Pesticides and Beneficial Organisms
IOBC/wprs Bulletin Vol. 29 (10) 2006
pp. 21-32

Building a selectivity list of plant protection products on beneficial arthropods in open field: a clear example with potato crop

Hautier, L.[1], Jansen, J-P.[1], Mabon, N.[2], Schiffers, B.[2]

[1] *Department of Biological Control and Plant Genetic Resources, Walloon Centre of Agricultural Research, Chemin de Liroux, 2, 5030 Gembloux, Belgium*
[2] *Analytical Chemistry and Phytopharmacy Unit, Agricultural Faculty of Gembloux, Passage des Déportés, 2, 5030 Gembloux, Belgium*

Abstract: In order to promote IPM and the use of selective pesticides in open fields, a program was initiated to provide a selectivity list to pesticide users. The first approach was with potato crop, because of intensive use of pesticides and interest of IPM in this crop in Belgium.

For this, the following beneficial arthropods species were selected: *Aphidius rhopalosiphi* (De Stefani-Perez) (Hym.; Aphidiidae), representative of parasitic Hymenoptera, *Adalia bipunctata* L. (Col.; Coccinellidae) and *Episyrphus balteatus* (De Geer) (Dipt.; Syrphidae), both representative of leaf dwelling predators. These are all aphid specific enemies, the main pest problem in potato in Belgium.

The toxicity of 20 fungicides and 12 insecticides used in potato during the period of potential exposure of these beneficials were assessed on these species according to methods previously developed. The tests included a glass plate test on inert surface according to IOBC standard and an extended-lab test on natural substrate (barley seedlings for *A. rhopalosiphi* and French bean seedlings for *E. balteatus* and *A. bipunctata*). The spray apparatus was calibrated to deliver a pesticide residue deposit similar to a field application. A chemical dosage of residue was realized at each test on natural substrate to validate the application and follow pesticide degradation during exposure.

According to results of both tests, products were rated as “Green” (harmless), “Yellow” (slightly harmful), “Orange” (moderately harmful) and “Red” (harmful). List were build-up according to toxicity results of the products and split in 4 periods of use depending on, aphid natural enemies presence and their importance in the field: period one (until 10 June) and four (after 31 July), no or limited, period 2 (10-30 June) exposure of aphid parasites and period 3 (July), exposure of leaf dwelling predators. These periods were based on field observations of aphids and natural enemies carried out since 1994 in the context of potato pest advisory systems.

A first list was compiled and distributed to farmers in 2004 and updated in 2005 with new compounds. The results show that it is currently possible to combine throughout the growing season an effective plant protection program with pesticides that are selective to main aphid natural enemies.

Keywords: Selectivity list, Aphidiidae, ladybird, hoverfly, *Aphidius rhopalosiphi*, *Adalia bipunctata*, *Episyrphus balteatus*, potato, insecticide, fungicide, potato aphids, plant protection products.

Introduction

The use of non-selective pesticides towards beneficial arthropods can have serious consequences on the efficiency of biological pest control. Parasites and predators suppression can lead to pest outbreak and an increase of the insecticides treatments (Ripper, 1956; Pimentel, 1961; Besemer, 1964; Vickerman & Sunderland, 1977; Shires, 1985; Borgemeister & Poehling, 1989; Croft & Slone, 1998).

Resurgence of secondary pests can also be the consequence of the suppression of beneficial arthropods by non-selective insecticides, herbicides or fungicides (Adams & Drew, 1965; Nanne & Radcliffe, 1971; Brown, 1978; Sotherton *et al.*, 1987; Sotherton & Moreby, 1988; Lagnaoui & Radcliffe, 1998). As a result, non-selective pesticides can lead to a multiplication of pesticides treatments, an increase of production cost and finally a negative impact on health and the environment. In the context of sustainable agriculture and implementation of integrated production systems, the use of selective pesticides towards pests natural enemies becomes necessary. Moreover, it's required for agricultural specifications and certification standards such as EUREPGAP, PERFECT and GIQF.

Aphids are the main insect pest problems encountered in ware potatoes. However, they are most of the time regulated by natural enemies, such as parasitic Hymenoptera, mainly Aphidiidae and aphidophagous predators, such as hoverflies, ladybirds and to a lesser extent lacewings (Jansen, 2000; Jansen & Warnier, 2004). On basis of 1994-2005 observations on more than 200 commercial potato fields, the economic threshold value for aphids has only be reached in only more or less 1 field out of 8 (Jansen, 2005a). On the other fields, aphid populations were naturally controlled by beneficial arthropods. In this context, the use of selective pesticides during aphid natural enemy activity period is of particular importance because the disruption of aphid natural control lead to severe aphid outbreaks and increase of insecticide use.

The aim of this research was to assess toxicity of pesticides currently used in potato towards natural enemies of aphids and to provide information to the farmers with help of selectivity lists. These lists can easily be integrated to IPM and potato inputs reduction programs. They can bring an additional support to aphids and potato blight advisory systems and allow a potato qualitative integrated production.

Material and methods

Selectivity lists were derived from a pesticides acute toxicity towards selected natural enemies and coincidence between beneficial arthropods activity and pesticides application periods, according to normal agricultural practices and phenology observed in Belgium.

Beneficials tested and phenology

According to the beneficial fauna encountered in potato and the main key pest, aphids, three aphid natural enemies were selected as representative species:

- *Aphidius rhopalosiphi* De Stefani-Perez (Hym.; Aphidiidae)
- *Adalia bipunctata* (L.) (Col.; Coccinellidae)
- *Episyrphus balteatus* (De Geer.) (Dipt ; Syrphidae)

A. rhopalosiphi is not encountered in potato but is the representative species for Aphidiidae and parasitic Hymenoptera in the context of product registration at European level. This species is more sensitive to pesticides than *Aphidius ervi* and *Aphidius picipes* (Maise *et al.*, 1997) that are the main species in potato (Jansen, 2005b). *A. bipunctata* is one of the four ladybird species found in potato and probably the most sensitive one (Jansen, in press). *E. balteatus* is the commonest hoverfly species in potato with up to 80% of the syrphid populations (Jansen & Warnier, 2004).

Phenology of beneficials met in potato fields was based on 162 field observations carried out between 1994 and 2002 in the context of aphid advisory system (Jansen, 2002).

Tested Products

20 fungicides, including products with 2 active ingredients and 12 insecticides were tested in their commercial forms. These products correspond to all registered products used in June and

July, when aphid natural enemies are active in the field, according to Belgian conditions. Insecticides were tested at the maximum recommended field rate on basis of a single application and fungicides were tested at 1.5 x recommended field rate for one application to take into account possible multiple applications of the products at short intervals. Tested products and doses are listed in table 1.

Application of products
The toxicity of each product towards beneficial arthropods was assessed according to SETAC guidelines (Barrett *et al*., 1994) and an original methodology developed by Copin *et al.* (2001). This original method is based on comparison of pesticide residue deposits on plants treated in the field with spray ramps (Azo 110) and laboratory aerograph Caussin sprayer. The laboratory sprayer was calibrated to have a more or less similar pesticide residue repartition as in the field, with part of the plants, as underside of leaves and basis of the plants receiving less pesticides than upper side of leaves and top of the plant. Spray volume was 200 l/ha ± 10%. All applications of plants were validated by pesticide residue dosage for the repartition and gravimetry.

Testing scheme
The acute toxicity was assessed according to a sequential testing scheme, as developed by the IOBC working group "Pesticides and Beneficial Organisms". The pesticide toxicity was evaluated first on an inert substrate (glass plates, A test). If the product induced a mortality higher than 30%, toxicity assessment was continued on a natural substrate (French bean for Syrphidae and Coccinellidae, barley for Aphidiidae, B test). According to the beneficial arthropods corrected mortality (Mc) observed after 48 h (glass tests and parasitoid tests on plants) or after 72 h (predators on plants), agrochemicals were classified in 4 categories:

1 - harmless product : Mc ≤ 30 % on glass or on plant
2 - slightly harmful product : 30% < Mc ≤ 60% on plant
3 - moderately harmful product : 60 % < Mc ≤ 80% on plant
4 - harmful product : Mc > 80% on plant

The limits of each category were selected to get a good discrimination of products in the final lists and to label red products that were known before to make problems in the field (pest resurgence, secondary pest outbreaks, ...).

Selectivity list building
The selectivity list will be build by a combination of toxicity test results and classification and insect phenology. Potato vegetation periods will be defined according to phenology of the beneficials and product classification will be done by period, according to final toxicity test results for the main beneficial encountered at this period. For periods when two species are of equal importance (by example ladybirds and hoverflies in July), the geometric mean of both corrected mortality test will be retained for product classification.

Toxicity tests
A. rhopalosiphi was exposed to fresh pesticide residues applied to glass plates and to barley seedlings in a similar way to that described by Mead-Briggs (Mead-Briggs & Longley, 1997; Mead-Briggs *et al*., 2000) except minor changes. For glass plates, there were 5 units of 10 wasps per product and for control instead of 4 x10. On plants, these were 10 x10 wasps per product instead of 5x5 females. Sugar solution was substituted by aphids with more than 100 aphids added to the plant 24h before spraying. Mortalities were assessed after 48h for both tests.

A. bipunctata exposure units were made of a circular glass plate (∅ 5cm) treated with pesticide and covered with a plastic ring coated with Fluon GP1 to prevent ladybird escape.

There were a total of 30 larvae/product and 30 larvae for control. For *E. balteatus*, two treated glass plates were used to form the ceiling and the floor of exposure units, with the treated faces turned inside the units. A plastic ring was inserted between the two glass plates and the units were connected to a pump to renew the air. There were 20 larvae per product and 20 larvae for control at each test. 2-3 day old hoverfly and ladybird larvae were used for the test. They were fed ad lib with pea aphids (*Acyrtosiphon pisum*). Mortalities were recorded after 48h of exposure.

Table 1: List of tested products. Commercial name, formulation type, active(s) ingredient(s) and tested dose.

	Commercial name	Formulation	active ingredient	tested rate (g a.s./ha)
Fungicide	GALBEN M	WP	benalaxyl + mancozeb	300 + 2438
	CLORTOSIP	SC	chlorothalonil	2250
	TATTOO C	SC	chlorothalonil + propamocarb	1519 + 1519
	RANMAN	SC	cyazofamid	120
	CURZATE M	WP	cymoxanil + mancozeb	135 + 1950
	AVISO	WG	cymoxanil + metiram	216 + 2880
	TANOS	WG	cymoxanil + famoxadone	225 + 225
	ACROBAT EXTRA	WG	dimetomorph + mancozeb	225 + 2513
	SERENO	WG	fenamidone + mancozeb	225 + 1125
	SHIRLAN	SC	fluazinam	300
	KOCIDE	WG	copper hydroxid	2400
	DEQUIMAN MZ	WG	mancozeb	4800
	UNIKAT PRO	WG	mancozeb + zoxamide	1801 + 224
	TRICARBAMIX EXTRA	WG	maneb	4800
	EPOK 600	EC	metalaxyl-m + fluazinam	150 + 300
	RIDOMIL GOLD SPECIAL 68	WP	metalaxyl-m + mancozeb	150 + 2400
	CUPRAVIT FORTE	WP	copper oxychlorid	3750
	ANTRACOL	WP	propineb	3150
	CUPRO-ANTRACOL	WP	propineb + copper oxychlorid	2775 + 1313
	MACC80 Bo. BORDELAISE	WP	copper sulfate	3750
Insecticide	FASTAC	EC	alpha-cypermethrin	12.5
	CARBISAN	WP	carbaryl	768
	CYMTOP 100	EC	cypermethrin	25
	DECIS 2,5	EC	deltamethrin	7.5
	HERMOOTROX	EC	dimethoate	200
	SUMI ALPHA	EC	esfenvalerate	7.5
	KARATE ZEON	SC	lambda-cyhalothrin	7.5
	OKAPI	EC	lambda-cyhalothrin + pirimicarb	7.5 + 150
	ZOLONE FLO	SC	phosalone	750
	PIRIMOR	WG	pirimicarb	200
	PLENUM	WG	pymetrozin	150
	FURY 10	EW	zeta-cypermethrin	10

Exposure of ladybird and hoverfly larvae to pesticides on plants was made with the same exposure units. Approximately after one week of emergence, young French bean plants were pinched out in order to keep approximately the two first leaves and 7-10 cm of stem, to produce a kind of “standardised” plant. The plants were thus treated and two larvae and aphids were added to the plants when the pesticide residue had dried. The plants were grown on ∅ 9 cm seedlings pots, the substrate was covered with sand and a plastic device with the inner walls coated with fluon was inserted around the French bean. With this device, if the larvae fell from the plant, they were unable to escape and had to stay on the sand or to climb on the plants where the aphids were. For ladybird and hoverfly, there were 2 larvae /plant and 15 plants treated and 15 for control by product. Mortality was recorded after 72h of exposure.

All test organisms used for the test were produced by the mass rearing of the laboratory. The three rearings were initiated with organisms collected at field margins and hedges, in an agricultural landscape. *Aphidius* rearing started in 1994, *Adalia* in 1995 and *Episyrphus* in 1996. New organisms were collected yearly to replenish the rearing. Observed mortalities were corrected with control mortality according to Abbott (Abbott, 1925). The validity criteria for acceptance of the results was control mortality below 10% on glass plates and 13% on plants.

Results and discussion

Beneficial phenology and pesticides periods application

In potato, aphid parasitoids and predators (ladybirds and syrphids) are the main beneficial insects controlling aphid populations (Jansen, 2000 ; Jansen, 2002). The phenology of these beneficial arthropods, based on field observations between 1994 and 2002, is illustrated in Figure 1. Hymenoptera Aphidiidae were the first active aphids enemies arriving in the field at the same time as the first aphids. The presence of winged parasitised aphids at the beginning of the season is very common, indicating that they arrived in the crop in a same time as aphids. The action of parasitic wasps is clearly very important at the beginning of the aphid infestation period and parasitic wasps are the key beneficial for aphid control in June.

Ladybirds and hoverflies generally arrive later. The first eggs were detected around the end of June when aphid populations were sufficient to allow the offspring development These aphidophagous insects remain in the field until aphid populations decline, from July 15 till the end of the month. Their action is curative and a rapid decline of aphid populations is generally observed at the middle of June, when aphid specific predators populations are at their maximum.

On the basis of beneficial insects phenology and the periods of application of plant protection products, the farming year was split in four periods, each corresponding to a particular situation:

– Period I (... – 10 June): Before aphid and the first beneficial arrival into the field, no restrictions concerning use of products towards their toxicity, except for products which would have a long duration of activity and interfered with other periods. Fungicides and herbicides are used during this period.

– Period II (10 June – 30 June): Main activity period of parasitic Hymenoptera. Selectivity list based on *Aphidius* test results. This period is particularly concerned with fungicides, that are applied weekly during this period. Insecticides can sometimes be used, but only for particular situations.

– Period III (1 July – 30 July): Peak aphid populations and the main activity period of aphid specific predators. Selectivity lists are based on *A. bipunctata* and *E. balteatus* toxicity results (geometric mean of both tests). Fungicides are routinely applied during this period and, if needed, insecticides to control aphids. No Colorado beetle treatments are needed according to Belgian conditions.

– Period IV (1 August – ...): No aphids and beneficials in the field, there are no restrictions concerning use of products towards their toxicity. Normally only fungicides are used during this period and herbicides at the end of the growing season for potato foliage desiccation before harvesting.

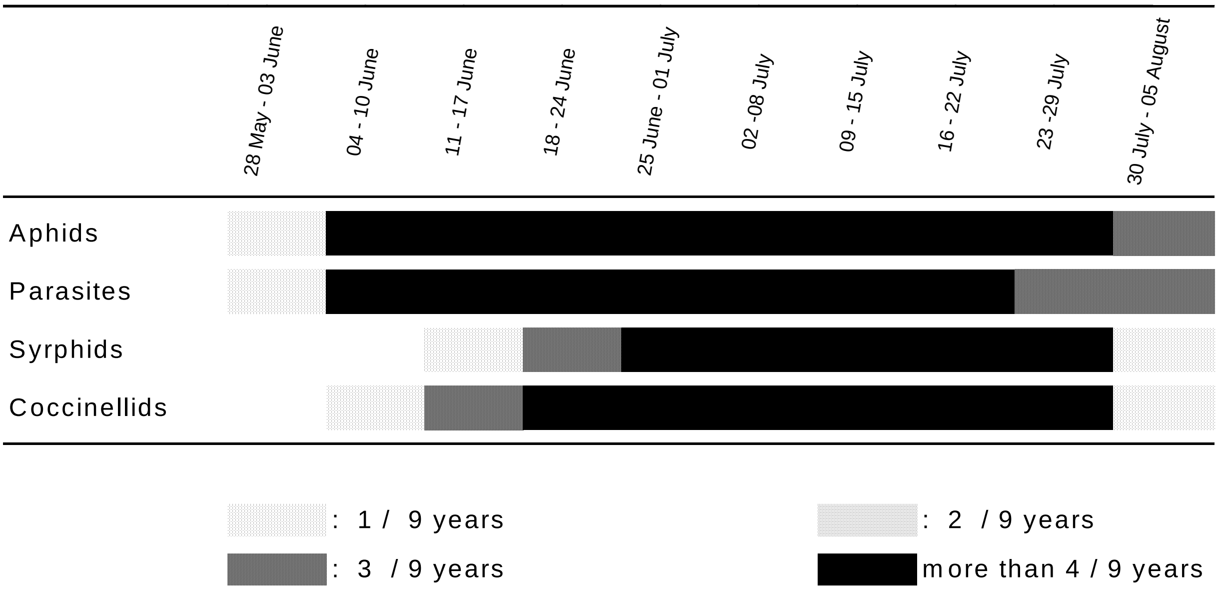

Figure 1. Frequency of aphids and aphid natural enemies arrival in potato in Belgian conditions (1994 to 2002).

Acute toxicity assessment

Results of glass plates tests (A test), extended lab-test (B test) and pesticide classification are listed in Table 2 (*Aphidius* test) and 3 (*Adalia* and *Episyrphus* tests).

Results with *A. rhopalosiphi* showed that all fungicides registered in June were harmless on plants, even if several were toxic on glass plates. With insecticides, results were contrasted but finally, several insecticides were rated as harmless: cypermethrin, esfenvalerate, lambda-cyhalothrin, pirimicarb, pymetrozin, zeta-cypermethrin and mixture lambda-cyhalothrin + pirimicarb. Pymetrozin was harmless even on glass plates. The others were still either slightly harmful (alpha-cypermethrin, carbaryl and phosalone), moderately harmful (deltamethrin) or harmful (dimethoate). There were sometimes great differences between pyrethroids, that are unexplained. The formulation type (EW against EC) and the recommended field dose (25g a.i./ha for cypermethrin but only 10 or 12.5 g a.i./ha for zeta and alpha-cypermethrin) could probably have had an influence on toxicity.

All fungicides were harmless for *A. bipunctata* except the mixture metalaxyl-M + fluazinam which was slightly harmful. For insecticides, only pirimicarb and pymetrozin were selective towards *A. bipunctata*; all the others were very toxic with mortality on plant higher than 80 % and often equal to 100%.

E. balteatus was not affected by fungicides used in potato. With insecticides, three products (alpha-cypermethrin, lambda-cyhalothrin and pymetrozin) were harmless on glass plates and two other ones, carbaryl and esfenvalerate, were harmless on plants. The others were slightly harmful as phosalone, moderately harmful (cypermethrin and deltamethrin), or harmful as dimethoate, pirimicarb and lambda-cyhalothrin + pirimicarb. If results obtained on *A. bipunctata* and *E. balteatus* are combined, pymetrozin was the only harmless product for both aphid predators. The other products were slighty harmful or totally harmful for at least one of the two species. Dimethoate, cypermethrin, deltamethrin and the mixture lambda-cyhalothrin + pirimicarb, with one compound highly toxic for ladybird and the other one toxic for hoverfly, were the most toxic insecticides.

Table 2: Result of toxicity test with *A. rhopalosiphi,* corrected mortality (A=glass plate, B=extended lab) and selectivity class: 1–harmless, 2-slightly harmful, 3-moderately harmful and 4-harmful.

		Aphidius test		
		A	B	Final
Fungicide	Benalaxyl + Mancozeb	0%	–	1
	Chlorothalonil	10%	–	1
	Chlorothalonil + Propamocarb	68%	1%	1
	Copper hydroxide	48%	23%	1
	Copper oxychlorid	20%	–	1
	Copper sulfat	0%	–	1
	Cyazofamide	32%	0%	1
	Cymoxanil + famoxadone	0%	–	1
	Cymoxanil + Mancozeb	4%	–	1
	Cymoxanil + Metiram	23%	–	1
	Dimetomorph + Mancozeb	2%	–	1
	Fluazinam	8%	–	1
	Mancozeb	6%	–	1
	Mancozeb + Zoxamide	0%	–	1
	Maneb	0%	–	1
	Metalaxyl-M + Fluazinam	6%	–	1
	Metalaxyl-M + Mancozeb	45%	4%	1
	Propineb	0%	–	1
	Propineb + Copper oxychlorid	0%	–	1
Insecticide	Alpha-cypermethrin	100%	38%	2
	Carbaryl	100%	51%	2
	Cypermethrin	100%	22%	1
	Deltamethrin	100%	80%	3
	Dimethoate	100%	100%	4
	Esfenvalerate	91%	6%	1
	Lambdacyhalothrin	100%	1%	1
	Lambdacyhalothrin + Pirimicarb	100%	3%	1
	Phosalone	68%	50%	2
	Pirimicarb	100%	12%	1
	Pymetrozin	4%	–	1
	Zeta-cypermethrin	100%	3%	1

Table 3: Result of toxicity test with *A. bipunctata* and *E. balteatus,* corrected mortality (A=glass plate, B=extended lab) and selectivity class: 1–harmless, 2-slightly harmful, 3-moderately harmful and 4-harmful.

		Adalia test		*Episyrphus* test		Final class
		A	B	A	B	
Fungicide	Benalaxyl + Mancozeb	0%	–	0%	–	1
	Chlorothalonil	0%	–	21%	–	1
	Chlorothalonil + Propamocarb	0%	–	0%	–	1
	Copper hydroxide	3%	–	0%	–	1
	Copper oxychlorid	0%	–	0%	–	1
	Copper sulphate	10%	–	0%	–	1
	Cyazofamide	7%	–	0%	–	1
	Cymoxanil + Famoxadone	0%	–	0%	–	1
	Cymoxanil + Mancozeb	0%	–	0%	–	1
	Cymoxanil + Metiram	10%	–	5%	–	1
	Dimetomorph + Mancozeb	0%	–	17%	–	1
	Fenamidone + mancozeb	40%	0%	26%	–	1
	Fluazinam	100%	20%	0%	–	1
	Mancozeb	3%	–	0%	–	1
	Mancozeb + Zoxamide	14%	–	11%	–	1
	Maneb	0%	–	16%	–	1
	Metalaxyl-M + Fluazinam	86%	47%	0%	–	1
	Metalaxyl-M + Mancozeb	33%	0%	45%	–	1
	Propineb	10%	0%	0%	15%	1
	Propineb + Copper oxychlorid	20%	–	0%	–	1
Insecticide	Alpha-cypermethrin	100%	100%	16%	–	2
	Carbaryl	100%	100%	100%	0%	2
	Cypermethrin	100%	100%	85%	80%	4
	Deltamethrin	100%	100%	75%	63%	4
	Dimethoate	100%	100%	100%	100%	4
	Esfenvalerate	100%	100%	47%	13%	2
	Lambdacyhalothrin	100%	100%	0%	–	2
	Lambdacyhalothrin + Pirimicarb	100%	100%	100%	100%	4
	Phosalone	96%	100%	63%	56%	3
	Pirimicarb	21%	–	80%	94%	2
	Pymetrozin	0%	–	0%	–	1
	Zeta-cypermethrin	100%	100%	65%	0%	2

Selectivity lists

According to the toxicity test results, beneficial arthropods phenology and normal use of the products, 4 selectivity lists, each corresponding to a different period, were built-up (Table 4). These lists were also printed and distributed to farmers and potato industry, with a colour key for toxicity, from green (harmless) to red (harmful) with yellow and orange category.

Examination of the lists indicates that fungicides actually used in Belgium are not a problem for aphid natural enemies and do not interfere with aphid natural control. However, as fungicides are widely used throughout the growing season, a great attention must be given to this aspect in the future for new compounds. With insecticides, the situation is not so easy, but several products can be listed as harmless or slightly harmful, at least during some periods. Pymetrozin has a very good selectivity for both parasitic wasp and aphid specific predators. This new compound is very interesting in the context of IPM, compared to other products. Dimethoate was particularly toxic to beneficials and its use must be avoided at any time. The other compounds had variable effects on the different tested species. Some of them

Table 4: Selectivity lists of products used in potato according to their toxicity towards main aphid natural enemies. 1 – harmless, 2 – slightly harmful, 3 – moderately harmful, 4 – harmful, X – not registered at this period.

		Periods			
		I (-10/06) No exposure	II (10-30/06) *Aphidius* tests	III (1-31/07) *Episyrphus* + *Adalia* tests	IV (1/08-..) No exposure
Fungicides	Benalaxyl + Mancozeb	1	1	1	1
	Chlorothalonil	1	1	1	1
	Chlorothalonil + Propamocarb	1	1	1	1
	Copper hydroxide	1	1	1	1
	Copper oxychlorid	1	1	1	1
	Copper sulfate	1	1	1	1
	Cyazofamide	1	1	1	1
	Cymoxanil + Famoxadone	1	1	1	1
	Cymoxanil + Mancozeb	1	1	1	1
	Cymoxanil + Metiram	1	1	1	1
	Dimetomorph + Mancozeb	1	1	1	1
	Fenamidone+ Mancozeb	1	X	1	1
	Fluazinam	1	1	1	1
	Mancozeb	1	1	1	1
	Mancozeb + Zoxamide	1	1	1	1
	Maneb	1	1	1	1
	Metalaxyl-M + Fluazinam	X	1	1	X
	Metalaxyl-M + Mancozeb	X	1	1	X
	Propineb	1	1	1	1
	Propineb + Copper oxychlorid	1	1	1	1
Insecticide	Alpha-cypermethrin	–	2	2	–
	Carbaryl	–	2	2	–
	Cypermethrin	–	1	4	–
	Deltamethrin	–	3	4	–
	Dimethoate	–	4	4	–
	Esfenvalerate	–	1	2	–
	Lambda-Cyhalothrin	–	1	2	–
	Lambda-cyhalothrin + Pirimicarb	–	1	4	–
	Phosalone	–	2	3	–
	Pirimicarb	–	1	2	–
	Pymetrozin	–	1	1	–
	Zeta-cypermethrin	–	1	2	–

were selective to parasitic wasps and can be used in June without restriction. In July, because of toxicity on ladybirds and/or hoverflies, use of several products, as cypermethrin, deltamethrin and the mixture lambda-cyhalothrin + pirimicarb, is not recommended. They were great differences in term of toxicity between cypermethrin and the two isomers alpha and zeta-cypermethrin. These differences are probably coming from a combination of tested dose, higher for cypermethrin than for isomers, formulation type and active ingredient toxicity itself.

Conclusions

The results obtained in this study show that it is possible to have a good pest and disease control with products that are selective towards main aphid natural enemies, during all the periods where these beneficial insects are active in the field. Fungicide applications for late blight control are not a problem for selectivity and it is possible, by avoiding the use of several insecticides at particular periods, to maintain aphid natural enemy activity. These selectivity lists can help the farmers to choose the product to spray; and they can also complete the information given by potato advisory systems for aphids control.

Acknowledgements

This study was funded by the Belgian ministry "SPF SANTE PUBLIQUE, Sécurité de la Chaîne alimentaire et Environnement, Direction générale Animaux, Végétaux et Alimentation, Division Matières premières et protection des végétaux". We thank A.M. Warnier, S. Mahiat, C. Torrekens and J. Vase for their contribution to this study.

References

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

Adams, J.B. & Drew, M.E. 1965: Grain aphids in New Brunswick. III. Aphid populations in herbicide-treated oat fields. – Canadian Journal of Zoology 43:789-794.

Barrett, K.L., Grandy, N., Harrison, E.G., Hassan, S.A. & Oomen, P. 1994: Guidance document on regulatory testing procedures for pesticide with non-target arthropods. – Workshop European Standard Characteristics of Beneficials Regulatory Testing (ESCORT) held at IAC Wageningen, The Netherlands, 28-30 March 1994, Society of Environmental Toxicology and Chemistry (SETAC) – Europe, ISBN 0 9522535 2 6.

Besemer, A.F. 1964: The available data on the effect of spray chemicals on useful arthropods in orchards. – Entomophaga 9: 263-269.

Borgemeister, C. & Poehling, H-M. 1989: The impact of insecticide treatments on the population dynamics of cereal aphids and their parasitoids. – IOBC/WPRS Bulletin 12(1): 122-132.

Brown, A.W. 1978: Insecticides and the arthropod fauna of plant communities. – In: Ecology of pesticides. John Wiley & Sons, New-York, USA: 28-62.

Copin, A., Latteur, G., Deleu, R., Mahaut, T. & Schiffers, B. 2001: Evaluation du risque de toxicité de pesticides vis-à-vis de trois auxiliaires (*Adalia bipunctata*, *Aphidius rhopalosiphi* et *Episyrphus balteatus*) par le dosage chimique des résidus. – Ministère des Classes moyennes et de l'Agriculture DG 6: 83 pp.

Croft, B.A. & Slone, D.H. 1998: Perturbation of regulated apple mites: Immigration and pesticide effects on outbreaks of *Panonychus ulmi* and associated mites (Acari: Tetranychidae, Eryophiidae, Phytoseiidae and Stigmatidae). – Environmental Entomology 27: 1548-1556.

Dixon, A.F. 2000: Insect predator – prey dynamics. – Cambridge University Press: Cambridge: 257 pp

Jansen, J.-P. 2000: Pucerons de la pomme de terre de consommation, bilan de la saison écoulée. – Parasitica 56(2-3): 47-57

Jansen, J.-P. 2002: Pucerons et auxiliaires de lutte en pomme de terre de consommation: synthèse des observations réalisées entre 1994 et 2001 en Belgique. – 2ème conférence internationale sur les moyens alternatifs de lutte contre les organismes nuisibles aux végétaux, Lille – 4, 5, 6 et 7 mars 2002.

Jansen, J.-P. 2005a: Aphid parasitoid complex in potato in Belgium in the context of IPM. – Comm. Appl. Biol. Sci., Ghent University, 70, in press.

Jansen, J.-P. 2005b: Pucerons en pomme de terre de consommation: bilan de 12 années d'observations. – In: Journée d'étude Pomme de terre du CRA-W 2005, 23 Novembre 2005: 41-50.

Jansen, J.-P. & Warnier, A.-M. 2004: Aphid specific predators in potato in Belgium. – Comm. Appl. Biol. Sci., Ghent University 69(3): 151-156.

Lagnaoui, A. & Radcliffe, E.B. 1998: Potato fungicides interfere with entomopathogenic fungi impacting population dynamics of green peach aphid. – American Potato Journal 75: 19-25.

Maise, S., Candolfi, P., Neumann, C., Vickus, P. & Mäder, P. 1997: A species comparative study: sensitivity of *Aphidius rhopalosiphi*, *A. matricariae* and *A. colemani* (Hymenoptera: Aphidiidae) to Dimethoate 40 EC under worst-case laboratory conditions. – In: Haskell, P. & McEwen, P.K. (eds.). New Studies in Ecotoxicology. Welsh Pest Management Forum Conference: 45-49.

Mead-Briggs, M. & Longley, M. 1997: A standard extended laboratory test to evaluate the effects of plant protection products on adults of the parasitoid *Aphidius rhopalosiphi* (Hymenoptera, Braconidae). – Internal method, unpublished.

Mead-Briggs, M.A, Brown, K, Candolfi, M.P., Coulson, M.J.M., Miles, M., Moll, M., Nienstedt, K., Schuld, M., Ufer, A., and McIndoe, E. 2000: A laboratory test for evaluating the effects of plant protection products on the parasitic wasp *Aphidius rhopalosiphi* (DeStephani-Perez) (Hymenoptera: Braconidae). – In: Guidelines to evaluate side-effects of plant protection products to non-target arthropods, eds. Candolfi et al., IOBC/wprs: 13-26.

Michelante, D., Rolot, J.-L. & Verlaine, A. 1998: Le service d'avertissements mildiou de la pomme de terre de la station de Haute-Belgique: fonctionnement et résultats. – 1er Colloque transnational sur les luttes biologique, intégrée et raisonnée. 21-23 janvier 1998, Lille: 345-353.

Nanne, H.W. & Radcliffe, E.B. 1971: Green peach aphid populations on potatoes enhanced by fungicides. – Journal of Economic Entomology. 64: 1569-1570.

Pimentel, D. 1961: An ecological approach to the insecticide problem. – Journal of Economic Entomology. 54: 108-114.

Ripper, W.E. 1956: Effect of pesticides on balance of arthropod populations. – Annual Review of Entomology. 1: 403-438.

Shires, S.W. 1985: Effects of aerial applications of cypermethrin and demeton-s-methyl on nontarget artrhopods. – Ecotoxicology and Environmental Safety 10: 1-11.

Sotherton, N.W. Moreby, S.J. & Langley, M.G. 1987: The effects of the foliar fungicide pyrazophos on beneficial arthropods in barley fields. – Annals of Applied Biology 111: 75-87.

Sotherton, N.W. & Moreby, S.J. 1988: The effects of foliar fungicides on beneficial arthropods in wheat fields. – Entomophaga 33: 87-99.

Stary, P. 1988: Parasites. – In: Aphids their biology, natural enemies and control. eds. Minks A.K. & Harrewijn, P., Elsevier, Amsterdam: 171-216.

Vickerman, G.P. & Sunderland, K.D. 1977: Some effects of dimethoate on arthropods in winter wheat. – Journal of Applied Ecology. 14: 767-777.