EFFECT OF INSECTICIDES ON IMMATURE AND MATURE STAGES OF *ENCARSIA CITRINA*, AN ARMoured SCALE PARASITOID

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ABSTRACT

Laboratory bioassays were conducted to determine the effect of *Bacillus thuringiensis*, diazinon, diofenolan and lufenuron on pre-imaginal and/or adult stages of *Encarsia citrina*, a key parasitoid of the armoured scale insects infesting kiwifruit. Bioassays were conducted by dipping potatoes, which were infested with second instar greedy scale (*Hemiberlesia rapax*) parasitised by *E. citrina*, in insecticide solutions, or caging adult parasitoids in treated Petri dishes. Of the insecticides tested, diazinon had the highest level of toxicity to the adult parasitoids. The need to change to insecticides with low or nil toxicity to scale parasitoids for increased biological control in 'Kiwigreen' is discussed.

Keywords: Kiwifruit, armoured scale insects, *Encarsia citrina*, *Bacillus thuringiensis*, diazinon, diofenolan, lufenuron

INTRODUCTION

By 1997, the entire New Zealand kiwifruit industry aims to shift from calendar based spraying with broadspectrum insecticides to using a first-stage Integrated Pest Management (IPM) system commonly called 'Kiwigreen' (Steven *et al.* 1994). At present, Kiwigreen involves the targeted use of mineral oil and *Bacillus thuringiensis* sprays against armoured scale insects and leafrollers respectively, although a limited number of applications of broadspectrum insecticides may still be used prior to 20 January. In the next stage of development of Kiwigreen, we aim to make greater use of biological control which has good potential to help manage some pests. Several species of parasitoids, for example *Encarsia citrina*, can parasitise a high proportion of armoured scale insects in unsprayed situations (Blank *et al.* 1995). However, we suspect that the continued presence of even a limited number of applications of broadspectrum insecticides may be hindering the biological control of pests in Kiwigreen.

A number of insecticides with less broadspectrum activity are becoming available which have good activity against kiwifruit pests. These include buprofezin and diofenolan (Tomkins 1994; Tomkins *et al.* 1994) which are effective against armoured scale insects, and lufenuron and tebufenozide with activity against leafrollers (Follas *et al.* 1994; Stevens and Steven 1994). In order to determine whether these insecticides have potential for use in second-stage Kiwigreen, we are screening the toxicity of these and currently used insecticides to selected natural enemies of kiwifruit pests. In a previous paper (Tomkins *et al.* 1995), we reported the effect of tebufenozide on *E. citrina*. This paper reports on further trials investigating the effect of various insecticides on both the larval and adult stages of *E. citrina*.

METHODS

Bioassays with immature parasitoids

Six potatoes per treatment were infested with greedy scale crawlers, which were allowed to settle and then left to develop until they reached the second instar. The

potatoes, infested with approximately 50 greedy scale, were then individually placed in plastic pottles which were fitted with gauze lids. In the parasitised treatments, 10 adult parasitoids were added to each pottle and provided with a honey and water solution and left for 24 h before the parasitoids were removed.

Within 48 h after exposure to parasitism, parasitised and unparasitised greedy scale were dipped into agitated solutions for 5 seconds. The chemicals used were, lufenuron (Match 050EC) at 0.03, 0.05 and 0.10 g ai/litre and *B. thuringiensis* (Bt) (Delfin WG) at 0.25, 0.5, 1.0 g product/litre. Water was used as the control, with the spreader Multifilm added to all treatments at 0.25 ml/litre. When dry, the potatoes were returned to the pottles which were held for 41 days for the lufenuron treatments or 47 days for the Bt, at 20°C before determining the scale stage (Ferguson 1974), parasitism, stage of parasitism and mortality of the scale insects.

Analyses of these data were made with the parasitised and unparasitised treatments pooled, or compared separately using generalised linear models with a logit link and errors proportional to those for a binomial model.

Bioassays with adult parasitoids

A bioassay was developed to determine the effects of pesticides on adult *E. citrina*. Petri dishes (40 x 10mm) with three 10 mm holes in their lids (two holes covered with very fine voile for gas exchange and the third for access) were dipped in the following insecticide solutions and allowed to air dry. Chemicals tested were lufenuron at 0.025, 0.05 and 0.1 g ai/litre, diazinon (Basudin 600EW) at 0.5 g ai/litre, and diofenolan (Aware 250EC) at 0.075, 0.1 and 0.2 g ai/litre. Water was used as the control with the spreader multifilm used with all treatments at 0.25ml/litre.

When dry, the two halves of the Petri dishes were bound together with parafilm. Approximately 10 newly-emerged adult *E. citrina* were then added via the access hole before it was quickly sealed with cotton wool. The dishes were held for 24 h at 20°C before mortality was assessed by lack of response to a prod with a fine pin. Six dishes (replicates) were used per treatment.

Due to the high mortality in the control, a second bioassay was conducted (B). The problem of the high control mortality in bioassay A was overcome in the second bioassay (B) by the provision of food for the parasitoids within the Petri dishes. This comprised a small droplet of honey, sugar, water and agar placed on the underside of each Petri dish lid.

The ability of those adult *E. citrina* surviving 24 h exposure to treatments, to parasitise armoured scale insects was determined by transferring the parasitoids from each Petri dish to a plastic pottle containing a potato infested with second instar oleander scale (*Aspidiotus nerii*). The *E. citrina* adults were provided with parasitoid food and the pottles were then left for 3-4 weeks to allow the oleander scale to reach the third instar (Tomkins *et al.* 1996). The scale stage and scale mortality, and percentage and stage of parasitism of the scale insects was then assessed.

The adult *E. citrina* bioassay data were analysed using logit regression analysis.

RESULTS AND DISCUSSION

Effect of pesticides on immature parasitoids

As the bioassay using lufenuron was left for 6 days longer (Table 1) than that using *B. thuringiensis* (Table 2), the greedy scale populations in the first bioassay were more mature at the time of assessment. Thus, the majority of greedy scale, in the lufenuron trial, which had not been exposed to parasitism, had reached the older immature stage of the third instar while in the *B. thuringiensis* trial most were still in the young immature third instar stage.

Neither lufenuron (Table 1) or *B. thuringiensis* (Table 2), at the rates tested, had any effect on greedy scale development since there was a similar age structure and mortality in the control and insecticide treatments. Second instar greedy scale parasitised by *E. citrina* were generally unable to continue their development to the next instar, as shown previously (Tomkins *et al.* 1995). This is shown by the relatively higher proportion of greedy scale, which had been exposed to parasitism, found in the second instar for both insecticides. Some greedy scale on the treatments

exposed to parasitism, did proceed past the second instar because not all the greedy scale in these treatments were parasitised, i.e., parasitism rate was 34-52% between treatments.

TABLE 1: Percentage ($\pm$ SE) of total greedy scale in different instars 47 days after treatment with lufenuron.

Treatment (g ai/litre)	Second	Stage (instar) 'Young' third	'Older' immature third
Not exposed to parasitism			
0	15.1(1.1)	35.0(2.8)	48.6(2.7)
0.025	16.3(1.4)	33.7(3.4)	49.0(3.4)
0.05	13.9(1.3)	35.5(3.4)	50.2(3.3)
0.10	16.3(1.2)	32.8(3.1)	50.2(3.1)
Significance ¹	NS	NS	NS
Exposed to parasitism			
0	64.0(5.5)	16.0(3.1)	20.0(3.3)
0.025	64.4(5.8)	12.6(3.0)	22.7(3.6)
0.05	59.8(4.9)	20.7(3.0)	19.4(2.8)
0.10	63.9(5.2)	19.4(3.2)	16.9(2.8)
Significance ¹	NS	NS	NS

¹ NS = not significant ($P>0.05$)

TABLE 2: Percentage ($\pm$ SE) of total greedy scale in different instars 41 days after treatment with *Bacillus thuringiensis*.

Treatment (g product/litre)	Second	Stage (instar) Young third	Older immature third
Not exposed to parasitism			
0	27.5(2.6)	67.7(2.6)	4.8(0.1)
0.25	23.0(2.6)	71.8(2.6)	5.2(0.9)
0.5	23.8(2.4)	72.9(2.5)	3.3(0.7)
1.0	24.3(2.3)	71.9(2.3)	3.8(0.7)
Significance ¹	NS	NS	NS
Exposed to parasitism			
0	60.3(6.0)	37.8(6.1)	1.9(0.6)
0.25	63.9(6.3)	34.4(6.5)	1.6(0.6)
0.5	66.9(6.9)	31.3(7.0)	1.8(0.7)
1.0	56.7(6.2)	42.1(6.4)	1.2(0.5)
Significance ¹	NS	NS	NS

¹ NS = not significant ($P>0.05$)

As with the development of greedy scale, the longer period of incubation for the lufenuron trial resulted in *E. citrina* being relatively more mature than in the *B. thuringiensis* trial (Table 3). No adverse effects on *E. citrina* development occurred with either insecticide, although some positive significant differences ($P<0.01$) on parasitoid development were found with lufenuron.

TABLE 3: Percentage ($\pm$ SE) of *Encarsia citrina* in different stages, found in second instar greedy scale that had been exposed to parasitism, 47 or 41 days after treatment with lufenuron or *Bacillus thuringiensis* respectively.

Treatment (g ai or product/litre)	Third instar	Pupae	Percentage stages Black pupae	Emerged
<i>lufenuron</i>				
0	-	21.8(2.8)	23.3(3.5)	54.7(4.1)
0.025	-	23.1(3.0)	14.9(3.1)	61.7(4.2)
0.05	-	10.4(1.9)	19.2(2.9)	70.3(3.3)
0.10	-	14.2(2.5)	18.0(3.0)	67.7(3.7)
Significance ¹	-	**	NS	**
<i>B. thuringiensis</i>				
0	6.0(2.5)	35.1(4.2)	28.4(4.3)	30.5(4.2)
0.5	3.1(2.0)	34.1(4.2)	26.9(4.2)	35.8(4.2)
1.0	7.2(2.9)	31.8(4.5)	23.8(4.4)	37.0(4.9)
2.0	5.3(3.1)	29.1(4.2)	25.3(4.5)	40.2(4.8)
Significance ¹	NS	NS	NS	NS

¹ NS = not significant; **= $P < 0.01$

Effect of pesticides on adult parasitoids

In both bioassays, exposure to diazinon used at the field rate resulted in complete mortality of the adult *E. citrina* (Table 4). Similar results have been found by Oomen *et al.* (1994) who classed diazinon as harmful to *Encarsia formosa*. Lufenuron had no effect on the parasitoid, whilst exposure to diofenolan did result in an increase in mortality with a rate effect evident. Oomen *et al.* (1994) also found that insect growth regulators generally have no or low toxicity to *Encarsia* sp.

E. citrina adults surviving the treatments in bioassay A were used to parasitise first instar oleander scale. Although the low numbers of survivors in all treatments resulted in a very low level of parasitism (3-13% Table 4), the results did indicate that some *E. citrina* surviving exposure to diofenolan and lufenuron were able to successfully parasitise scale insects.

TABLE 4: Percentage ($\pm$ SE) of adult *Encarsia citrina* dead after 24h exposure to treatment residues and percent parasitism ($\pm$ SE) of oleander scale achieved by surviving parasitoids.

Treatment (g ai/litre)		Percent parasitoid mortality A ¹	B	Percent parasitism of oleander scale
control		34.9(8.7)	8.8(3.4)	2.6(1.0)
diazinon	0.5	100	100	-
diofenolan	0.075	66.1(7.9)	11.7(4.4)	8.1(2.4)
	0.10	54.1(8.9)	15.6(5.1)	5.6(1.7)
	0.20	51.8(9.2)	20.7(4.9)	6.8(2.2)
lufenuron	0.03	47.9(8.7)	5.8(3.2)	4.5(1.4)
	0.05	54.3(11.1)	9.8(3.8)	12.9(3.0)
	0.10	63.8(9.1)	8.4(3.5)	8.8(2.5)

¹ data from 2 bioassays (A,B) with survivors from bioassay A used to parasitise oleander scale

These bioassays have demonstrated that the continuing use of some broadspectrum insecticides in Kiwigreen is likely to adversely affect the biological control of armoured scale insects. A key step in the next phase of the development of Kiwigreen must be to replace remaining broadspectrum insecticides, where necessary, with alternative insecticides that have low or no toxicity to pest natural enemies. This should enable these natural enemies to exert a greater impact on kiwifruit pests and bring Kiwigreen a step closer to the concept of IPM and long-term sustainability of the system.

ACKNOWLEDGEMENTS

We wish to thank Ms B. Dow for statistical analyses. The bioassays with the immature stages of *E. citrina* were funded by the Foundation for Research, Science and Technology contract CO6315, with the studies using adult *E. citrina* funded by Ciba Geigy N.Z. Ltd.

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