

## OPTIONS FOR REDUCING THE NUMBER OF CHORUS CICADA, *AMPHIPSALTA ZELANDICA* (BOISDUVAL), IN KIWIFRUIT ORCHARDS

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### ABSTRACT

Chorus cicadas are regarded as a potential constraint to the productivity of kiwifruit orchards in New Zealand. However, limited research has been conducted on their management. In this study, the efficacy of insecticides and cultural methods to reduce numbers of cicadas in kiwifruit was determined. Chlorpyrifos and thiamethoxam applied to egg-nests did not reduce cicada hatch. Soil application of thiamethoxam and pymetrozine at 800 g ai/ha did not reduce numbers of cicada nymphs in soil or emerging from soil to moult to adults. Hoeing to a depth of 10 cm and application of a groundcover effectively reduced numbers of emerged cicada nymphs by 40-50%. Failure of insecticide treatments may be related to dry soil conditions and further trials of insecticides may be warranted. Biological and cultural options such as the development of a biopesticide should also be considered as a more sustainable option to insecticides.

**Keywords:** cicadas, nymph, insecticides, cultural control, kiwifruit.

### INTRODUCTION

Chorus cicadas, *Amphipsalta zelandica* Boisduval, are considered to be pests of kiwifruit and affect production in several ways. Sooty mould associated with adult cicada feeding leads to increased orchard labour costs as a result of fruit thinning and fruit cleaning, and increased fruit reject rates during packing. Significant damage occurs to fruiting canes from egg-laying, particularly in young canes of gold kiwifruit, *Actinidia chinensis* 'Hort16A'. This damage is not usually detected until winter and can result in gaps in the canopy, or force the selection of poorer quality fruiting canes. There may also be negative impacts on vine growth and health from nymphal feeding on roots, and cane death following entry of the budbreak promoter Hi-Cane® into the cane via egg-laying sites. These impacts may be more severe in the future, as cicada numbers are increasing in many orchards (Logan et al. 2009).

There are currently no recommendations for managing cicadas in New Zealand kiwifruit. Netting and frequent application of insecticides are recommended to prevent damage to young fruit and ornamental trees by adult periodical cicadas, *Magicicada* spp., in eastern USA (Day et al. 2002; Johnson & Townsend 2004). Experimental work to control cicadas elsewhere has principally involved knockdown insecticides against adults, and systemic insecticides for control of nymphs (Hogmire et al. 1990; Gonzalez et al. 1998; Martinelli et al. 2000).

In this study, several exploratory options for reducing numbers of immature cicadas were tested. Chorus cicadas and other species lay eggs in stacks of ca 2-10 in alternating left and right slits cut through the epidermis and sapwood of canes. Eggs are hidden beneath a layer of damaged fibrous epidermis and alternating egg stacks are collectively known as an egg-nest (Gerhard 1923). Chlorpyrifos and thiamethoxam were applied to kiwifruit canes to kill eggs in egg-nests. Thiamethoxam and pymetrozine were tested by application to soil for root uptake to kill cicada nymphs. Chlorpyrifos is an

organophosphate compound that inhibits acetylcholinesterase activity in a wide range of organisms after contact, ingestion or inhalation. Thiamethoxam is a neonicotinoid compound that is translocated in both xylem and phloem tissue and causes cessation of feeding by sucking insects (Senn et al. 1998). Pymetrozine is a pyridine azomethine compound that disrupts feeding by paralysing the cibarial muscles of xylem-feeding insects and may result in death by starvation (Harrewijn & Kayser 1997). Two cultural control methods (a synthetic groundcover and rotary-hoeing) were tested for their efficacy in reducing the number of nymphs emerging from soil to become adults. The groundcover is used by some growers to improve fruit yields by reflecting sunlight into the vine canopy. Hoeing beneath vines is not a regular practice but was considered likely to kill mature nymphs in shallow subsurface emergence tunnels.

## METHODS AND MATERIALS

### Effect of insecticides on egg hatch

Cicada egg-nests were selected on separate canes of *Actinidia deliciosa* vines in a breeding selection block at the Plant & Food Research orchard, Te Puke, and allocated randomly to one of three treatments: sprayed with chlorpyrifos (LORSBAN®), sprayed with thiamethoxam (ACTARA® 25WG) and an unsprayed control. There were 20 egg-nests per treatment. On 3 September 2007, chlorpyrifos (50 ml/100 litres) and thiamethoxam (20 g/100 litres) were applied directly to egg-nests with a backpack sprayer, until run-off. Funnel traps to capture emerging cicada nymphs were secured to canes one day after insecticide treatment and trap catch containers were checked for nymphs weekly from 12 September until 5 December 2007. The sums of weekly counts per trap were analysed by 1-way ANOVA, after transformation by  $\log(x+0.5)$  showed that variance was stabilised and residuals normally distributed. Statistical analysis for this trial, and for all others reported below, was carried out using Genstat Release 9 [(PC/Windows XP) Copyright 2006, Lawes Agricultural Trust (Rothamsted Experimental Station)].

### Effect of insecticides and cultural methods on nymphal survival

Soil-insecticide and cultural control treatments were applied to 55 vines in a block of *A. deliciosa* 'Hayward' kiwifruit at the Plant & Food Research orchard, Te Puke. Vines were 25 years old and grown on T-bars, and in the recent past had supported relatively large numbers of *A. zelandica* (Logan & Connolly 2005; D.P. Logan, unpubl. data). Five treatments: pymetrozine (CHESS WG®) or thiamethoxam (ACTARA® 25WG) applied pre-flowering; rotary-hoeing in January to kill final instar nymphs just prior to emergence; Extenday® reflective covers on the ground to reduce emergence; and an untreated control, were each applied to 11 plots approximately 3 m × 5 m centred on a vine. Treatments were allocated in a completely randomised design.

Thiamethoxam and pymetrozine were applied to closely-mown groundcover in the plot area on 5 and 6 November 2007, respectively. Both insecticides were applied at a rate of 800 g ai/ha, twice the highest recommended rate for control of aphids and whitefly on vegetables, and a high water rate of 20 litres/m<sup>2</sup> in an attempt to maximise uptake by the vines and subsequent negative effects on feeding cicada nymphs. Insecticides were applied prior to flowering to minimise any negative impacts on bees and reduce the risk of residues on fruit at harvest. Pieces of Extenday® reflective groundcover measuring 4.5 m × 4 m were securely fastened to the ground below 11 vines on 8 January 2008. Packaging tape was used to secure the Extenday® to the base of the vine and pegs at approximately 0.5-m intervals used to secure the edges. Soil in the 3 m × 5 m plot area of a further 11 vines was dug over to a depth of 100 mm using a hand-held rotary-hoe on 9 and 10 January 2008. Barriers of weed-mat 400 mm high were erected to form a perimeter around each plot to reduce or eliminate the number of emerging nymphs crossing between plots.

The number of surviving nymphs in insecticide-treated and control plots was determined by excavating soil from holes measuring 200 mm square and 400 mm deep. One hole was dug per plot on 13-18 December 2007, and each hole was approximately 500 mm from the vine. All nymphs were assumed to be *A. zelandica*, based on previous

studies of the block where 98-99% of exuviae were *A. zelandica* (Logan & Connolly 2005). The five nymphal instars were separated by length of the mesotibia (D.P. Logan, unpubl. data). Data for nymph instars were combined into one count and transformed by square root to normalise the data and reduce variance heterogeneity before 1-way ANOVA. Analyses were repeated for numbers of fifth or final instar, fourth instar, and combined counts of first, second and third instar nymphs. Counts of the final instar exuviae of *A. zelandica* on vine trunks, adjacent groundcover and on the inside surface of plot barriers were completed between 18 January and 28 February 2008 to estimate cicada emergence. Data for final instar exuviae for the treated area (vine + adjacent groundcover) and for plot barriers were transformed by  $\log(x)$  before 1-way ANOVA. For each analysis, means were separated using the LSD test when F values were significant at  $P < 0.05$ .

#### Residue sampling

Samples of xylem sap for residue analysis were taken on 12 November and 3 December, 1 and 4 weeks after insecticide application, respectively. Sap was collected on still, humid nights following the method of Clearwater et al. (2007) by first drilling a 1-mm hole at the base of the vine trunk within 100 mm of the soil surface. A new 16-gauge hypodermic needle was inserted into the hole and exudate collected as it seeped out under positive root-pressure. Sap samples were collected from all insecticide-treated vines, and bulked and sub-sampled on the day following collection so that there was 150 ml of sap for vines treated with pymetrozine and thiamethoxam. Sap was frozen and sent to Hill Laboratories Limited for a multi-residue liquid chromatography-tandem mass spectrometry (LCMSMS1) analysis. Five fruit were collected from each of the insecticide-treated and control vines on 25 March 2008, bulked and sub-sampled and 18 fruit per treatment sent to Hill Laboratories Limited for a multi-residue LCMSMS1 analysis.

## RESULTS

### Effect of insecticides on egg hatch

There was no effect of chlorpyrifos or thiamethoxam on the number of nymphs that hatched from sprayed egg-nests ( $P > 0.05$ ) (Table 1). Nymphs were found in 49 of 60 traps and some hatching may have occurred before treatment application in September.

**TABLE 1: Numbers of cicada nymphs hatching from egg-nests in canes sprayed with insecticides or left untreated. Values are mean of  $\log(x+0.5)$  counts of first instar nymphs/egg-nest  $\pm$  one sample standard deviation.**

Treatment	Log counts of hatched cicadas/egg-nest
Control	1.09 $\pm$ 0.90
Chlorpyrifos	0.96 $\pm$ 0.87
Thiamethoxam	1.30 $\pm$ 0.84
P value	$P > 0.05$

### Effect of insecticides and cultural methods on nymphal survival

Based on excavations, thiamethoxam reduced numbers of fifth instar nymphs by approximately 30%, but did not reduce numbers of smaller instars or have a significant effect on total nymph counts (Table 2). Pymetrozine had no effect on numbers of fifth instar nymphs. Numbers of final instar exuviae of *A. zelandica* were reduced by approximately 50% and 40% respectively, relative to the control, in hoeing and Extenday® plots (Table 3). Thiamethoxam and pymetrozine had no effect on numbers of final instar exuviae. There were significant reductions of cicada exuviae on vine trunks and surrounding soil in plots that were hoed or had an Extenday® groundcover, but there were no effects on numbers of exuviae found on plot barriers (Table 3).

**TABLE 2:** Numbers of cicada nymphs excavated from soil of plots treated with insecticides or left untreated. Values are square-root transformed mean counts/hole  $\pm$  one sample standard deviation. Within columns, means followed by the same letters are not significantly different at  $P < 0.05$ .

Treatment	1st to 3rd instar nymphs	4th instar nymphs	5th instar nymphs	Total nymphs
Control	1.90 $\pm$ 0.86a	2.11 $\pm$ 1.00a	2.56 $\pm$ 0.72a	4.01 $\pm$ 0.86a
Thiamethoxam	1.75 $\pm$ 0.80a	1.95 $\pm$ 0.86a	1.85 $\pm$ 0.49b	3.37 $\pm$ 0.64a
Pymetrozine	1.73 $\pm$ 0.48a	2.34 $\pm$ 1.14a	2.35 $\pm$ 0.77ab	3.87 $\pm$ 1.00a
P value	>0.05	>0.05	0.047	>0.05
LSD ( $P < 0.05$ )			0.58	0.73

**TABLE 3:** Numbers of emerged cicadas in plots treated with insecticides or cultural controls. Values are means of log-transformed counts of *Amphipsalta zelandica exuviae*  $\pm$  one sample standard deviation. Within columns, means followed by the same letters are not significantly different at  $P < 0.05$ .

Treatment	Vine and soil	Plot barrier	Plot total
Control	2.147 $\pm$ 0.287c	2.178 $\pm$ 0.272a	2.482 $\pm$ 0.242c
Extenday®	1.320 $\pm$ 0.383a	2.717 $\pm$ 0.217a	2.288 $\pm$ 0.195ab
Hoe	1.751 $\pm$ 0.261b	2.034 $\pm$ 0.176a	2.227 $\pm$ 0.183a
Thiamethoxam	2.044 $\pm$ 0.206c	2.204 $\pm$ 0.200a	2.448 $\pm$ 0.159bc
Pymetrozine	2.233 $\pm$ 0.258c	2.297 $\pm$ 0.223a	2.579 $\pm$ 0.205c
P	<0.001	>0.05	<0.001
LSD ( $P < 0.05$ )	0.244		0.170

### Residue sampling

Xylem sap samples taken on 12 November and 3 December 2007 and fruit sampled on 25 March 2008 had no detectable residues of pymetrozine or thiamethoxam.

### DISCUSSION

Application of chlorpyrifos and thiamethoxam directly to egg-nests failed to reduce hatching of eggs. Insecticide application in September was approximately halfway through the period of egg hatch (June-December) and any treatment effects may have been obscured by variation due to completed hatching. Eggs are covered by a layer of macerated epidermal tissue that may have prevented penetration and contact by chlorpyrifos and thiamethoxam.

Thiamethoxam and pymetrozine applied to soil at twice the recommended rate in October had no effect on numbers of nymphs found in soil 5–6 weeks later or emerging from soil 11–15 weeks later. Vegetative groundcover in the trial plots in late spring and early summer was relatively sparse and cicada nymphs were probably feeding predominantly on kiwifruit roots, not grass and weed roots. Lack of residues in xylem sap samples suggest that neither insecticide was taken up from soil by kiwifruit roots in significant quantities. This may explain the failure to reduce numbers of cicada nymphs.

Surface roots may have been inactive because of an extended period of dry weather at the time of application and were not affected by irrigation just prior to insecticide application. Performance of soil-applied insecticides is often poor in dry soil conditions (Sutter et al. 1989). Given adequate surface soil moisture, application of systemic insecticides may be effective against those nymphs feeding on roots of vegetative groundcover. In this trial, it is not certain to what degree low inherent toxicities of the insecticides, suboptimal conditions of application, or a failure to reach significant numbers of feeding cicadas contributed to lack of effect. Imidacloprid, fipronil and thiamethoxam have provided effective control of soil insects under other production systems (e.g. Kuhar & Alvarez 2008). Application of imidacloprid to the soil by sprinklers led to a substantial reduction of numbers of the xylem-feeding glassy-winged sharpshooter, *Homalodisca coagulata*, on citrus trees (Castle et al. 2005). Given the dry and suboptimal conditions during this study and published reports of the efficacy of systemic insecticides against other xylem-feeding insects, further trials of thiamethoxam, pymetrozine and other insecticides such as imidacloprid and fipronil are arguably warranted.

Rotary-hoeing to 100 mm deep resulted in a 50% reduction of final instar nymph emergence. It is possible that rotary-hoeing also reduced numbers of younger nymphs, as many were found in the top 200 mm of soil in December. Rotary-hoeing probably killed other invertebrates, particularly earthworms, and would have destroyed fine surface roots. Vines in the trial block were mature and it is likely that fine root damage will be transient. The relatively high expense of rotary hoeing and grower's concerns that sward and soil health may be compromised by this technique are likely to limit wide adoption of rotary-hoeing, despite its apparent effectiveness against chorus cicadas.

An Extenday® groundcover reduced numbers of emerged nymphs by 40%. Although groundcover was securely fastened to the ground with pegs at approximately 0.5-m intervals, it is clear that some nymphs escaped. These nymphs moulted to adults on the plot barriers. The effectiveness of groundcover is likely to increase with more extensive coverage of the soil, for example an entire row. This is because the edge to area ratio will be smaller, so that relatively fewer nymphs will emerge near the groundcover edge and be able to escape. The cost of applying a groundcover is significant and unlikely to be adopted for cicada control alone. However, as some growers use reflective groundcover to improve fruit yields and dry matter, there may be an opportunity to alter the way it is currently used to also reduce cicada emergence. Compared with insecticides and rotary-hoeing, use of reflective groundcover has potentially fewer detrimental effects on the environment.

The cryptic location of eggs in canes and nymphs in soil presents a significant challenge for reducing chorus cicada numbers in kiwifruit orchards. Adults are large robust insects and industry trials of contact insecticides have not successfully reduced adult numbers or egg-laying within orchards (D.P. Logan, unpubl. data). Application of insecticides to the canopy in January and February can lead to residue problems on fruit. Further, application of insecticides to soil in kiwifruit orchards may have undesirable effects on non-target organisms such as earthworms and may be unsustainable because of market compliance requirements for safeguarding the environment. Entomopathogen-based products are worthy of consideration for cicada control despite questions over their economic viability in a relatively small market. Natural enemies do not currently have any significant impact on numbers of chorus cicada. The mymarid egg parasitoid *Idiocentrus* sp. occurs at low density (<10% parasitism of egg-nests) in some shelter trees and in mahoe in surrounding forest but has not yet been found parasitising egg-nests in kiwifruit (D.P. Logan, unpubl. data). More targeted methods, such as the development of insecticide bands for vine trunks and support posts to trap and kill migrating final instar nymphs, may be more effective approaches.

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