PESTICIDES SELECTIVITY LIST TO BENEFICIAL ARTHROPODS IN FOUR FIELD VEGETABLE CROPS

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SUMMARY

Selectivity of pesticides to beneficial arthropods is a key data for the implementation of IPM program. In the context of field vegetables crop, a set of 16 fungicides, 17 herbicides and 14 insecticides commonly used in Belgium were tested on 5 indicator species: the parasitic hymenoptera *Aphidius rhopalosiphi* (De Stefani-Perez) (Hym., Aphidiidae), the aphid foliage dwelling predators *Adalia bipunctata* (L.) (Col., Coccinellidae) and *Episyrphus balteatus* (Dipt., Syrphidae) and the ground-dwelling predators *Aleochara bilineata* (Col., Staphyllinidae) and *Bembidion lampros* (Col., Carabidae).
Pesticides were tested according a testing scheme including a first assessment on inert substrate (glass plates for adults of *A. rhopalosiphi*, larvae of *A. bipunctata* and *E. balteatus*, sand on adults of *A. bilineata* and *B. lampros)* and, for product that were toxic, a second assessment on natural substrate (barley seedlings for *A. rhopalosiphi*, french bean plants for *A. bipunctata* and *E. balteatus* and two type of soil for *B. lampros* and *A. bilineata*). The effects of the product were assessed on basis on mortality, except for *A. bilineata* (Onion fly pupae parasitism). According to the final results obtained at the end of this testing scheme, the product were listed in toxicity class: green list if effect ≤30%, yellow list 30% < effect ≤ 60% and orange list 60% < effect ≤ 80%. Products with toxicity higher than 80% on plants or on soils, or that reduce parasitism more than 80% on soil were put in red list and are not recommended for IPM.
Results showed that all fungicides and herbicides were included in the green list except tebuconazole and boscalid + pyraclostrobin that were labeled as yellow for *A. bipunctata*. In opposite, no foliar insecticide was totally selective for all beneficial tested. However some products are in green list for one or several species. Soil insecticides were all are very toxic for ground dwelling arthropods and classed in red list.
All results obtained during this study and further upgrade will be available on www.cra.wallonie.be/selectivite.
In conclusions, fungicides and herbicides tested are compatible with IPM programs. For foliar insecticides, some treatments can be used carefully according to the selectivity. But for soil insecticide treatments, their toxicity raise the question of their use in IPM programs in vegetables and the need of new compounds or development of alternative pest control programs.

INTRODUCTION

In vegetable production in open field, as in other crops, beneficial arthropods are a key factor in the biological control of several pests (Hughes and Salter, 1959; Read, 1962; Coaker and William, 1963; Lövei and Sunderland, 1996). In the context of a sustainable agriculture and IPM implementation, these beneficial arthropods must be preserved from adverse effects, especially from non-selective pesticides. By eliminating pest natural enemies, non selective insecticides can enhance pest outbreak, with population levels that even reached higher levels than those observed without any insecticide treatment (Ripper, 1956; Pimentel, 1961; Besemer, 1964; Vickerman and Sunderland, 1977; Croft and Slone, 1998). Resurgence of pest of secondary importance, simply because their natural enemies have been eliminated is also a consequence of the use of non-selective compounds, even with a simple fungicide or herbicide application (Nanne and Radcliffe, 1971; Sotherton and Moreby, 1988; Lagnaoui and Radcliffe, 1998). Both pest outbreak and pest resurgence multiply pest problems and insecticide use, increase cost production and negative impact of pest control on human health and environment. This situation could be avoid at the beginning, if selective pesticide were available and used instead of non-selective compounds. Actually, there is a clear trends to try to use selective products, as claimed by certification standard guidelines as EUREPGAP and Chart PERFECT. However, clear information that can directly be used by producers and pesticide users are missing.

In the context of IPM implementation and pesticide users information, the selectivity of pesticides used in Belgium in carrot, onion, pea and bean has been determined according to the methodology previously used for building selectivity list in potato (Hautier *et al.*, 2006). 16 fungicides, 17 herbicides and 13 insecticides have been tested on 2 to 5 beneficial arthropods species selected as indicator species for these crops. According to the results obtained, products were rated in different toxicity classes and selectivity lists were build.

MATERIALS AND METHODS

Assessment of selectivity of pesticides was realized on basis of both bibliographic data for products that were well documented and on basis of toxicity test results. Bibliographic data were retained when the methods used fulfill the IOBC standard (Hassan, 1994) and were similar or close to those used to build selectivity list (residual contact toxicity test with inert and/or natural substrate, susceptible life stage, product application and tested rate, exposure time, ...).

Toxicity tests were realized on 2 to 5 different species, according to the use of the product (crop, timing of application and beneficial exposition risk). The tested species were : adult of the parasitic wasp *Aphidius rhopalosiphi* De Stefani-Perez (Hym.; Aphidiidae), larvae of the ladybird *Adalia bipunctata* (L.) (Col.; Coccinellidae) and the hoverfly *Episyrphus balteatus* (De Geer.) (Dipt.; Syrphidae), adults of the carabid beetle *Bembidion lampros* (Herbst.) (Col.; Carabidae) and the rove beetle *Aleochara bilineata* Gyll. (Col.; Staphylinidae).

Toxicity tests fulfilled to the SETAC recommendations (Barrett *et al.*, 1994) and were developed by Copin *et al.* (2001) for parasitic hymenoptera and aphid predators and by Heimbach *et al.* (2000) and Grimm *et al.* (2000) for carabid and rove beetle, respectively. Pesticides were tested at the maximum recommended field rate for one application, on basis of available commercial formulations. Herbicides were only tested on the carabid and rove beetle, as the exposure risk for plant dwelling predator and parasite was negligible or null. Insecticides and fungicides were tested on the 5 selected species. Most products were applied as spray mixtures in water, with rates of 200 $l.ha^{-1}$ ±10% on glass plates and 400 $l.ha^{-1}$ ±10% on sand and soil. Thiram was applied as dusting powder and, when required, soil insecticides were incorporated into the soil as granule.

For all product, test followed a classical IOBC testing scheme (Figure 1.) Pesticides were first tested at their maximum field rate on an inert substrate (glass plates or sand). Products that lead to effects (mortality or reduction in parasitism rate with Aleochara) higher than 30% were further tested on natural substrate (plants or soils). According the results of the tests, products were labeled as harmless (□) and included in a green list, slightly harmful - yellow list (•), moderately harmful - orange list (••) and harmful - red list (•••). Green list include all selective compounds and red list all harmful products that must be avoided if possible. Yellow and orange list are intermediate products, that have to be used carefully, when no equivalent in green list exist or for very specific uses, as pest resistance management.

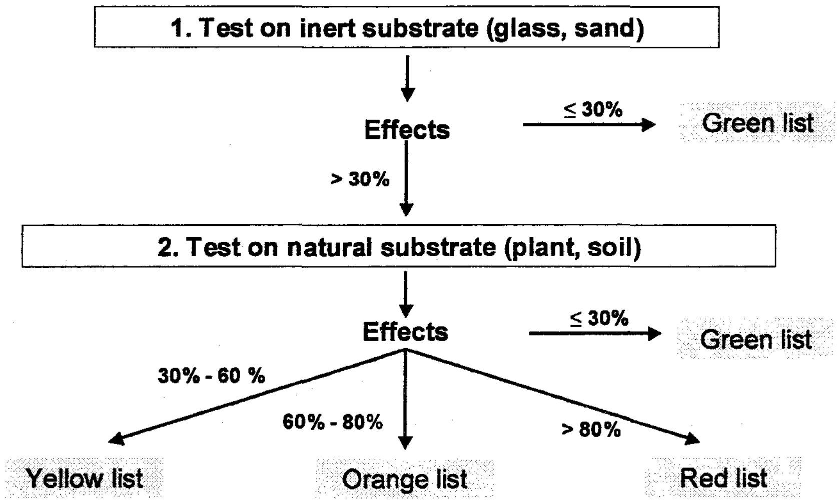

Figure 1. Sequential testing scheme of pesticide selectivity assessment

RESULTS

On basis of bibliographic analysis, the insecticides carbofuran, chlorpyriphos-ethyl, diazinon and dimethoate were rated as harmful for carabid and rove beetles according to their high toxicity for these insects (Mowat and Coaker, 1967; Hassan, 1969; Edwards and Thompson, 1975; Finlayson, 1979; Finlayson *et al.*, 1980; Kirknel, 1978; Cockfield and Potter, 1983; 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). On the opposite, pirimicarb was included in the green list according to its high selectivity for these ground dwelling beneficial insects (Unal and Jepson, 1992; Samsoe Petersen, 1993).
With herbicides and fungicides, Samsoe Petersen (1995a,b) has conclude that cycloxydim and tebuconazole were not toxic for *A. bilineata*. Fluazifop-p-butyl and glyphosate were also harmless for this rove beetle (Naton, 1989), as glufosinate was (EFSA Scientific Report, 2005). The other products, were no pertinent information were found in the literature, were tested according to the testing scheme described. All the results are listed in table 1 (insecticides), 2 (fungicides) and 3 (herbicides).

Table 1. Insecticide selectivity: ○ : harmless, • : slightly harmful •• : moderately harmful ••• : harmful, - : not tested, * bibliographic data
B : beans, C : carrots, O : onions, P : peas

Active(s) substance(s)	Tested rate (g a.s./ha)	*A. rhopalosiphi*	*A. bipunctata*	*E. balteatus*	*A. bilineata*	*B. lampros*	Used in
Alpha-cypermethrin	12,5	•	•••	○	-	-	P
Bifenthrin	40	•••	•••	○	-	-	B, P
Carbofuran	-	-	-	-	•••*	•••*	C, O
Carbosulfan	0,0625	-	-	-	•••	•••	C
Chlorpyriphos	-	-	-	-	•••*	•••*	C, O
Deltamethrin	10	••	•••	••	•	○	B, C, O, P
Diazinon	-	-	-	-	•••*	•••*	C, O
Dimethoate	250	•••	•••	•••	•••*	•••*	C
Lambda-cyhalothrin	10	○	•••	○	•••	○	B, C, P
Methiocarb	750	•••	•••	•••	•••	•••	O
Pirimicarb	200	○	○	•••	○*	○*	B, C, P
Pirimicarb + Lambda-cyhalothrin	150 + 7,5	○	•••	•••	•••	○	B, C, O, P
Pyrethrins + Piperonyl butoxide	100 +1275	•••	•••	••	○	••	B, C, O, P

Table 2. Fungicide selectivity ○: harmless, •: slightly harmful ••: moderately harmful •••: harmful, - : not tested, * bibliographic data
B: beans, C: carrots, O: onions, P: peas

Active(s) substance(s)	Tested rate (g a.s./ha)	*A. rhopalosiphi*	*A. bipunctata*	*E. balteatus*	*A. bilineata*	*B. lampros*	Used in
Azoxystrobin	250	○	○	○	○	○	C, P
Boscalid + Pyraclostrobin	200,25 + 50,25	○	•	○	○	○	C
Chlorothalonil	1500	○	○	○	-	-	P
Difenoconazole	125	○	○	○	○	○	C
Dimethomorph + Mancozeb	187,5 + 1667,5	○	○	○	○	○	O
Dithianon	1260	○	○	○	○	○	C
Fluazinam	250	○	○	○	○	○	O
Iprodione	750	○	○	○	○	○	B, C, P
Mancozeb	2400	○	○	○	○	○	B, O
Maneb	1600	○	○	○	○	○	B, O
Myclobutanil	60	○	○	○	○	○	C
Procymidone	500	○	○	○	-	-	B
Sulfur	4000	○	○	○	○	○	B, C, P
Tebuconazole	250	○	•	○	○	○	C
Thiram	2000	○	○	○	-	-	B
Vinclozolin	750	○	○	○	○	○	B,C,D

Table 3. Herbicide selectivity: o: harmless, •: slightly harmful ••: moderately harmful •••: harmful, - : not tested, * bibliographic data
B: beans, C: carrots, O: onions, P: peas

Active(s) substance(s)	Tested rate (g a.s./ha)	*A. rhopalosiphi*	*A. bipunctata*	*E. balteatus*	*A. bilineata*	*B. lampros*	Used in
Bentazone	800	-	-	-	o	o	O
Chlorpropham	2400	-	-	-	o	o	C, O
Clomazone	90	-	-	-	o	o	C
Cycloxydim	600	-	-	-	o*	o	C, O
Fluazifop-p-butyl	500	-	-	-	o*	o	C, O
Glufosinate -ammonium	600	-	-	-	o*	o	C
Glyphosate	2176	-	-	-	o*	o	C, O
Isoxaben	100	-	-	-	o	o	O
Linuron	500	-	-	-	o	o	C
Metoxuron	3600	-	-	-	o	o	C
Paraquat	1000	-	-	-	o	o	C, O
Paraquat + diquat	600 + 400	-	-	-	o	o	C, O
Pendimethalin	1000	-	-	-	o	o	O
Propachlor	4800	-	-	-	o	o	O
Quizalofop-ethyl D	150	-	-	-	o	o	C, O
Tepraloxydim	100	-	-	-	o	o	C, O

DISCUSSION – CONCLUSION

Results showed that all tested herbicides were harmless to the carabid and rove beetle: *A. bilineata* et *B. lampros*. With the fungicides, all products were selective for the 5 beneficial species except tebuconazole and the association boscalid + pyraclostrobin that were slightly harmful for larvae of the ladybird *A. bipunctata*. However, these products were selective for the larvae of the hoverfly *E. balteatus* and, as both ladybirds and hoverflies are most of the times acting together on aphids, effects of these fungicides on aphid specific predator would probably be negligible. Results are indicating that all these products can be used without any restriction in the context of IPM programs.

With the insecticides, results must be separated in soil applied insecticides (carbofuran, carbosulfan, chlorpyrifos-ethyl and diazinon) and foliar insecticides (all the other ones). With the foliar insecticide, no products were selective for all species, but some of them were harmless for one to four species, as pirimicarb, selective for *A. rhopalosiphi*, *A. bipunctata*, *B. lampros* et *A. bilineata* but toxic for *E. balteatus* or lambda-cyhalothrin, harmless for *A. rhopalosiphi*, *E. balteatus* and *B. lampros*. On the opposite, several products were harmful for all beneficials, as dimethoate and methiocarb and their use in IPM program must be avoid. It is im-

portant to point out that one product on basis on natural pyrethrin and piperonyl-butoxide used in organic farming has more or less the same selectivity as synthetic pyretrhinoids, that will say moderately harmful or harmful on 4 beneficial tested out of 5. These results suggest that products used in organic farming could not always be rated as harmless for beneficial and that the use of these products must be, in a same approach as in classical agriculture, discussed. According to the results, it could be possible, on basis of a case-by-case analysis considering both pest to control and beneficial to preserve, to use selective compound in several cases.
The selectivity of soil-applied insecticide on the two ground dwelling beneficial tested was dramatically very low. All products exhibit a high toxicity and were included in the red list. Their possible use in the context of IPM programs is not possible without an adaptation of normal use, in term of field rate and application timing. In the context of sustainable agriculture, the development of new compounds with an higher selectivity or alternative control methods are urgently needed. A fisr approach could be an adaptation of the doses according to soil composition to reduce the rates and increase selectivity (Hautier *et al.*, 2007).

DIFFUSION OF RESULTS

All results obtained during this study and those concerning selectivity of plant protection products in potato (Hautier *et al.*, 2006), as the further update(s) will be available on www.cra.wallonie.be/selectivite

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REFERENCES

BALE J.S., EKEBUISI M. & WRIGHT C. (1992). Effects of seed bed preparation, soil structure and release tiime on the toxicity of a range of grassland pesticides to carabid beetle *Pterostichus melanarius* (Ill.) (Col., Carabidae) using a microplot technique. *Journal of Applied Entomology*, **113**:175-182.

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.

CASTEELS H. & DE CLERCQ R. (1990). The impact of some commonly used pesticides on the epigeal arthropod fauna in winter wheat. Mededelingen Faculteit Landbouwkundige, **55(2b)**:477-482.

COAKER T.H. & WILLIAMS D.A. (1963). The importance of some Carabidae and Staphylinidae as predators of the cabbage root fly (Erioischia brassicae (Bouché)). *Entomologia Experimentalis et Applicata*, **6**:156-164

COKFIELD S.D. & POTTER D.A. (1983). Shot-term effects of insecticidal applications on predaceous arthropods and oribatid mites in Kentucky Bluegrass Turf. Environmental Entomology, **12**:1260-1264.

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 pages.

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, Eryophidae, Phytoseiidae and Stigmatidae). *Environmental Entomology*, **27(6)**:1548-1556.

EDWARDS C.A. & THOMPSON A.R. (1975). Some effects of insecticides on predatory beetles. *Proc. Assoc. Appl. Biol.* **79**:132-135.

EFSA SCIENTIFIC REPORT (2005). Conclusion on the peer review of Glufosinate, **27**:1-81. http://www.efsa.eu.int/science/praper/conclusions/895_en.html

FINLAYSON D.G. (1979). Combined effects of soil-incorporated and foliar-applied insecticides in bed-system production of brassica crops. Canadian Journal of Plant Science, **59**:399-410.

FINLAYSON D.G., MACKENZIE J.R. & CAMPBELL C.J. (1980). Interactions of insecticides, a Carabid Predator, A Staphylinid Parasite and Cabbage Maggots in Cauliflower. *Environmental Entomology*, **9**:789-794.

FLOATE K.D., ELLIOTT R.H., DOANE J.F. & GILLOTT C. (1989). Field bioassay to evaluate contact and residual toxicities of insectides to carabid beetles (Coleoptera : Carabidae). *Journal of Economic Entomology*, **82(6)**:1543-1547.

GRIMM C., REBER B., BARTH M., CANDOLFI M.P., DREXLER A., MAUS C., MORETH L., UFER A. & WALTERSDORFER A. (2000). A test for evaluating the chronic effects of plant protection products on the rove beetle Aleochara bilineata Gyll. (Col. Staphylinidae) under laboratory and extended laboratory conditions. In Candolfi M.P., Bluemel S., Forster R., Bakker F.M., Grimm C., Hassan S.A., Heimbach U., Mead-Briggs M.A., Reber B., Schmuck R., Vogt H. Guidelines to evaluate side-effects of plant protection products to non-target arthropods. Bulletin OILB-SROP / IOBC-WRPS Bulletin. 158 pp

HASSAN S.A. (1969). Observations on the effect of insecticides on coleopterous predators of Erioischia brassicae (Diptera: Anthomyiidae). *Entomologia Experimentalis et Applicata*, **12**:157-168.

HASSAN S.A., BIGLER F., BOGENSCHÜTZ H, BOLLER E., BRUN J., CALIS J.N.M., CHIVERTON P., COREMANS-PELSENEER J., DUSO C., LEWIS G. B., MANSOUR F., MORETH L., OOMEN P. A., OVERMEER W. P. J., POLGAR L., RIECKMANN W., SAMSOE-PERTERSEN L., STAUBLI A., STERCK G., TAVARES K., TUSET J.J. & VIGGIANI G. (1991). Results of the fifth joint pesticide testing programme carried out by the IOBC/WPRS-Working Group "Pesticides and Beneficial Arthropods". Entomophaga, **36**:55-67.

HASSAN S.A. (1994). Activities of the IOBC/WPRS working group " Pesticides and beneficial organisms" *Bulletin OILB-SROP / IOBC-WRPS Bulletin*, **17(10)**:1-5.

HAUTIER L., JANSEN J-P., MABON N., SCHIFFERS B., DELEU R. & MOREIRA C. (2006). Building selectivity list of plant protection products on beneficial arthropods in open field: a concrete example with potato crop. *IOBC/wprs Bulletin*, **29(10)**:21-32.

HAUTIER L., JANSEN J-P., MABON N. & SCHIFFERS B. (2007). Influence of organic matter on bioavailability of carbosulfan and its toxicity on a Carabid beetle. Communications in Agricultural and Applied Biological Sciences, see this volume.

HEIMBACH U., DOHMEN P., BARRETT K.L., BROWN K., KENNEDY P.J., KLEINER R., RÖMBKE J., SCHMITZER S., SCHMUCK R. & WILHELMY H. (2000). A method for testing effects of plant protection products on the carabid beetle Poecilus cupreus (Coleoptera, Carabidae) under laboratory and semi-field. In Candolfi M.P., Bluemel S., Forster R., Bakker F.M., Grimm C., Hassan S.A., Heimbach U., Mead-Briggs M.A., Reber B., Schmuck R., Vogt H. Guidelines to evaluate side-effects of plant protection products to non-target arthropods. *Bulletin OILB-SROP / IOBC-WRPS* Bulletin. 158 pp

HUGHES R.D. & SALTER D.D. (1959). Natural mortality of Erioschia brassicae (Bouché) (Dipt. Anthomyiidae) during the immature stages of the first generation. *Journal of Animal Ecology*, **28**:343-357.

KEGEL B. (1989). Laboratory experiments on the side effects of selected herbicides and insecticides on the larvae of three sympatric Poecilus-species (Col., Carabidae). *Journal of Applied Entomology*, **108**:144-155.

KIRKNEL E. (1978). Influence of Diazinon, trichloronate, Carbofuran and chlorfenvinphos on the parasitization capacity of the rove-beetle Aleochara bilineata (Gyll.). Tidsskrift for Planteavl, **82**:117-129.

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.

LÖVEI G.L. & SUNDERLAND K.D. 1996. Ecology and behaviour of ground beetles (Coleoptera: Carabidae). *Annu. Rev. Entomol.* **41**:231-256.

MOWAT D.J. & COAKER T.H. (1967).The toxicity of some soil insecticides to carabid predators of the cabbage root fly. *Annals of Applied Biology*, **59**:349-354.

NANNE H.W. & RADCLIFFE E.B. (1971). Green peach aphid populations on potatoes enhanced by fungicides. *Journal of Economic Entomology*. **64**:1569-1570.

NATON E. (1989). Die prüfung der nebenwirkung von pflanzenscutzmitteln auf Aleochara bilineata Gyll. (Col., Staphylinidae). *Anz. Schädlingskde Pflanzenschultz. Umweltschutz*. **62**:1-6

PIMENTEL D. (1961). An ecological approach to the insecticide problem. *Journal of Economic Entomology*, **54**:108-114.

READ D.C. (1962). Notes on life history of Aleochara bilineata (Gyll.) (Coleoptera: Staphylinidae) and on its potential value as a control agent for cabbage maggot, Hylemya brassicae (Bouche) (Dipt.: Antomyiidae). *Canadian Entomology*, **94**:417-424.

RIPPER W.E. (1956). Effect of pesticides on balance of arthropod populations. *Annual Review of Entomology*, **1**:403-438.

SAMSOE-PETERSEN L. (1993). Effects of 45 insecticides, acaricides and molluscides on the rove beetle Aleochara bilineata (Col.: Staphylinidae) in the laboratory. *Entomophaga*, **38(3)**:371-382.

SAMSOE-PETERSEN L. (1995a). Effects of 37 fungicides on the rove beetle Aleochara bilineata (Col.: Staphylinidae) in the laboratory. *Entomophaga*, **40(2)**:145-152.

SAMSOE-PETERSEN L (1995b). Effects of 67 herbicides and plant growth regulators on the rove beetle Aleochara bilineata (Col. Staphylinidae) in the laboratory. *Entomophaga*, **40**(1):95-104.

SIVASUBRAMANIAM W. & WRATTEN S.D. (1995). Effects of insecticides on the abundance of arthropod predators in carrots in Canterbury; Proceedings of the 48th New Zealand Plant Protection Conference, **48**:302-308.

SOTHERTON N.W. & MOREBY S.J. (1988). The effects of foliar fungicides on beneficial arthropods in wheat fields. *Entomophaga*, **33**:87-99.

UNAL G. & JEPSON P.C. (1991). The toxicity of aphicide residues to beneficial invertebrates in cereal crops. *Ann. Appl. Biol.*, **118**:493-502.

VICKERMAN G.P. & SUNDERLAND K.D. (1977). Some effects of Dimethoate on arthropods in winter wheat. *Journal of Applied Ecology*, **14**:767-777.

VICKERMAN G.P., COOMBES D.S., TURNER G., MEAD-BRIGS M.A. & EDWARDS J. (1987). The effects of Pirimicarb, Dimethoate and Deltamethrin on carabidae and staphylinidae in winter wheat. *Mededelingen -Faculteit-Landbouwkundige*, **52**:213-223