction in the infectivity of conidia (E), fungicides were classified as harmless (class 1, E<25%), slightly harmful (class 2, 25<E<50%), moderately harmful (class 3, 50<E<75%) or harmful (class 4, E>75%). Details of the methods and the results are given in Latteur & Jansen (in press).

Syrphidae and other plant dwelling predators

Laboratory trials

Laboratory trials were done with larvae of the aphid specific predator *Episyrphus balteatus* (DEGEER) (Dipt.: Syrphidae). 2-3 day old larvae were exposed to insecticides residue on glass petri dishes. Surviving larvae were fed ad lib. with living aphids till pupation occurred. Larval, pupal and early adult mortality was recorded. The fertility of surviving adults was also assessed and results of this assessment and the mortalities were combined to calculate the reduction in the beneficial capacity of the insect. Products were then classified in one of the four IOBC categories for initial toxicity tests (see test with *A. rhopalosiphi*). Details of the methods and the results have already been published (Jansen, 1998).

Semi-field trials

The short-term effects of six insecticides previously tested on glass plates against syrphids were assessed on field populations of syrphids, ladybirds and lacewings in small plots of winter wheat. 3x10m plots were sprayed with insecticides at their recommended field rate. Plant dwelling predator (hoverfly and lacewing larvae and ladybird) were sampled 3 days after treatment using a beating method. Insecticides were tested in groups of 3, each with an untreated control, and with 3 replicates for each treatment. The experiment was repeated over 3 years (1994, 1995 and 1997). According to the reduction of captures of the different aphid specific predators, insecticides were classified as harmless (class 1, E<25%), slightly harmful (class 2, 25<E<50%), moderately harmful (class 3, 50<E<75%) or harmful (class 4, E>75%). Details of the methods and the results are given in Jansen (in press).

Field trials

In 1998, a field study was done to test the effects of deltamethrin and esfenvalerate on plant dwelling predators in winter wheat. A wheat field of about 2 ha was divided into 9 plots of 40x40 m. In each field, 3 plots were left untreated as the control and the others received an insecticide application (3 plots/product, 2 products/field) at GS 65 (Zadoks *et al.*, 1974). Sampling was done before and during the 20 days after treatment using a beating method. On each sampling date, 20 m of wheat row were beaten in the 30x30 m central area of each plot. Results were compared with a Student t-test (Dagnelie, 1970).

RESULTS

Aphidiidae

Laboratory trials

Classes of toxicity of insecticides in glass plate tests, in leaf tests and in mummy tests are given in table 1. All the insecticides can be considered as harmful for adults of *A. rhopalosiphi* on glass plate test. The use maize leaves as a natural substrate instead of glass plates did not reduce the mortality of the insecticides. On the other hand, insecticides toxic for adult wasps had little or no effect on the emergence of mummies when they were treated. Only deltamethrin (which diminished the proportion emerging) and phosalon (which reduced the fertility of emerging adults) were slightly harmful.

Table 1: Effects of insecticides on *A. rhopalosiphi* in the laboratory. Results (IOBC toxicity class) of glass plate tests and leaf tests with adults and mummy test

Active ingredient	trade name	tested dose (g a.i./ha)	IOBC toxicity class		
			glass plate test	leaf test	mummy test
bifenthrin	Talstar flo	7.5	4	4	1
cyfluthrin	Baythroid EC050	15	4	4	1
cypermethrin	Cymbush DG	20	4	4	1
deltamethrin	Decis EC25	5	4	4	2
esfenvalerate	SumiAlpha	5	4	4	1
fluvalinate	Mavrik 2F	36	4	4	1
lambdacyhalothrin	Karate 25	5	4	4	1
phosalon	Zolone flo	750	4	4	2
pirimicarb	Pirimor G	125	4	4	1

The results of glass plate tests and extended-lab tests on plants with fungicides are given in Table 2. Compared to insecticides, fungicides were less toxic to adult wasps than insecticides on glass plates, but several compounds were harmful. The results of extended lab tests showed that when they are tested in a more realistic way, fungicides containing one active ingredient were harmless or only slightly harmful for aphidiids. However, some tank-mixes of two of these products were still moderately harmful or harmful and need further testing in semi-field or field conditions. All mixes containing fenpropidin or tebuconazole and some of these containing fenpropimorph or tridemorph gave results of this kind. Observations on adult wasps showed that the reduction in aphid parasitism was correlated with a repellent effect of the products, indicating that sublethal effects of the products must also be studied.

Table 2: Effects of fungicides on adults of *A. rhopalosiphi* in the laboratory. Results (IOBC toxicity class) of glass plate tests and extended lab test on plants

Active ingredient	trade name	dose (g a.i./ha)	IOBC toxicity class	
			glass plate test	extended-lab test
1. Single products				
carbendazim	Agrichim Carbendazim	200	1	-
chlorothalonil	Daconil 500 flo	1250	2	-
cyproconazole	Alto 100SL	80	1	-
epoxyconazole	Opus	125	3	2
fenpropidin	Mildin 750EC	563	4	1
fenpropimorph	Corbel	750	3	1

Active ingredient	trade name	dose (g a.i./ha)	IOBC toxicity class	
			glass plate test	extended-lab test
flusilazole	Capitan	250	4	2
flutriafol	Impact	125	3	1
hexaconazole	Sirocco	250	2	-
prochloraz	Sportak	450	4	1
propiconazole	Tilt 250EC	125	1	-
tebuconazole	Horizon	250	4	1
triadimenol	Bayfidan 250EC	125	2	-
tridemorph	Calixin	750	4	1
2. Tank-mixes				
carbendazim + cyproconazole	*(Alto Combi, Larsen)*	150 + 80	1	-
carbendazim + epoxyconazole	*(Duett)*	150 + 125	2	4
carbendazim + fenpropimorph	*(Corbel Duo)*	188 + 563	4	3
carbendazim + flusilazole	*(Punch C)*	100 + 200	4	4
carbendazim + flutriafol	*(Impact R)*	250 + 118	4	2
carbendazim + hexaconazole	*(Planete R)*	150 + 250	1	-
carbendazim + tebuconazole	*(Libero SC)*	200 + 250	-	4
chlorothalonil + cyproconazole	*(Alto Elite)*	750 + 80	4	2
chlorothalonil+fenpropimorph	*(Corbel Star)*	1250 + 750	4	3
chlorothalonil + flusilazole	*(Triumph)*	500 + 200	4	3
chlorothalonil + flutriafol	*(Impact 2000)*	900 + 118	2	1
chlorothalonil + hexaconazole	*(Sirius)*	750 + 188	3	1
cyproconazole + prochloraz	*(Sportak Delta)*	72 + 480	4	1
epoxyconazole + tridemorph	*(Tango)*	125 + 375	-	2
epoxyconazole+fenpropimorph	*(Opus team)*	125 + 375	3	1
fenpropidin + propiconazole	*(Zenit)*	375 + 125	-	4
fenpropidin + tebuconazole	*(Bufalo)*	375 + 250	-	4
fenpropimorph + fenpropidin	*(Boscor)*	563 + 188	-	4
fenpropimorph + prochloraz	*(Rival CS)*	563 + 450	4	4
fenpropimorph+ propiconazole	*(Archer)*	375 + 125	4	1
propiconazole + tridemorph	*(Tilt Turbo 475EC)*	125 + 350	-	1
triadimenol + tridemorph	*(Dorine)*	125 + 375	-	1
tebuconazole + triadimenol	*(Matador)*	250 + 125	-	4

Field tests

Numbers of Aphidiidae sampled in the field by D-vac apparatus and yellow water traps before and after treatment with deltamethrin and esfenvalerate are given in Fig 1 and Fig 2. Visual inspection of tillers gave poor results, because of low densities of aphids and aphid mummies. Results showed that both insecticides had little effect on parasite populations. In yellow water traps, significant differences were only observed 25 days after treatment. Reasons for these delayed effects remain unexplained. For the D-vac samples, no results differed significantly from the control.

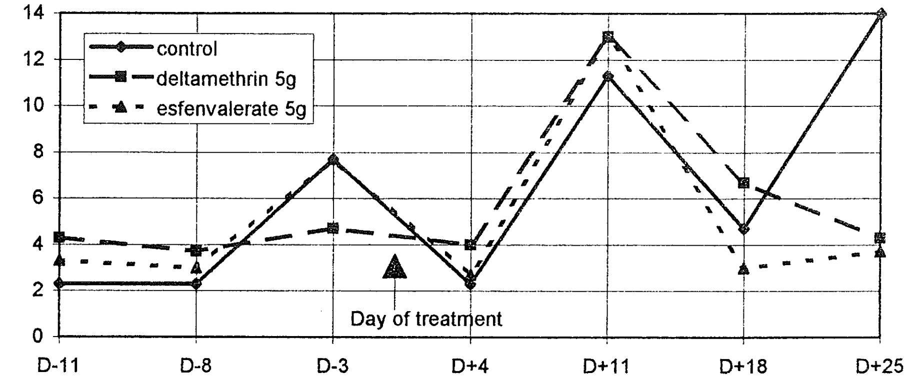

Figure 1: Effects of insecticides on Aphidiidae in a winter wheat field. Numbers of Aphidiidae samples in Water Yellow Trap in treated and untreated plots (3 plots/product).

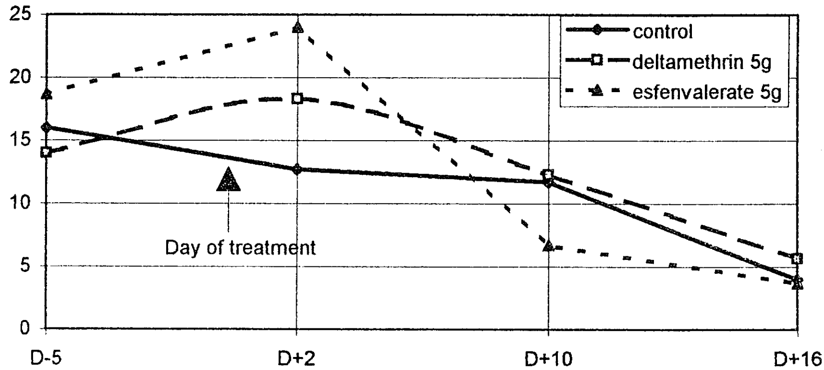

Figure 2: Effects of insecticides on Aphidiidae in a winter wheat field. Numbers of Aphidiidae sampled by D-vac in treated and untreated plots (3 plots/product).

The effects of fungicides on the parasitism of aphids in treated plots of wheat field are illustrated in Fig 3. A significant reduction of parasitism of aphids was observed in plots treated with Bufalo two days after treatment, but had no effect on the aphid population level. However, levels of parasitism were low and consequently the influence of aphidiids on the aphid population was probably limited. This kind of experimentation should be repeated in fields where parasitism is high and an important factor in the regulation of aphids.

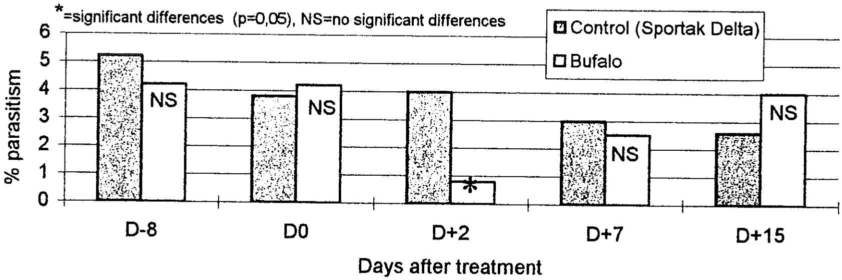

Figure 3: Effects of Bufalo on Aphidiidae in a wheat field. % parasitism of aphids before and after treatment.

Entomopathogenic fungi

Laboratory trials

The effects of fungicides on the infectivity of *E. neoaphidis* are given in Table 3. Few products can be considered as harmless or only slightly harmful for Entomophthorales: the two benzimidazoles tested (carbendazim and thiophanate-methyl), kresoxym-methyl, nuarimol and propiconazole. Other products were moderately harmful or harmful. None of the aphids inoculated by conidia treated with chlorothalonil, fenpropimorph, spiroxamine and tebuconazole were killed by the fungi while 80 to 90 % of the control aphids, inoculated with water-treated conidia, died 4 to 6 days after infection.

Table 3: Effects of fungicides on the infectivity of conidia of *E. neoaphidis* in the laboratory (IOBC toxicity class)

Active ingredient	trade name	dose (g a.i./ha)	IOBC toxicity class
azoxystrobine	Amistar	250	3
carbendazim	Agrichim Carbendazim	200	1
chlorothalonil	Daconil 500 flo	1250	4
cyproconazole	Alto 100SL	100	4
cyprodynil	Chorus	250	4
epoxyconazole	Opus	125	3
fenpropimorph	Corbel	750	4
flusilazole	Capitan	100	4
flutriafol	Impact	125	3
hexaconazole	Sirocco	250	3
iprodione	Rovral	200	3
kresoxym-methyl	Candit	100	1
nuarimol	Tridal	40	1
prochloraz	Sportak	450	3
propiconazole	Tilt 250EC	125	2
spiroxamine	Impulse	750	4

Active ingredient	trade name	dose (g a.i./ha)	IOBC toxicity class
tebuconazole	Horizon	250	4
thiophanate-methyl	Topsin M	420	1
triadimenol	Bayfidan 250EC	125	3
tridemorph	Calixin	750	4

Syrphidae and other plant dwelling aphid predators

Laboratory trials

The effects of insecticides on larvae of the aphid specific predator *E. balteatus* are given in table 4. All those tested, except fluvalinate (harmless) and bifenthrin and esfenvalerate (slightly harmful), were harmful for syrphid larvae. Lambdacyhalothrin did not kill all the larvae but the adults obtained were unable to produce fertile eggs. Others products killed all the larvae, sometimes after only 2 days of exposure.

Table 4: Effects of insecticides on larvae of *E. balteatus* in the laboratory. Results (IOBC toxicity class) of glass plate tests

Active ingredient	trade name	dose (g a.i./ha)	IOBC toxicity class
bifenthrin	Talstar Flo	7.5	2
cyfluthrin	Baythroid EC050	15	4
cypermethrin	Cymbush DG	20	4
deltamethrin	Decis EC25	5	4
esfenvalerate	Sumi Alpha	5	2
fluvalinate	Mavrik 2F	36	1
lambdacyhalothrin	Karate 25	5	4
phosalone	Zolone Flo	750	4
pirimicarb	Pirimor G	125	4

Semi-field trials

The results of the trials carried out in wheat in 1994, 1995 and 1997 are summarised in Table 5 (hoverfly larvae, ladybird adults and larvae, lacewing larvae). Results obtained in 1996 were inconclusive because aphids and aphid predators were very scarce. Esfenvalerate and fluvalinate appeared to be harmless for syrphid larvae; numbers of larvae sampled in treated plots were significantly not different from the control. Deltamethrin had no effect in two years out of three but its toxicity was more marked in 1997. This could be explained by the low temperatures observed in 1997 (mean of 14.5°C) compared to the two other years (22.9 & 22.5°C), pyrethroids being known to be more efficient at low than high temperatures. Cyfluthrin, phosalone and pirimicarb were moderately harmful for syrphids, with populations reduced by 50 to 75 % compared to the control 3 days after treatment. The toxicity of the insecticides was more marked for ladybirds. Reductions of more than 75 % of the populations compared to the control were observed for cyfluthrin, deltamethrin, fluvalinate and phosalone. Pirimicarb was without effect on ladybirds and esfenvalerate was moderately harmful. Populations of lacewings were not reduced by more than 25%, compared to the control, by any of the insecticides, except deltamethrin which was slightly harmful.

Table 5: Effects of insecticides on aphid plant dwelling predator in semi-field test. Reduction of populations compared to control 3 days after treatment in winter wheat

Active ingredient	trade name	dose (g a.i./ha)	IOBC toxicity class			
			1994	1995	1997	mean
I. Syrphidae						
cyfluthrin	Baythroid EC050	15	3	3	3	3
deltamethrin	Decis EC25	5	1	1	3	2
esfenvalerate	Sumi Alpha	5	1	1	1	1
fluvalinate	Mavrik 2F	36	1	2	1	1
phosalone	Zolone Flo	750	3	4	2	3
pirimicarb	Pirimor G	125	4	3	2	3
II. Ladybirds						
cyfluthrin	Baythroid EC050	15	4	4	4	4
deltamethrin	Decis EC25	5	4	4	4	4
esfenvalerate	Sumi Alpha	5	3	3	1	3
fluvalinate	Mavrik 2F	36	3	4	3	4
phosalone	Zolone Flo	750	4	4	4	4
pirimicarb	Pirimor G	125	1	1	1	1
III. Lacewings						
cyfluthrin	Baythroid EC050	15	1	1	3	1
deltamethrin	Decis EC25	5	1	1	3	2
esfenvalerate	Sumi Alpha	5	1	1	3	1
fluvalinate	Mavrik 2F	36	2	1	1	1
phosalone	Zolone Flo	750	1	1	1	1
pirimicarb	Pirimor G	125	3	1	2	1

Field trials

The development of populations of aphid-specific predators after treatment with deltamethrin and esfenvalerate are given in Fig. 4 (syrphid larvae) and Fig. 5 (adults and larvae of ladybirds). No significant differences in numbers of syrphids between control and treated plots were observed. Conversely, numbers of adults and larval ladybirds were drastically reduced. Effects were even detected 18 days after treatment. These results confirm those obtained in semi-field conditions and esfenvalerate and deltamethrin can be considered as toxic for ladybirds in field conditions while syrphid larvae are unaffected by these products.

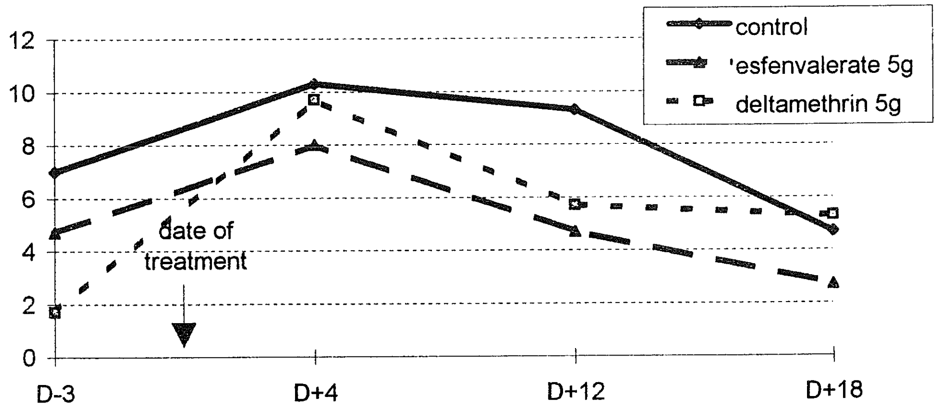

Fig. 4: Effects of insecticides on syrphids in a winter wheat field. Numbers of syrphid larvae sampled by beating in treated and untreated plots (3 plots/products).

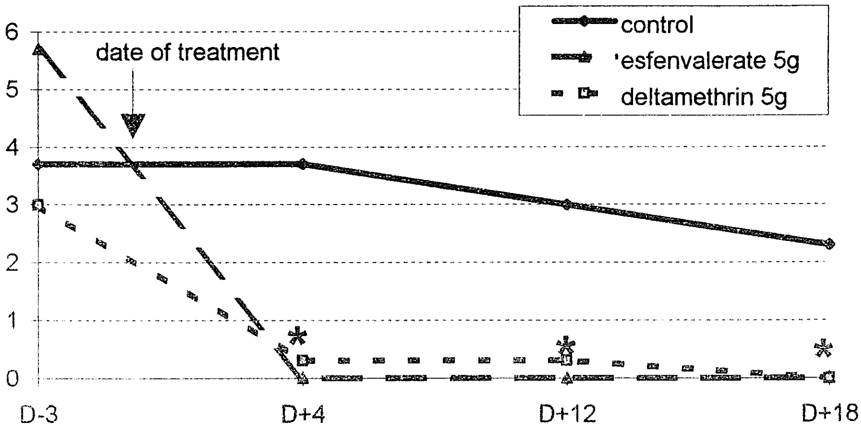

Fig. 5: Effects of insecticides on ladybirds in a winter wheat field. Numbers of adults and larvae of ladybirds sampled by beating in treated and untreated plots (3 plots/product).
* = significant differences (p=0.05)

DISCUSSION

To test the side effects of pesticides on beneficial insects, only field testing can provide results that reflect agricultural conditions. However, field tests are time consuming and expensive. Furthermore the results are sometimes difficult to interpret because of the variability in numerous environmental factors. For this reason laboratory and semi-field methods have been developed and used over many years. Important progress in the standardisation of these methods has been accomplished, especially by the IOBC working group "Pesticides and Beneficial Organisms" (Hassan, 1992). Products must be tested according a testing scheme involving laboratory, semi-field and field trials. Laboratory experiments using glass plates as inert surfaces are considered as worst case studies and are used only to prove the harmlessness of a product. Products shown to be toxic in these tests need more appropriate experimentation for an adequate evaluation. As a second step in a testing scheme, experiments using a natural substrate such as leaves or whole plants are done. As the products are thus tested in a more realistic way, the results of these experiments take precedence over those obtained on inert surfaces. Tests with insecticides and fungicides on Aphidiidae and tests with insecticides on syrphids were carried out in this way. For the conidia of *E. neoaphidis*, it was impossible to use an artificial substrate such as glass plates or sand and the fungicides were tested directly on leaves as a natural substrate.

Glass plate tests and maize leaf tests with insecticides showed that they were highly toxic for adults wasps in the laboratory and that field tests must be carried out with these products. However, when they were applied on the protected life stage of the wasp, as aphid mummies are, the insecticides had no or little effects. This protection has been described previously by several authors (Delorme, 1975, Stevenson *et al.*, 1984; Borgemeister *et al.*, 1993) and may considerably benefit aphidiid populations in the field. When products that are toxic for aphidiid adults are applied, their populations will be restored by parasitoids newly emerging from mummies. Results of field tests which showed that deltamethrin and esfenvalerate had no effects on aphidiid populations could be explained in this way. However, these young parasitoids are also exposed to the pesticide residues and can be killed if the product does not rapidly lose its toxic activities. In this way, studies on the persistence of the chemicals that have been tested in this study are needed. Another aspect to be considered is the availability of the host after treatment. If all the aphids are killed by an insecticide, adult parasitoids emerging from treated mummies will emigrate to other fields. Ideally, insecticides must not kill all the aphids so that to a parasite population remains in the field and prevents a second aphid build-up.

If the IOBC testing scheme is used to interpret the data obtained in the laboratory, it can be concluded that, when they are applied at their recommended field rates, all the fungicide formulations containing one active ingredient are harmless or slightly harmful for aphidiid wasps. However, most farmers use more than one active ingredient at the same time and very few tank-mixes that were tested were harmless for *A. rhopalosiphi*, even on plants. Results of a field experiment showed that the effects of fungicides on aphid parasites can be detected, but the effects on aphid populations was insignificant probably because the parasitism rate was low. The majority of fungicides used in wheat to control diseases also reduced the infectivity of conidia of *E. neoaphidis* in laboratory trials and these products must be tested in field conditions before an adequate assessment of their impact on Entomopathogenic fungi can be made. Other than carbendazim, no fungicides that have been tested on both beneficial organisms can be considered safe for Aphidiidae and Entomopathogenic fungi. Results showed that fungicide applications might affect the development of aphid populations by reducing the effects of parasitic wasps and entomopathogenic fungi as natural enemies of aphids. Field tests with these products are needed when aphid parasites and pathogens are numerous. Effects of fungicides were not assessed on aphid specific predators because these beneficials are generally found too late in the wheat-growing season to be exposed to fungicides residues. Furthermore, data from the literature show that fungicides have little effect on aphid specific predators (Hassan *et al.*, 1987, 1988, 1991), with the exception of pyrazophos (Sotherton *et al.*, 1987, Sotherton & Moreby, 1988) which is not registered in Belgium for use on wheat crops.

Results obtained with insecticides used to control cereal aphids on larvae of *E. balteatus* in the laboratory showed that these compounds can be classified in different categories. Cyfluthrin, cypermethrin, deltamethrin, lambda-cyhalothrin, phosalon and pirimicarb were harmful in the laboratory and need further testing for an adequate assessment of their toxic effects in practical conditions. Bifenthrin, esfenvalerate and fluvalinate were harmless or slightly harmful. The harmlessness of fluvalinate and esfenvalerate for *E. balteatus* in the laboratory was confirmed by the results obtained in semi-field tests. Cyfluthrin, deltamethrin, phosalone and pirimicarb were less toxic in semi-field than in laboratory tests, but the reduction in syrphid numbers were still considerable. Results of semi-field experiments also showed that no insecticide was without effect on both syrphids and ladybirds. Pirimicarb was the only product harmless for ladybirds but it was also one of the most toxic for syrphids. Lacewings seem not to be affected by insecticides, but their populations were smaller and their roll in the limitation of aphid populations is low in cereals in Belgium. Because of differences in the susceptibility of syrphids and ladybirds to the range of insecticides available, choice of product must ideally be based on the presence and relative abundance of these aphid predators. As syrphids appear to be the most important aphid predator in wheat in Belgium and bordering countries, the use of deltamethrin, esfenvalerate and fluvalinate should be encouraged in these countries and products such as pirimicarb, cyfluthrin and phosalon 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 as spiders, carabids and staphylinids beetles must also be take into consideration.

In conclusion, these results show that all pesticides used in wheat interfere to a greater or lesser extent with the natural control of aphids often provided by beneficial organisms at the end of spring, beginning of summer. Accordingly, choice of fungicides and insecticides in wheat must ideally be not only based on cost and efficacy but also on their effects on these agents of natural control. Results of laboratory and semi-field trials also showed that numerous pesticides used in wheat must be tested in the field. Because field tests are time consuming and expensive, the development of alternative methods that give results which allows extrapolation to a field context is urgently needed.

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RESUME

Les effets d'une série d'insecticides et de fongicides utilisés en céréales en Belgique on été déterminés sur les trois principaux groupes d'ennemis naturels des pucerons : hyménoptères parasites, prédateurs spécifiques des pucerons et champignons entomopathogènes.
Les insecticides utilisés pour contrôler les populations de pucerons des céréales ont été très toxique pour les adultes de l'hyménoptère parasite Aphidius rhopalosiphi lors du test réalisé sur verre et sur feuille en laboratoire. Le dernier stade larvaire et la nymphe du parasites sont toutefois protégés des effets secondaires des insecticides par l'enveloppe durcie du puceron momifié. Les résultats des essais en champ montrent que les insecticides n'ont pas d'effets ou un effet limité dans le temps sur les populations de parasites. les fongicides étaient en général moins toxiques que les insecticides pour A. rhopalosiphi lors du test réalisé sur verre mais beaucoup de ces produits couramment utilisés étaient toxiques. La toxicité de ces produits se réduisait lorsqu'ils étaient testés sur des plantes de froment, mais quelque uns d'entre-eux ont montrés un effet répulsif marqué, conduisant les femelles de parasite à passer moins de temps sur les plantes traitées et réduisant de la sorte leur capacité à parasiter les pucerons. Une étude en champ montre que le taux de parasitisme des pucerons peut être réduit par certains fongicides, mais cette réduction est de courte durée et sans conséquence notable sur l'évolution des populations de pucerons.
21 fongicides ont aussi été testés à leur dose d'application recommandée sur le champignon entomopathogène *Erynia neoaphidis*. La plupart des produits ont réduit l'infectivité des conidies de ce champignon, parfois d'une manière drastique.
Les effets des insecticides vis-à-vis des prédateurs spécifiques de pucerons ont été déterminés en laboratoire (syrphe) et en champ (syrphes, coccinelles et chrysopes). Certains produits étaient non toxique ou légèrement toxique pour les syrphes au laboratoire, mais la majorité d'entre-eux étaient toxiques. Ces résultats ont été confirmés par les études réalisées en champ. Aucun produit ne peut être considéré comme étant sans danger en champ à la fois pour les syrphes et les coccinelles. Les chrysopes n'ont pas semblé être affectés par les insecticides.
Une analyse globale des résultats obtenus depuis 1993 indique qu'aucun insecticide ne peut être considéré comme sélectif pour les principaux ennemis des pucerons rencontrés en céréales et utilisés sans tenir compte de ces auxiliaires. Certains résultats obtenus vis-à-vis des hyménoptères parasites et des champignons entomopathogènes montrent aussi que le choix des fongicides utilisés pour lutter contre les maladies du froment ne doit pas uniquement être basé sur l'efficacité des produits et le coût des traitements mais aussi sur les effets possibles de ces produits sur les ennemis naturels des pucerons.

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