Pesticides and Beneficial Organisms
IOBC/wprs Bulletin Vol. 24 (4) 2001
pp. 17 - 24

Toxicity of insecticides used in wheat to adults of *Aphidius rhopalosiphi* DeStefani-Perez (Hymenoptera: Aphidiidae) with field treated plants

J.P. Jansen
Laboratoire d'Ecotoxicologie, Ministry of Agriculture, Agricultural Research Centre, Gembloux, Department of Biological control and Plant genetic resources, Gembloux, Belgium

Abstract: Effects of 8 insecticides used in wheat to control cereal aphids were assessed on adults of the parasitic wasp *A. rhopalosiphi* using a semi-field test design. Products were applied at their maximum field rate recommended in Belgium on small plots of wheat. Directly after treatment, plants were sampled randomly and brought back to the laboratory to form the exposure units where adult wasps were released. Units were placed outdoor and surviving females were collected 24 h later and assessed for fecundity in the laboratory. Mortality and fecundity were used to estimate the reduction of beneficial capacity, compared to control. Products were rated according IOBC standards. In order to assess duration of harmful effects, experiments with products that were initially toxic were repeated in the same way sampling plants either 1 or 3 days after pesticide application.

Exposure of wasps to plants treated with cyfluthrin, cypermethrin, fluvalinate, lambdacyhalothrin and pirimicarb lead to less than 25% control corrected mortalities. Mortalities higher than 25% were obtained for bifenthrin, deltamethrin and esfenvalerate. Mortalities were reduced to less than 25% with deltamethrin and esfenvalerate one day after treatment, but were still higher than 25% for bifenthrin. However, no effects were detected with this compound 3 days after treatment.

From these results, it can be concluded that exposure of wasps to field treated ear and last leaves of wheat was either harmless or short persistent. Harmful effects observed at day 0 did not last for more than 1 or 3 days.

Keywords: *Aphidius rhopalosiphi*, bifenthrin, cyfluthrin, cypermethrin, deltamethrin, esfenvalerate, fluvalinate, lambdacyhalothrin, pirimicarb, semi-field test, wheat, persistence.

Introduction

Aphidiid wasps are one of the major aphid natural enemies in different crops. Their action greatly contributes to the natural control of aphid populations (Stary, 1988). In wheat, several authors have reported their beneficial activity (Jones, 1972, Powell, 1983, Latteur & Moens, 1990, Oakley *et al.*, 1996). *A. rhopalosiphi* is the commonest species found in wheat in Belgium (Latteur, 1973, Latteur & Destain, 1980) and one of the most important ones in Western Europe (Stary, 1970, Dedryver *et al.*, 1985).

Several laboratory studies showed that adults of *A. rhopalosiphi* were highly sensitive to pesticides and especially to insecticides (Kühner *et al.*, 1985, Krespi *et al.*, 1991, Borgemeister *et al.*, 1993). The effects of products used in Belgium to control cereal aphids were previously assessed in the laboratory on both adult wasps and aphidiid nymphs protected inside mummified aphids (Jansen, 1996). Insecticides were found to be toxic to adults by contact on both glass plates and maize leaves previously treated, but their effects were limited when products were applied on aphid mummies. Thus, although field application of these insecticides could affect adult parasitoid populations, adults emerged from treated mummies could restore aphidiid populations within a few days provided that pesticide residues rapidly

loose their toxicity. In this context, determination of harmful activity of insecticides is of particular importance.

The objective of this study was to test the toxicity and duration of harmful activity of insecticides used in wheat to control cereal aphids when adult wasps were exposed to field treated plants under conditions close to farmer practises. Methods used for this study are quite similar to those previously used to test wheat fungicides against the same species (Jansen, 2000).

Material and methods

Chemicals

All insecticides tested in this study are used in wheat to control aphid populations at the end of spring, beginning of summer. They were tested at the maximum field rate recommended in Belgium. Details of trade name, formulation, active ingredients and tested rate are given in table 1. These insecticides were previously tested in the laboratory and were selected for this study because they were toxic for adults of *A. rhopalosiphi* on glass plates test and detached maize test (Jansen, 1996).

Table 1: Insecticides applied in the field and tested on *A. rhopalosiphi*

trade name	formulation	active ingredient	tested dose (g a.i./ha)
Baythroid EC050	EC	cyfluthrin	10.0
Cymbush DG	DG	cypermethrin	15.0
Decis EC 2,5	EC	deltamethrin	5.0
Karate	EC	lambdacyhalothrin	5.0
Mavrik 2 F	SC	fluvalinate	36.0
Pirimor G	WG	pirimicarb	125.0
Sumi Alpha	EC	esfenvalerate	5.0
Sumi Alpha	EC	esfenvalerate	5.0
Talstar Flo	SC	bifenthrin	7.5

Application of chemicals

Insecticides were applied in the field on rectangular wheat plots (3 m x 10 m) at the end of flowering (GS 69, Zadoks *et al.*, 1974). Plots were delimited in a wheat field (cv "Pajero") conducted according to normal agricultural practices, except that they were not treated with fungicides. Test products were applied with a 3 m ramp bearing 6 Azo 110° nozzles at 50 cm spacing, connected to a knapsack sprayer. Work pressure was 2.5 b and products were diluted and applied in a volume equivalent to 300 l of water/ha. Products were applied in 2 different sets of 4 products each. Each treatment included one plot per product and for the control (untreated).

Exposure units

30 minutes to 1 h after the treatment, when residues were dry, 30 to 40 stems of wheat with ear, first and second leaves were randomly selected from the central part of the plot (2 m x

8 m). Plants were put in plastic trays and immediately brought back in the laboratory located nearby the field.

In the laboratory, wheat plants were carefully inspected and aphids, aphidiid mummies and aphid predators (syrphid eggs or larvae, ladybirds) were removed. Terminal sections of wheat stem, with last leaf and ear were immediately used to form exposure units. Exposure units were made of 4 stems of about 30cm long planted in pots (∅: 12cm) containing moistened vermiculite (Sibli, grade 5). 5 units were assembled for each product and 5 for control. Vermiculite was directly covered with sand (1cm height) to form a uniform untreated surface and a cylindrical Perspex cage (∅: 12cm, h:25 cm) was added on each unit. Top of cage and two rectangular cutaways were covered with nylon netting for ventilation. Ear and last leaves of wheat were selected to represent a worst-case field exposure in the laboratory. According to Cilgi & Jepson (1992) and Longley & Jepson, (1997b), these leaves received a greater amount of products that the rest of the plants.

Conduct of trials

Immediately after unit assembling, six 2-48h old adults of *A. rhopalosiphi* (3 males, 3 females) were introduced and left undisturbed for a 24h period. Wasps were obtained from a laboratory colony established in 1993. Details of the rearing are given in Jansen (1996 and 1998). Plants used for the test were covered with natural honeydew produced by aphids in the field. At the moment of treatment, aphid population reached a mean of 3.5-4.0 aphids/tiller. No artificial manipulations, such as sucrose solution application to stimulate wasp foraging, were applied.

During exposure, wasps were observed 10 times in each unit (50 observations per product and control) and the number of wasps found on plants or on sand and perspex cage was noted. Mean percentages of wasps found on plants were calculated and compared to control to detect possible repellent effects of products. The percentage of wasps found on plants were compared to control and a Student *t*-test was applied(Dagnelie, 1974).

24 h after wasp release, units were disassembled and surviving wasps counted. Missing wasps were considered as dead. Mortalities were calculated in each object and corrected with the mean mortality observed in the control units (Abbott, 1925). Exposure of wasps to treated plants was made outdoor under a plastic shelter for rain protection.

Surviving wasps were collected, sexed and females were used to assess effects on fertility. Ten surviving females per product and control were individually confined in fertility assessment units, similar to those described in previous publications (Jansen, 1998). Females were removed from the units 24h later and aphid mummies were left to develop and counted 10-12 days later. Mean number of mummies produced in each unit were compared to control and a Student *t*-test (Dagnelie, 1974) applied. Fertility assessments were made in the laboratory in climatic chamber at 20°± 2°C and 50-90% RH.

Reduction in beneficial capacity (E) was calculated according to Overmeer-Van Zon (1982) whose formula combines mean mortality and reproductive performance results. According to the E value, products were classified in one of the four IOBC categories for extended-lab test and semi-field tests:

1 – "harmless", E < 25%
2 – "slightly harmful", 25% < E < 50%
3 – "moderately harmful", 50 % < E < 75 %
4 – "harmful", E > 75 %

To determine duration of harmful activity of insecticides, products resulting in more than 25% corrected mortality, experiments were repeated as described but plants were taken from the same plots 1 or 3 days after treatment, until mortality decreased below 25%.

Climatic conditions

Temperature and rainfall measured during experiments are summarised in table 2. Results were provided by the automatic meteorological station of Gembloux-Ernage, which is located approximately 3 km away from the experimental site.

Table 2: Minimum, maximum and mean (minimum+maximum/2) temperatures, and rainfall recorded during the assay.

			Temperature (°C)			Rainfall (mm)
			minimum	maximum	mean	
Set 1	exposure	day 0	12.3	20.0	16.2	(protected)
		day 1	10.0	20.6	15.3	(protected)
		day 3	11.0	16.1	13.6	(protected)
	field	day 0-1	10.0	20.6	15.3	0.0 mm
		day 1-3	6.3	20.6	13.5	6.4 mm
Set 2	exposure	day 0	11.8	20.9	16.4	(protected)
		day 1	12.3	20.0	16.2	(protected)
	field	day 0-1	12.3	20.0		2.4mm

Results

Results of the 2 sets of experiments are listed in table 3. Control mortalities ranged from 6.7% to 10.0%. In set 1, corrected mortalities with cyfluthrin, cypermethrin and lambdacyhalothrin were lower than 25% and these products did not affect fertility capacity of surviving females. According to reduction of beneficial capacity and IOBC rating, these products were considered as harmless. Bifenthrin was more toxic, with mortalities reaching 40%. Repetition of the experiments one day after treatment did not reduce observed mortalities but no harmful effects were detected 3 days after treatment. In the second set of experiments, fluvalinate and pirimicarb were harmless while deltamethrin and esfenvalerate were toxic, with corrected mortalities of 46.4% for both products. No harmful effects were detected with deltamethrin and esfenvalerate one day after treatment.

Observations of wasps during exposure showed that some of the insecticides had repellence effects on adult wasps. Adult wasps were observed less frequently on plants treated with cyfluthrin, cypermethrin (set 1), deltamethrin and esfenvalerate (set 2) in a statistically significant way compared to control. However, no relation between repellence and mortality can be established.

Discussion

Results obtained in these experiments show that when adults of *A. rhopalosiphi* are exposed to insecticide field treated plants, effects observed directly after treatment are generally low.

Furthermore, for products that were initially toxic, duration of harmful activity is limited in time, with no detectable effects 3 days after treatment. Because methods used in this study greatly differ from previously used ones, comparison of results is difficult. However, effects observed during this study are surprisingly low. These results could be partly explained as follows.

Table 3: Initial toxicity (day 0) and determination of duration of harmful activity (day 1-3) of selected insecticides to adults of *A. rhopalosiphi*. Observed and corrected mortalities, wasp activity during exposure, mummy production, and IOBC rating for semi-field tests.

trade name	observed mortality (%)	corrected mortality (%)	% wasp on plants	# mummies/ unit	E (%)	IOBC class
set 1 – day 0						
control	10.0	-	24.8a	19.8a	-	-
bifenthrin	46.7	40.8	27.2a	21.5a	35.7	2
cyfluthrin	13.3	3.7	15.3b	17.7a	13.9	1
cypermethrin	13.3	3.7	16.1b	21.2a	-3.1	1
lambdacyhalothrin	20.0	11.1	23.5a	22.9a	-2.8	1
set 1 – day 1						
control	10.0	-	29.9a	22.3a	-	-
bifenthrin	40.0	33.3	28.0a	19.7a	41.1	2
set 1 – day 3						
control	6.7	-	31.0a	23.7a	-	
bifenthrin	10.0	3.6	28.4a	26.8a	-9.0	1
set 2 – day 0						
control	13.3	-	36.2ab	42.6a	-	-
deltamethrin	50.0	46.4	17.3d	43.9a	44.8	2
esfenvalerate	50.0	46.4	26.9c	23.8a	69.8	3
fluvalinate	16.7	10.7	37.3a	45.4a	4.8	1
pirimicarb	23.3	17.9	29.8bc	50.8a	2.1	1
set 2 – day 1						
control	10.0	-	32.7a	33.1a	-	-
deltamethrin	26.7	18.5	28.0a	31.2a	23.2	1
esfenvalerate	23.3	14.8	29.0a	30.5a	21.5	1

Within a column, figures followed by the same letter are not significantly different (Student *t*-test at p=0.05 level).

Contact toxicity on plant is generally lower than on glass plates. Pesticides are less available to insects on leaves than on inert, nonporous surfaces (Longley & Jepson, 1997a). Furthermore, when products are applied in the field, repartition of pesticide residues is more heterogeneous than in the laboratory and generally lower pesticide concentrations can be found on treated substrates. Chemical analysis of residues of field applied pesticides have

shown that ear and last leaf of wheat receive more or less 20 to 25% of the field rate, the rest of the dose being distributed on stem, other part of plants and soil (Cilgi & Jepson, 1992, Longley & Jepson, 1997b). Upperside of leaves generally receive a greater amount of pesticide and very low levels of pesticide residues are found on the underside of leaves (Longley & Jepson, 1997b). Thus, application of pesticides in the field with spraying equipment similar to that used by farmers leads to a more heterogeneous distribution of residues and a reduction of doses as compared to results obtained when laboratory spraying equipment is used.

Low toxicity values observed in this study can also be explained by wasp behaviour during exposure. With either glass plate or detached leave tests, adult wasps are released for a certain period of time in an artificial environment and contact between treated surfaces and insects is forced and non-natural. On plants, females wasps exhibit a typical pattern sequence in search for aphids to parasitize (Ayal, 1987, Cloutier & Bauduin, 1990). This pattern is generally repeated several times and separated by flight activity. Thus, contact between parasitoid and plant in natural environment is not continuous but disrupted, as contact with pesticide residues when plants are treated. Furthermore, detection of pesticide residues by adult wasps can modify the behaviour of this insect by repellency effects (Kühner *et al.*, 1985), adult wasps spending less time on treated plants than on untreated ones (Jansen, 1999, Jansen, 2000). Adult wasps are also attracted by aphid honeydew cover which is linked to the presence and abundance of aphids. Longley and Jepson (1997b) have shown that cereal aphids, such as *Sitobion avenae* and *Metapolophium dirhodum* preferred underside of leaves as feeding site. As pesticide residues are mostly distributed on the upperside of leaves, adult wasps spend most of the time in contact with limited concentration of pesticides. Thus, exposure of adult wasps to insecticides applied on plants cannot be considered continuous as in laboratory tests but discontinuous. Furthermore, wasp behaviour tends to diminish contact with parts of plants receiving highest amounts of pesticides.

Climatic conditions observed during experiments can also partly explain the results obtained. Some rainfall occurred after insecticide applications and plant sampling 1 and 3 day after treatment. These rains probably reduced pesticide concentration on plants and subsequently observed toxicity. These climatic conditions were not considered as unusual for the season, but repetition of experiments in different climatic conditions could be of high interest to determine influence of the rain on duration of harmful activity of tested insecticides.

Conclusions

According to the results obtained in this study, it can be concluded that exposure of adult wasps to insecticide field treated plants at their maximum recommended field rate did not lead to marked toxic effects. When significant toxicity was observed with freshly applied insecticide residues, effects were short-lived and no harmful effects could be detected 3 days after treatments. Because the absence of effects of these products on aphidiid nymphs was already known, these results can lead to the general conclusion that the insecticides tested could have a very limited effect on aphidiid field populations. The low toxicity of these products to *A. rhopalosiphi* could be explained by parameters such as heterogeneity of pesticide deposits on plants, real amount of pesticide residues in contact with adult wasps when products are field applied, wasp behaviour and climatic conditions. Repetition of these experiments to encounter other climatic conditions could be helpful to confirm these results.

References

Abbott, S.W. 1925: A method of computing the effectiveness of insecticides. Journal of Economic Entomology 18: 265-267.

Ayal, Y. 1987: The foraging strategy of *Diaeretiella rapae*. I. The concept of the elementary unit of foraging. Journal of Animal Ecology 56: 1057-1068.

Borgemeister, C., Poehling, H.-M., Dinter, A. & Höller, C. 1993: Effects of insecticides on life history parameters of the aphid parasitoid *Aphidius rhopalosiphi* (Hym.: Aphidiidae). Entomophaga 38: 245-255

Cilgi, T. & Jepson, P. 1992: The use of tracers to estimate the exposure of beneficial insects to direct pesticide spraying in cereals. Annals of Applied Biology 121: 239-247.

Cloutier, C. & Bauduin, F. 1990: Searching behaviour of the aphid parasitoid *Aphidius nigripes* (Hymenoptera: Aphidiidae) foraging on potato plants. Environmental Entomology 19: 222-228.

Dagnelie, P. 1974: Théorie et méthodes statistiques, Vol. 2, ed. by Duculot SA, J., Gembloux, Belgium.

Dedryver, C.A., Ankersmit, G.W., Basedow, T., Bode, E., Carter, N., Castanera, P., Chambers, R., Dewar, A., Keller, S., Latteur, G., Papierok, B., Powell, W., Rabbinge, R., Sotherton, N.W., Sunderland, K., Wilding, N. & Wratten, S.D. 1985: Rapport de synthèse sur les activités du sous-groupe «Ecologie des pucerons des céréales». IOBC/WPRS Bulletin 8(3): 57-104.

Jansen, J.-P. 1996: Side effects of insecticides on *Aphidius rhopalosiphi* (Hym., Aphidiidae) in laboratory. Entomophaga 41:37-43.

Jansen, J.-P. 1998: Effects of wheat foliar fungicides on the aphid endoparasitoid *Aphidius rhopalosiphi* DeStefani-Perez (Hym.; Aphidiidae) on glass plates and on plants. Journal of Applied Entomology 123: 217-223.

Jansen, J.-P. 2000: Toxicity of fungicides to adults of *Aphidius rhopalosiphi* DeStefani-Perez (Hymenoptera: Aphidiidae) in laboratory tests with field treated wheat. IOBC/WPRS Bulletin 23(9): 73-80.

Jones, M. 1972: Cereal aphids, their parasites and predators caught in cages over oats and winter wheat crops. Annals of Applied Biology 72: 13-25.

Krespi, L., Rabasse, J.M., Dedryver, C.A. & Nenon J.P. 1991: Effect of three insecticides on the life cycle of *Aphidius uzbekistanicus* Luz. (Hym.: Aphidiidae). Journal of Applied Entomology 111: 113-119.

Kühner, C., Klingauf, F. & Hassan, S.A. 1985: Development of laboratory and semi-field methods to test the side-effect of pesticides on *Diaeretiella rapae* (Hym: Aphidiidae) Med. Fac. Landbouww. Rijksuniv. Gent 50/2b: 531-538.

Latteur, G. & Destain, J. 1980: Etude de l'action des champignons et des hyménoptères parasites inféodés aux populations de *Sitobion avenae* (F.) et de *Metopolophium dirhodum* (Walk.) dans le champ expérimental de Milmort en 1978 et 1979. IOBC/WPRS Bulletin 1980/III/4: 11-17.

Latteur, G. & Moens, R. 1990: Rôle clef de la lutte biologique naturelle dans la lutte intégrée contre les pucerons des céréales en été. Fumure et protection phytosanitaire des céréales, 1990. Ed. Faculté Sciences Agronomiques de Gembloux et Centre de Recherches Agronomiques de l'état, Gembloux, Belgique.

Latteur, G. 1973: Etude de la dynamique des populations des pucerons des céréales - Premières données relatives aux organismes aphidiphages en trois localités différentes. Parasitica 29: 134-151.

Longley, M. & Jepson, P. 1997a: Effects of life stage, substrate, and crop position on the exposure and susceptibility of *Aphidius rhopalosiphi* De Stefani-Perez (Hymenoptera: Braconidae) to deltamethrin. Environmental Toxicology and Chemistry 16(5): 1034-1041.

Longley, M. & Jepson, P. 1997b: Cereal aphid parasitoid survival in a logarithmically diluted deltamethrin spray transect in winter wheat: field-based risk assessment. Environmental Toxicology and Chemistry 16(8): 1761-1767.

Oakley, J.N., Walters, K.F., Ellis, S.A., Green, D.B., Watling, M. & Young, J.E. 1996: Development of selective aphicide treatments for integrated control of summer aphids in winter wheat. Annals of Applied Biology 128: 423-436.

Overmeer, W.P.J. & van Zon, A.Q. 1982: A standardised method for testing the side-effects of pesticides on the predacious mite *Amblyseius potentillae* Garman (Acarina: Phytoseiidae). Entomophaga 27: 357-364.

Powell, N. 1983: The role of parasitoids in limiting cereal aphid populations. In: Aphid antagonists, proceedings of a meeting of the EC experts group, Portici, Italy, 1983. R. Cavalloro (ed.), Balkema, Rotterdam.

Stary, P. 1970: Biology of Aphid parasitoids (Hymenoptera: Aphidiidae) with respect to integrated control. Series Entomologica, Dr. W. Junk Publ., Den Haag.

Stary, P. 1988: Natural enemies: Parasites. In: World Crop Pests, Aphids, their biology, natural enemies and control. A.K. Minks and P. Harrewijn (eds.), Vol. 2B: 171-188.

Zadoks, J.C., Chang, T.T. & Konzak, C.F. 1974: A decimal code for the growth stages of cereals. Weed Research 14: 415-421.