TOXICITY OF CHEMICALS COMMONLY USED IN AUSTRALIAN APPLE ORCHARDS TO THE EUROPEAN EARWIG *FORFICULA AURICULARIA* L. (DERMAPTERA: FORFICULIDAE)

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Summary

Chemicals commonly used in Australian apple orchards were tested for their contact toxicity to *Forficula auricularia* L., a key predator of the apple pest woolly aphid *Eriosoma lanigerum* Hausmann. The relative toxicity to *F. auricularia* and an assessment of each chemical's potential to disrupt the biological control of *E. lanigerum* is given. The chemicals, alpha-cypermethrin, azinphos-methyl, carbaryl, chlorpyrifos, fenthion and parathion-methyl were highly toxic to *F. auricularia* and therefore likely to be highly disruptive to the control of *E. lanigerum*. Endosulfan, imidacloprid and tau-fluvalinate were assessed as moderately disruptive. The insecticides abamectin, fenoxycarb, pirimicarb, propargite, tebufenozide, tebufenpyrad and vamidothion; the fungicides, bupirimate, dithianon, dodine, mancozeb, penconazole and thiram; the crop regulators benzyladenine and ethephon and the herbicide glyphosate were all shown to have low toxicity to *F. auricularia* and therefore were considered unlikely to be disruptive to the biological control of woolly aphid.

Key words: IPM, biological control, orchard management, European earwig, *Forficula auricularia.*

INTRODUCTION

Woolly aphid (*Eriosoma lanigerum* Hausmann) is an important secondary pest of apples that infests both the aerial and edaphic parts of the tree. It feeds by piercing the bark and sucking the sap. This causes the formation of galls. Heavy infestations, particularly in young trees, can reduce the tree's growth and vitality, destroy buds, reduce cropping and lower fruit quality. Field experiments conducted by Stap *et al*. (1987) and Mueller *et al*. (1988) in the Netherlands, have shown European earwig (*Forficula auricularia* L.) to be an important woolly aphid predator. In Australia, Nicholas (2000) has also shown that earwigs are capable of providing effective biological control of woolly aphid.

Apples are subjected to a wide range of insect and mite pests and diseases. Pesticides continue to play an important role in orchard management, including IPM programs. Chemicals toxic to *F. auricularia* have the potential to disrupt effective biological control of woolly aphid.

The aim of this study was to test a range of freshly dried chemical residues (insecticides, fungicides, herbicides and crop regulators) commonly used in Australian apple orchards for their toxicity to *F. auricularia* and assess their potential to disrupt the biological control of woolly aphid.

MATERIALS AND METHODS

Earwigs

European earwigs were collected from domestic gardens in the Bathurst district with no previous pesticide spray history. They were maintained in ventilated plastic chambers (36 x 28 x 28 cm deep) filled with sand to a depth of 4 cm and fed lettuce, sliced stone fruit and pollen.

Chemicals

Commercially available (proprietary formulation) pesticide preparations, listed in Table 1, were tested. Chemicals were initially divided into two groups: insecticides, which were expected to be toxic to earwigs; and fungicides, crop regulators and a herbicide, all expected to be less toxic.

Bioassay procedure

Standard 90 mm diameter sterile plastic Petri dishes were modified and used as disposable bioassay chambers. Each chamber was connected to an air supply to prevent the build up of fumes and condensation. The air supply was filtered and drawn through distilled water to moderate the humidity. Air was exchanged 3 times/min (flow rate 200 $cm^3 min^{-1}$) and vented through a 15 mm diameter hole in the lid. The air supply and ventilation ports were covered externally with voile (nylon) gauze fixed in place with non-toxic, solvent free glue (UHU Stic® UHU GmbH & Co. Burl, Germany).

The sprays were applied to all internal surfaces of the chamber using a Potter tower (Burkard, model S.T. 4. Rickmansworth, England) calibrated with 48 kPa air-flow pressure and suction flow rate 0.5 mL s^{-1}. The lid and base were sprayed separately with 3 mL of aqueous pesticide or with distilled water (control) resulting in an aqueous deposit of 1.4 mg cm^{-2} which was left to dry for 24 h. The chamber was sealed with Parafilm® "M" (American Can Co. Greenwich CT. USA). Microscopic inspection confirmed that the spray deposit, droplet size and distribution pattern on the chamber surface was evenly distributed.

Preliminary tests were conducted for each chemical to identify the appropriate concentration range. For the insecticides, each test included five concentrations and a distilled water control and was replicated six times. Ten mature female earwigs, each weighing 50 to 60 mg, were placed in each chamber and exposed to the dried residues for 24 h (cannibalism occurred after 24 h in the chamber) after which the level of mortality was assessed. Moribund earwigs were classed as dead if, when turned onto their back, they were unable to regain their feet. A test was rejected if the control mortality exceeded 15%. Probit regressions were calculated following the principles of Finney (1971) using a PC program Probit 5 (Gillespie 1995) and the LC_{50} values estimated with their respective 95% fiducial limits.

The second group of chemicals (fungicides, crop regulators and herbicide) was tested as above but at concentrations of one and ten times the product's recommended field rate only. Because of insufficient earwigs, tests were replicated four times rather than six.

RESULTS

On the basis of estimated LC_{50}s, relative to recommended field rate, each chemical was ranked for its potential to disrupt the biological control of woolly aphid. Risk of disruption was assessed as low if the LC_{50} was greater than ten times the registered field rate, moderate if the LC_{50} was between one and ten times the registered field rate and high if the LC_{50} was less than one times the registered field rate.

All chemicals tested are listed in Table 1 in order of toxicity within their functional groups. Azinphos-methyl had an estimated LC_{50} below the recommended field rate. Imidacloprid, endosulfan, tau-fluvalinate, pirimicarb and vamidothion all had LC_{50} estimates greater than their respective recommended field rates. In the case of endosulfan, imidacloprid and tau-fluvalinate, the LC_{50} was greater than one but less than 10 times the recommended field rate. These chemicals are therefore rated as moderately toxic. During preliminary range-finding tests, fenoxycarb, propargite and tebufenozide failed to kill earwigs at concentrations equivalent to 100x the recommended field rate. These chemicals were wettable powder formulations and higher concentrations could not be applied using the Potter tower due to spray nozzle blockage. The toxicity of abamectin was also low, killing only 20% at a concentration equivalent to 100x the recommended field rate.

All the chemicals in the second group had a zero mortality rate at concentrations equivalent to 10x their respective recommended field rates.

DISCUSSION

Our results suggest that differential susceptibility of *F. auricularia* to dried residues of commonly used pesticides may impact on its capacity to control woolly aphid. Earwigs are nocturnal and take refuge in cool dark cracks and crevices such as under flaking bark or in leaf litter during the day. They are therefore more likely to come into contact with dried chemical residues the following night than in direct contact with aqueous sprays at the time of application.

The chemicals, alpha-cypermethrin, azinphos-methyl, carbaryl, chlorpyrifos, fenthion and parathion-methyl had LC_{50} estimates at rates lower than their respective recommended field rate and are highly toxic to *F. auricularia* and a single application would be very likely to disrupt the biological control of woolly aphid. Carbaryl, used both as an insecticide and a crop regulator (thinner), will be extremely toxic to earwigs regardless of its function.

Endosulfan and tau-fluvalinate are likely to disrupt biological control of woolly aphid if applied early, or repeatedly in the growing season. This is because the earwigs enter the trees and have their greatest impact on the suppression of woolly aphid numbers early in the season. As the season progresses and alternative food sources become more available, the earwig is less effective. As well, *F. auricularia* has only one generation per season and any reduction in the population would have an effect throughout the season unless rapid and adequate migration occurred. The LC_{50} of imidacloprid, a systemic insecticide applied as a root drench early in the growing season to control woolly aphid, suggests that this insecticide is also likely to kill earwigs in subterranean nests close to the tree. The surrounding soil, containing residues, may also be toxic to earwigs *en route* to the tree. These three chemicals have therefore been rated as moderately toxic and their use should be minimised to maintain biocontrol of woolly aphid.

Table 1. Chemicals commonly used in apple orchards ranked according to the toxicity of their residues to adult female European earwigs (*Forficula auricularia*) based on the LC_{50} obtained from log-dose probability regressions and the recommended field use concentration (FR).

Function and chemical	Product tested	Slope (± s.e.)	LC_{50}(95% FL)[1]	XFR[2]	Toxicity
Insecticide					
parathion-methyl	Penncap M®	6.5 (0.5)	0.03 (0.03-0.02)	0.06	high
alpha-cypermethrin	Fastac®	1.7 (0.4)	0.01 (0.05-0.002)	0.07	high
carbaryl[3]	Bugmaster®	5.1 (0.7)	0.10 (0.11-0.09)	0.07	high
chlorpyrifos	Lorsban® (500 EC)	4.0 (0.6)	0.05 (0.06-0.04)	0.07	high
fenthion	Lebaycid®	2.2 (0.3)	0.20 (0.49-0.08)	0.17	high
azinphos-methyl	Gusathion®	3.3 (0.6)	0.35 (0.42-0.29)	0.52	high
imidacloprid	Confidor®	4.2 (0.8)	2.47 (3.11-1.95)	3.0	moderate
endosulfan	Endosulfan (Nufarm)	2.9 (0.2)	3.25 (4.29-2.46)	3.5	moderate
tau-fluvalinate	Mavrik®	1.6 (0.2)	0.36 (0.56-0.23)	5.4	moderate
tebufenpyrad	Pyranica®	4.7 (0.2)	1.0 (1.3-0.8)	14.3	low
pirimicarb	Pirimor®	3.1 (0.2)	19.0 (23.4-15.4)	54.2	low
vamidothion	Kilval®	1.7 (0.7)	295 (7982-11)	421	low
abamectin	Avid®	-	-	>100	low
fenoxycarb	Insegar®	-	-	>100	low
propargite	Omite®	-	-	>100	low
tebufenozide	Mimic®	-	-	>100	low
Fungicide[4]					
Bupirimate	Nimrod®	-	-	>10	low
Dithianon	Delan® (750 SC)	-	-	>10	low
Dodine	Dodine (Rhone-Poulenc)	-	-	>10	low
Mancozeb	Dithane®	-	-	>10	low
Penconazole	Topas®	-	-	>10	low
Thiram	Thiragranz®	-	-	>10	low
Crop regulator[4]					
Benzyladenine	Cylex®	-	-	>10	low
Ethephon	Ethrel®	-	-	>10	low
Herbicide[4]					
glyphosate	Glyfos® (Bayer)	-	-	>10	low

[1]ai µg cm^{-2}
[2]multiple of field rate
[3]carbaryl also functions as a crop regulator (chemical thinner)
[4]nil mortality at concentration 10x FR
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Tebufenpyrad and pirimicarb, with estimated LC_{50}s equivalent to 14.3 and 54.2 times the recommended field rate respectively, are rated as having low toxicity and are unlikely to disrupt the biological control of woolly aphid. Abamectin, fenoxycarb, propargite, tebufenozide and all the fungicides, crop regulators and the herbicide glyphosate (Table 1) showed no indication of being toxic at ≥10 times their recommended field rates and consequently are ranked as low risk to *F. auricularia* control of woolly aphid.

This study will assist growers to select chemicals that are least toxic to earwigs and therefore least disruptive to the biological control of woolly aphid. However, the effectiveness of a chemical and consequently the number applications likely to be applied must be taken into account. A chemical (or combination of chemicals) ranked as moderate or low and applied repeatedly could be as disruptive as one ranked high and applied once. For example fenoxycarb causes sterility in some insects, e.g. the German cockroach, *Blattellia germanica* (L), which is associated with the morphogenetic effect of "wing twisting" (King and Bennet 1989). Nicholas (2000) noted some *F. auricularia* with twisted wings in plots treated with fenoxycarb and, although ranked low risk by this study, the repeated use of fenoxycarb may be detrimental to the population and long term biocontrol of woolly aphid.

Moreover, the bioassay technique used in this study does not determine the toxicity of chemicals when ingested, nor does it identify those with repellent effects. Further work is also required to evaluate the effects of chemicals on immature life stages and possible sub-lethal effects, such as reductions in longevity or fecundity.

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REFERENCES

Finney D.J. (1971). *Probit Analysis* (3rd Ed). Cambridge University Press.

Gillespie, P. (1995). Probit 5 for windows. *In:* 26th AGM and Scientific Conference of the Australian Entomological Society, 24-28 September 1995, Tamworth. 38.

King, J.E. and Bennett, G.W. (1989). Comparative activity of fenoxycarb and hydroprene in sterilizing the German cockroach (Dictyoptera: Blattellidae). *Journal of Economic Entomology* **82:** 833-838.

Mueller T.F., Blommers, L.H.M. and Mols, P.J.M. (1988). Earwig (*Forficula auricularia*) predation on the woolly apple aphid, *Eriosoma lanigerum*. *Entomologia Experimentalis et Applicata* **47:** 145-152.

Nicholas A.H. (2000). The Pest Status and Management of Woolly Aphid in an Australian Apple Orchard IPM Program. Ph. D. Thesis, University of Western Sydney Hawkesbury, Richmond, NSW Australia.

Robertson, J.L., Smith, K.C., Savin, N.E. and Lavigne, R. (1984). Effects of dose selection and sample size on the precision of lethal dose estimates in dose-mortality regression. *Journal of Economic Entomology* **77:** 833-837.

Stap, J.S., Mueller, T.F., Drukker, B., Van, Der Blom, J., Mols, P.J.M. and Blommers, L.H.M. (1987). Field studies on the European earwig (*Forficula auricularia* L.) as a predator of the woolly apple aphid (*Eriosoma lanigerum* Hausm.). *Mededelingen Faculteit Landbouwwetenschappen Rijksuniversiteit Gent* **52:** 423-431.