Selectivity Lists of Pesticides to Beneficial Arthropods for IPM Programmes in Carrot - First results

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Abstract

In order to improve IPM programs in carrot, 7 fungicides, 12 herbicides and 9 insecticides commonly used in Belgium were tested for their toxicity towards five beneficial arthropods representative of most important natural enemies encountered in carrot: parasitic wasps - *Aphidius rhopalosiphi* (De Stefani-Perez) (Hym., Aphidiidae), ladybirds - *Adalia bipunctata* (L.) (Col., Coccinellidae), hoverfly - *Episyrphus balteatus* (Dipt., Syrphidae), rove beetle – *Aleochara bilineata* (Col., Staphyllinidae) and carabid beetle – *Bembidion lampros* (Col., Carabidae).

Firstly, all plant protection products were tested on inert substrate glass plates or sand according to the insect. Products with a corrected mortality (CM) or a parasitism reduction (PR) lower than 30% were kept for the constitution of positive list (green list). The others compounds were further tested on plant for *A. rhopalosiphi, A. bipunctata, E. balteatus* or soil for *B. lampros* and *A. bilineata*. With these extended laboratory tests results, products were listed in toxicity class: green category [CM or Rp ≤ 30%], yellow category [30% < CM or PR ≤ 60%] and orange category [60% < CM or PR ≤ 80%]. Products with toxicity higher than 80% on plants or that reduce parasitism more than 80% on soil were put in red category and are not recommended to Integrated Pest Management programs in carrot.

Results showed that fungicides protection do not disrupt natural enemies, excepted one product, Tebuconazole, wich is slightly harmfull to *A. bipunctata.* All others fungicides tested can be used without restrictions at recommended rates and according to good agricultural practices. For herbicides, first results showed that products tested were harmless to *A. bilineata* and *B. lampros* excepted Chlorpropham, very toxic on sand towards *A. bilineata*.

All soil insecticides tested were very toxic for ground beneficials and considered as non-selective. They must be avoided for IPM. Among foliar insecticides, Dimethoate and Deltamethrin are not recommended for IPM. The others products are selective but not for the five beneficials at the same time. They must be applied with judgment.

Introduction

Since pesticides have been used, negative impacts on beneficial insects are often reported with consequences as a pest growth and thus an increase of insecticides treatments (Ripper, 1956; Pimentel, 1961; Besemer, 1964; Vickerman and Sunderland, 1977; Shires, 1985; Borgemeister and Poehling, 1989; Croft and Slone, 1998) or secondary pest resurgence (Adams and Drew, 1965; Nanne and Radcliffe, 1971; Brown, 1978; Sotherton *et al.,* 1987; Sotherton and Moreby, 1988; Lagnaoui and Radcliffe, 1998). These consequences come from non-selective pesticides application that suppress biological control made by natural ennemies. Thus in the context of sustainable agriculture and to improve Integrated Pest Management (IPM) programs, pesticides have to be applied with caution to preserve this biological control. In this goal, the pesticides selectivity towards beneficials have to be evaluated. Moreover, agricultural specifications and certification standard as EUREPGAP, PERFECT and GIQF, claim more and more about these data.

In North temperate regions, the main carrot pest is the carrot fly - *Psila rosae* (F.) (Dipt., Psilidae) that create serious damages with economic consequences. *P. rosae* larvae mines the carrot root which may be followed by fungal and bacterial attacks (Dufault and Coaker, 1987). An other pest problem come from aphids that may attack carrot at the begining of the season. Aphids can transmit virus or cause foliage deformity (Hulle *et al.*, 1999).
These pests are more or less controled by beneficial insects. For example, in organic farming, pests / beneficials balance can be reached in carrot crop without insecticides applications.
During the last years, several studies have improved our knowledge about the carrot entomaufauna and especially on beneficial insects. About soil insects, the authors have identified several species of carabids and staphylinids as mainly: *Pterostichus melanarius* (Illiger), *Trechus quadristiatus* (Schrank), *Bembidion* spp., *Aleochara bipustulata* (L.), *Atheta* sp. (Albert *et al.,* 2003; Felix, 2004). As aphids predators and parasites, Colignon *et al.* (2002) have caught in carrot mainly three beneficial families: Syrphidae, Aphididae and Coccinellidae.

In view of this biological control in carrot crop, the use of non-selective plants protection products (herbicides, fungicides or insecticides) towards these natural enemies can have negative impacts. With Consequently, the more numerous insecticide treatments increase the production costs and finally have a negative impact on health and environment.

The goal of this research was to assess the toxicity of pesticides currently used in carrot crop towards natural enemies and to provide information to the farmers through of selectivity lists. These lists can easily be integrated into IPM and inputs reduction programs.

Material and methods

Currently in Belgium, 28 pesticides (7 fungicides, 9 insecticides and 12 herbicides) are registered and commonly used in carrot crop (Table 1). Edification of pesticide selectivity lists was based on available ecotoxicological data or on toxicity tests.

Ecotoxicological data

Ecotoxicological data come from scientific periodicals with specific attention on: active ingredients, dose, application rate and experimental design as substrate or exposition time. Products have been integrated in selectivity lists if they were harmful at equal or lower dose than at registered dose, or harmless at equal or at higher dose than at registered dose in Belgium.

Toxicity tests

Pesticide application

Pesticides were tested at the maximum authorized rate, in their commercial forms (Table 1). They are applied with a pneumatic atomizer, with a maximum standard deviation of 10%, at 200 $l.ha^{-1}$ for glass and plants, but at 400 $l.ha^{-1}$ for sand and soil in order to get better impregantion of the substrate.

Toxicity assessment

Pesticides toxicity towards beneficial arthropods were assessed according to SETAC guidelines (Barrett *et al.,* 1994), an original methodology developed by Copin *et al.* (2001) for aphids predators and parasites and for ground insects from Heimbach *et al.* (2000) and Grimm *et al.* (2000).

Five beneficial insects were selected for toxicity tests: adult of parasitic waps - *Aphidius rhopalosiphi* De Stefani-Perez (Hym.; Aphidiidae), larvae of ladybird - *Adalia bipunctata* (L.) (Col.; Coccinellidae) and larvae of hoverfly - *Episyrphus balteatus* (De Geer.) (Dipt.; Syrphidae), adult of ground beetle – *Bembidion lampros* (Herbst.) (Col.; Carabidae) and adult of rove beetle - *Aleochara bilineata* Gyll. (Col.; Staphylinidae). Herbicides were tested only on ground insects because in field, they are highly exposed to these treatments, unlike aphids predators or parasites.

The acute toxicity was assessed according to a sequential testing scheme (Fig. 1).

First step, all products were tested on an inert substrate, glass or sand, according to the insect.

Mortalities of aphids parasites and predators after 48 hours exposition or after 2 weeks for carabids were noted to calculate corrected mortality (CM) in accordance with Abbot formula (1925). For staphylinid, parasitism reduction (PR) is calculated after 4 weeks in comparaison with control. If the product induce a corrected mortality or a parasitism reduction was lower than or equal to 30%, the product was considered as harmless and listed in "green category". If CM was higher than 30%, toxicity assessment was gone on in semi-controlled conditions on a natural substrate (horse bean for Syrphidae and Coccinellidae, barley for Aphidiidae, soil for Carabidae and Staphylinidae). In these conditions, corrected mortality or parasitism reduction was calculated and the product was listed in one of the four categories:

- Green category, harmless product : CM or PR ≤ 30 % on glass or on plant or soil;
- Yellow category, slightly harmful product : 30%<CM or PR ≤ 60% on plant or soil,
- Orange category, moderately harmful product : 60 % < CM or PR ≤ 80% on plant or soil,
- Red category, harmful product, CM or PR > 80% on plant or soil.

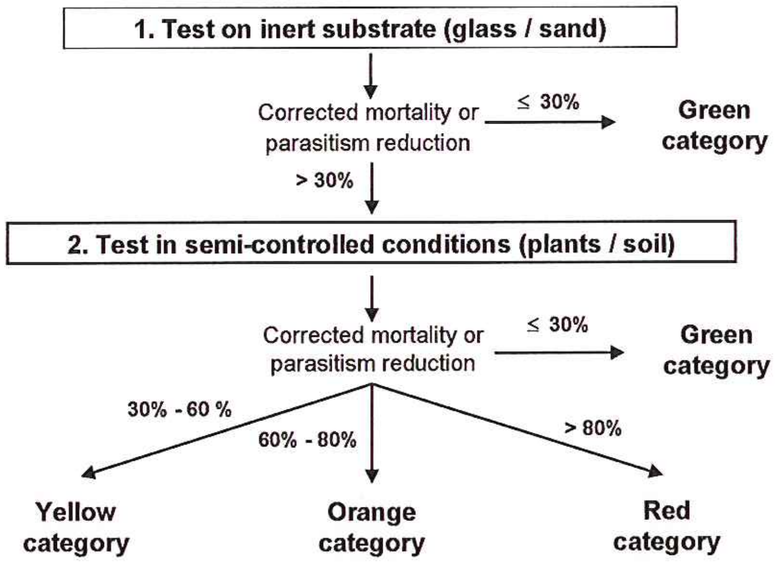

Fig 1. Sequential testing diagram of toxicity assessment.

Chemical determination of residues

For each toxicity test, on glass or on plant, active ingredient on the substrate is measured by chemical analysis at the beginning and at the end of the test.

Chemical analysis are carried out to know the accurate pesticide concentration the insects have been exposed to and to follow the pesticide residue evolution after application (Copin *et al.,* 2001). According to these results, compounds are considered as stable after application on glass if at least 85 % of active ingredient is recovered after 48h; and instable in other case.

Results and discussion

Ecotoxicological data

With the help of bibliographic data, we have classified for *A. bilineata* : 5 insecticides, 4 herbicides, 1 fungicide and for *B. lampros* : 5 insecticides. Insecticides as Carbofuran, Chlorpyriphos-ethyl, Diazinon and Dimethoate have been put in red category because several studies have showed high toxicity on carabids and staphylinids (Mowat and Coaker, 1967; Hassan, 1969; Edwards and Thompson, 1975; Finlayson, 1979; Kirknel, 1978; Finlayson *et al.*, 1980; Cockfield and Potter, 1983; Edwards *et al.*, 1984; Vickerman *et al.*, 1987; Floate *et al.*,1989; Kegel, 1989; Casteels and De Clerq, 1990; Bale *et al.*, 1992; Samsoe-Petersen, 1993; Sivasubramanian and Wratten, 1995). Conversely, Pirimicarb was classified in green category because weak toxicity are recorded on carabids and staphylinids (Unal and Jepson, 1992; Samsoe Petersen, 1993).

For herbicides and fungicides, Samsoe Petersen (1995a,b) has showed in laboratory that Cycloxydime and Tebuconazole were not toxic for *A. bilineata*. Naton (1989) has classified as harmless for this staphylinid Fluazifop-p-butyl and glyphosate. The same for Glufosinate at 600 g a.i./ha that reduced till 25% the parasitism rate by *A. bilineata* (EFSA Scientific Report, 2005).

Toxicity assessment

Tests on *Aphidius rhopalosiphi*

At the end of the sequential tests procedure, all foliar insecticides were very toxic on glass towards *A. rhopalosiphi* but tests on plants showed only the toxicity of two products: Deltamethrin (CM = 75%, moderately harmful) and Dimethoate (CM = 100%, harmful) (Table1). The others were harmless (Lambda-cyhalothrin, Pirimicarb and mixture Pirimicarb + Lambda-cyhalothrin) and are classified in green category.

For fungicides, on glass, three products have a corrected mortality more than 30% : Azoxystrobin, Dithianon, Tebuconazole. These products were tested on plant and results were below 30%. Thus, all fungicides are considered as harmless for this aphid parasite.

Tests on *Adalia bipunctata*

Tests have showed that insecticides were very toxic for *A. bipunctata* on glass but also on plants with corrected mortality about 100 % except one product, the Pirimicarb, that was harmless (CM = 12%) on glass.

For fungicides, two active ingredients must be tested on plants, Sulfur (CM = 40%) and Tebuconazole (CM = 96%), the others (Azoxystrobin, Difenoconazole, Dithianon, Iprodione, Myclobutanil) were harmless on glass for this ladybird. On plant, Sulfur was harmless (CM = 11%), contrary to Tebuconazole which was slightly harmful (CM = 32%).

Tests on *Episyrphus balteatus*

For this syrphid, insecticides were also toxic on glass with a corrected mortality more than 30%. On plant, except Lambda-cyhalothrin that was harmless (CM = 0%), the others were moderately harmful as Deltamethrin or harmful as Dimethoate, Pirimicarb and mixture Pirimicarb + Lambda-cyhalothrin.

All fungicides tested (Azoxystrobin, Difenoconazole, Dithianon, Iprodione, Myclobutanil, Sulfur and Tebuconazole) were harmless on glass towards *E. balteatus.*

Tests on *Aleochara bilineata*

On sand, tests of carbosulfan, Deltamethrin, Lambda-cyhalothrin, Pirimicarb and mixture Pirimicarb + Lambda-cyhalothrin have indicated to a high toxicity towards *A. bilineata* with 100 % parasitism reduction. Thus, in the future, they must be tested on soil to be classified.

Fungicides as Azoxystrobin, Difenoconazole, Dithianon, Iprodione, Myclobutanil and Sulfur were harmless for this staphylinid on sand.

For herbicides, all products (Clomazone, Linuron, Metoxuron, Paraquat, Paraquat + diquat, Quizalofop-ethyl-D and Tepraloxydim) were selective on sand, excepted the Chlorpropham which is very toxic with a parasitism reduction was 100 %.

Tests on *Bembidion lampros*

Three insecticides, Deltamethrin, Lambda-cyhalothrin and mixture Pirimicarb + Lambda-cyhalothrin have been tested on sand and were toxic towards this carabid with a corrected mortality more than 30%. So, they must be tested on soil.

In opposite, all the fungicides tested on sand (Azoxystrobin, Difenoconazole, Dithianon, Iprodione, Myclobutanil, Sulfur and Tebuconazole) were harmless.

For the herbicides tested on sand (Clomazone, Cycloxydime, Linuron, Fluazifop, Quizalofop-ethyl-D and Tepraloxydim) on this carabid, these products were harmless.

Selectivity list

We underline that all fungicides used in carrot crops are harmless for aphids parasites, ladybirds, syrphids, ground and rove beetles except one product, Tebuconazole, slightly harmfull for ladybirds. Thus, all product tested are listed in green category and Tebuconazole in yellow category (Table 2).

Unlike fungicides, soil insecticides as Carbofuran, Chlorpyriphos-ethyl, Diazinon, show a high toxicity to soil beneficial organisms. These products can stop the biological control by natural enemies, and thus are not recommended in IPM program because of their lack of selectivity.

For foliar insecticides, to date, two product are not recommended to IPM programs, Dimethoate and Deltamethrin, in view of toxicity towards beneficials. For the others, no products are harmless for these five beneficials insects at the same time, but Pirimicarb is harmless for parasites, ladybirds, carabids and coccinellids excepted for syrphids; Lambda-cyhalothrin is harmless for syrphids; and Lambda-cyhalothrin, Pirimicarb and mixture Pirimicarb + Lambda-cyhalothrin are harmless for aphids parasites.

In the end, all herbicides tested to date are harmless to soil insects, excepted the Chlorpropham. This product shows an high toxicity on sand for staphylinids and must be tested on soil.

Conclusion

First results show that all fungicides tested don't disrupt natural enemies and can be used without restriction according to good agricultural practices and in accordance with registration.

Herbicides tested till today are harmless except one product, the Chlorpropham towards staphylinids tested on sand which is harmful.

All soil insecticides tested are very toxic for ground beneficials and can disrupt biological control in carrot crop. The same results have been obtained for Dimethoate and Deltamethrin which are non-selective towards aphids parasites and predators. On the contrary, some foliar insecticides are harmless for some beneficials but not for all. Thus in IPM carrot programs, it is therefore necessary to manage insecticide treatments and to choose the most suitable products. The choice should be done on basis of efficacity, the presence or absence of beneficials and on selectivity towards these beneficials.

Table 1. Results of toxicity tests, corrected mortality (CM) or parasitism reduction (PR) (%). **A**: results on inert substrate (glass or sand); **B**: results in semi-controled conditions (plants or soil); **-**: no or weak pesticide exposition; **ED**: ecotoxicological data; **§**: not yet completely tested.

	Active Ingredients (a.i.)	Formulation	a.i. concentration (%)	g a.i./ha	*A. rhopalosiphi*		*A. bipunctata*		*E. balteatus*		*A. bilineata*		*B. lampros*	
					A	B	A	B	A	B	A	B	A	B
Insecticides	Carbofuran	Curater	5	0,0625	-	-	-	-	-	-	ED		ED	
	Carbosulfan	Sheriff 1 Gr	1	0,0625	-	-	-	-	-	-	100	§	§	§
	Chlorpyriphos-ethyl	Dursban 5G	5	0,2	-	-	-	-	-	-	ED		ED	
	Deltamethrin	DECIS 2,5 - EC	2,5	10	100	75	100	100	75	77	100	§	72	§
	Diazinon	Disonal	60	510	-	-	-	-	-	-	ED		ED	
	Dimethoate	Hermootrox- EC	50	250	100	100	100	100	100	100	ED		ED	
	Lambda-cyhalothrin	Karate Zéon- CS	10	10	100	1	100	100	0		100	§	100	§
	Pirimicarb	Pirimor - WG	50	200	100	12	21		80	94	ED		ED	
	Pirimicarb + Lambda-cyhalothrin	Okapi - EC	10 + 0,5	150 +7,5	100	3	100	100	100	100	100	§	96	§
Fungicides	Azoxystrobin	Ortiva - SC	25	250	63	7	21		14		1		4	
	Difenoconazole	Geyser - EC	25	125	0		3		21		0		20	
	Dithianon	Ditho - WG	70	1260	35	24	17		0		0		0	
	Iprodione	Rovral - WG	50	750	6		30		10		0		0	
	Myclobutanil	Systhane 24 - EC	20	60	4		0		0		0		4	
	Tebuconazole	Horizon - EW	25	250	92	5	96	32	10		ED		0	
	Sulfur	Hermovit - WG	80	4000	17		45	11	7		0		0	
Herbicides	Chlorpropham	Chloor IPC - EC	40	2400	-	-	-	-	-	-	100	§	§	§
	Clomazone	Centium 360 - CS	36	90	-	-	-	-	-	-	0		14	
	Cycloxydime	Focus Plus - EC	10	600	-	-	-	-	-	-	ED		0	
	Fluazifop-p-butyl	Fusilade - EC	25	500	-	-	-	-	-	-	ED		4	
	Glufosinate -ammonium	Basta S - SL	20	600	-	-	-	-	-	-	ED		§	§
	Glyphosate	Roundup energy - SG	68	2176	-	-	-	-	-	-	ED		§	§
	Linuron	Linuron 500 - SC	50	500	-	-	-	-	-	-	16		10	
	Metoxuron	Dosanex - WP	80	3600	-	-	-	-	-	-	2		§	§
	Paraquat	Gramoxone - SL	20	1000	-	-	-	-	-	-	1		§	§
	Paraquat + Diquat	Priglone - SL	12 + 8	600 + 400	-	-	-	-	-	-	18		§	§
	Quizalofop-ethyl D	Targa Prestige - EC	5	150	-	-	-	-	-	-	2		30	
	Tepraloxydim	Aramo - EC	5	100	-	-	-	-	-	-	0		0	

Table 2. Carrot selectivity list. **g**: green category = harmless; **y**: yellow category = slightly harmful; **o**: orange category = moderately harmful; **r**: red category = harmful; **-**: no or weak pesticide exposition; **§**: not yet completely tested.

	Active ingredients	*A. rhopalosiphi*	*A. bipunctata*	*E. balteatus*	*A. bilineata*	*B. lampros*
Insecticides	Carbofuran	-	-	-	r	r
	Carbosulfan	-	-	-	§	§
	Chlorpyriphos-ethyl	-	-	-	r	r
	Deltamethrin	o	r	o	§	§
	Diazinon	-	-	-	r	r
	Dimethoate	r	r	r	r	r
	Lambda-cyhalothrin	g	r	g	§	§
	Pirimicarb	g	g	r	g	g
	Pirimicarb + lambda-cyhalothrin	g	r	r	§	§
Fungicides	Azoxystrobin	g	g	g	g	g
	Difenoconazole	g	g	g	g	g
	Dithianon	g	g	g	g	g
	Iprodione	g	g	g	g	g
	Myclobutanil	g	g	g	g	g
	Sulfur	g	g	g	g	g
	Tebuconazole	g	y	g	g	g
Herbicides	Chlorprophame	-	-	-	§	§
	Clomazone	-	-	-	g	g
	Cycloxydime	-	-	-	g	g
	Fluazifop-p-butyl	-	-	-	g	g
	Glufosinate -ammonium	-	-	-	g	§
	Glyphosate	-	-	-	g	§
	Linuron	-	-	-	g	g
	Metoxuron	-	-	-	g	§
	Paraquat	-	-	-	g	§
	Paraquat + diquat	-	-	-	g	§
	Quizalofop-ethyl D	-	-	-	g	g
	Tepraloxydim	-	-	-	g	g

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