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SELECTIVITY LISTS OF PESTICIDES TO BENEFICIAL ARTHROPODS FOR IPM PROGRAMS 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., Staphylinidae) and carabid beetle – *Bembidion lampros* (Col., Carabidae).

Initialy, 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 other compounds were further tested on plant for *A. rhopalosiphi, A. bipunctata, E. balteatus* and soil for *B. lampros* and *A. bilineata.* With these extended laboratory tests results, products were listed in toxicity class: green category [CM or PR ≤ 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 all fungicides tested were harmless to beneficials except Tebuconazole, which was slightly harmful for *A. bipunctata.* Herbicides were also harmless for soil beneficials, except Chlorpropham. This product was very toxic on sand towards *A. bilineata* and must be tested on soil. All soil insecticides tested were very toxic for ground beneficials and considered as non-selective. Their use in IPM is subject to questioning in view of negative impacts on beneficials. Among foliar insecticides, Dimethoate and Deltamethrin are not recommended for IPM because their high toxicity for all beneficials. The other foliar insecticides were more selective; any of them were harmless for all species tested.

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 insecticide 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 pesticide 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.

According to this potentially biological control in carrot crop, the use of non-selective plant 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 aim 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, inputs reduction programs and agricultural specifications and certification standard.

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 and toxicity tests.

Ecotoxicological data

Ecotoxicological data came from scientific periodicals with specific attention on: active ingredients, application rate, experimental design as substrate or exposition time and on methods that must be following IOBC specifications (Hassan, 1994). 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 were applied with a pneumatic atomizer at 200 $l.ha^{-1}$ ±10% for glass and plants, and at 400 $l.ha^{-1}$ ±10% for sand and soil.

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 on ground insects while fungicides and insecticides were tested both ground and foliar insects.
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 were assessed after 48 hours exposition or after 2 weeks for carabids and calculate corrected mortality (CM) were calculated (Abbot, 1925). For staphylinid, parasitism reduction (PR) was calculated after 4 weeks in comparaison with control. If the product induced a corrected mortality or a parasitism reduction lower than or equal to 30%, the product was considered as harmless and listed in "green category". If not, toxicity was realised 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.

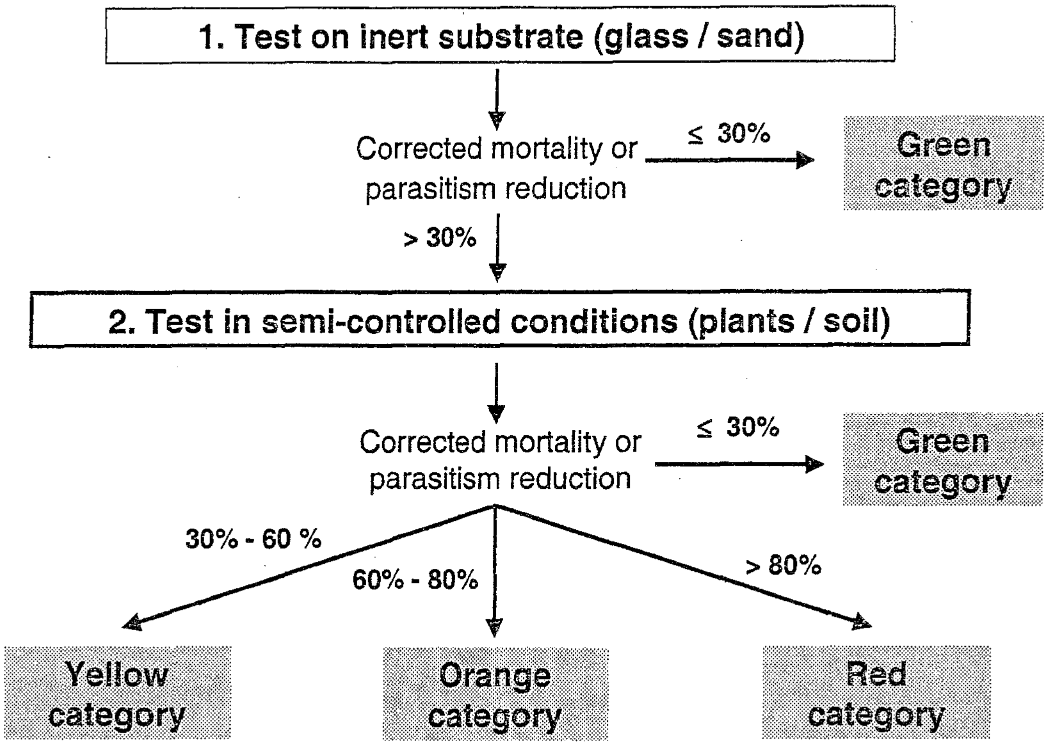

Figure 1. Sequential testing diagram of toxicity assessment

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

On the basis of bibliographic data, insecticides as Carbofuran, Chlorpyriphos-ethyl, Diazinon and Dimethoate were put in red category because several studies 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 was recorded on carabids and staphylinids (Unal and Jepson, 1992; Samsoe Petersen, 1993).
For herbicides and fungicides, Samsoe Petersen (1995a,b) showed in laboratory that Cycloxydime and Tebuconazole were not toxic for *A. bilineata*. Na-

ton (1989) classified 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 A. 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 were classified in green category. For fungicides, on glass, three products had a corrected mortality higher than 30% : Azoxystrobin, Dithianon, Tebuconazole. These products were tested on plant and results were below 30%. Thus, all fungicides were considered as harmless for this aphid parasite.

Tests on A. bipunctata

Tests showed that insecticides were very toxic for *A. bipunctata* on glass but also on plants with corrected mortality about 100 % except one product, Pirimicarb, that was harmless (CM = 12%) on glass. For fungicides, Azoxystrobin, Difenoconazole, Dithianon, Iprodione, Myclobutanil were harmless on glass for this ladybird while Sulfur (CM = 40%) and Tebuconazole (CM = 96%) were toxic on this substrate. Tests on plant showed that Sulfur was harmless (CM = 11%), contrary to Tebuconazole which was slightly harmful (CM = 32%).

Tests on E. balteatus

For this species, insecticides were 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. Conversely, all fungicides tested (Azoxystrobin, Difenoconazole, Dithianon, Iprodione, Myclobutanil, Sulfur and Tebuconazole) were harmless on glass towards *E. balteatus*.

Tests on A. bilineata

On sand, tests of Carbosulfan, Deltamethrin, Lambda-cyhalothrin, Pirimicarb and mixture Pirimicarb + Lambda-cyhalothrin have showed a high toxicity towards *A. bilineata* with 100 % parasitism reduction. Thus, they must be tested on soil before final classification. 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 was very toxic with a parasitism reduction of 100 % in comparaison with control.

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	formulation	a.i. concentration (%)	g a.i./ha	A. rhopalosiphi		a. bipunctata		E. balteatus		A. bilineata		B. lampors	
					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 2.5EC	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	
	λ-cyhalothrin	Karate Zeon CS	10	10	100	1	100	100	0		100	§	100	§
	pirimicarb	Pirimor WG	50	200	100	12	21		80	94	ED		ED	
	pirimicarb+λ-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 24EC	20	60	4		0				0		4	
	sulfur	Horizon EW	25	250	92	5	96	32	10		ED		0	
	tebuconazole	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 WP80		3600	-	-	-	-	-	-	2		§	§
	paraquat	Gramoxone SL	20	1000	-	-	-	-	-	-	1		§	§
	paraquat+diquat	Prigione SL	12+8	600+400	-	-	-	-	-	-	18		§	§
	quizalofop-ethyl D	Targa Prestige EC	5	150	-	-	-	-	-	-	2		30	
	tepraloxydim	Aramo EC	5	100	-	-	-	-	-	-	0		0	

Tests on **B. lampros**

Three insecticides, Deltamethrin, Lambda-cyhalothrin and mixture Pirimicarb + Lambda-cyhalothrin were tested on sand and were toxic towards this carabid with a corrected mortality higher 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 underlined that all fungicides used in carrot crops were harmless for aphids parasites, ladybirds, syrphids, ground and rove beetles except, Tebuconazole, which was slightly harmfull for ladybirds. Thus, all product tested were 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.

Table 2. Carrot selectivity list. □: green category = harmless; ⊡: yellow category = slightly harmful; ▣: orange category = moderately harmful; ■: 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	-	-	-	■	■
	carbosulfan	-	-	-	§	§
	chlorpyriphos-ethyl	-	-	-	■	■
	deltamethrin	▣	■	▣	§	§
	diazinon	-	-	-	■	■
	dimethoate	■	■	■	■	■
	λ-cyhalothrin	□	■	□	§	§
	pirimicarb	□	□	■	□	□
	pirimicarb+ λ-cyhalothrin	□	■	■	§	§
fungicides	azoxystrobin	□	□	□	□	□
	difenoconazole	□	□	□	□	□
	dithianon	□	□	□	□	□
	iprodione	□	□	□	□	□
	myclobutanil	□	□	□	□	□
	sulfur	□	□	□	□	□
	tebuconazole	□	⊡	□	□	□
herbicides	chlorpropham	-	-	-	§	§
	clomazone	-	-	-	□	□
	cycloxydime	-	-	-	□	□
	fluazifop-p-butyl	-	-	-	□	□
	glufosinate-ammonium	-	-	-	□	§
	glyphosate	-	-	-	□	§
	linuron	-	-	-	□	□
	metoxuron	-	-	-	□	§
	paraquat	-	-	-	□	§
	paraquat+diquat	-	-	-	□	§
	quizalofop-ethyl D	-	-	-	□	□
	tepraloxydim	-	-	-	□	□

For foliar insecticides, to date, two products are not recommended for IPM programs, Dimethoate and Deltamethrin, in view of toxicity towards beneficials. For the others, no products were harmless for these five beneficial insects at the same time, but Pirimicarb was harmless for parasites, ladybirds, carabids and coccinellids except for syrphids; Lambda-cyhalothrin was harmless for syrphids and parasites; and mixture Pirimicarb + Lambda-cyhalothrin were harmless for aphids parasites. In the end, all herbicides tested to date were harmless to soil insects, excepted the Chlorpropham. This product showed an high toxicity on sand for staphylinids and must be tested on soil.

CONCLUSION

First results showed 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 were very toxic for ground beneficials and can probably disrupt biological control in carrot crop. The same results were obtained for Dimethoate and Deltamethrin which were non-selective towards aphids parasites and predators. On the contrary, some foliar insecticides were harmless for some beneficials but any product were harmless for all beneficials. 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 efficaciouness, the presence or absence of beneficials and on selectivity towards these beneficials.

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