Control of passionvine hopper and cicada eggs on kiwifruit canes with bifenthrin and a new super-penetrant adjuvant

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Abstract A novel option for control of passionvine hopper (PVH, *Scolypopa australis*) and chorus cicada (*Amphipsalta zelandica*) on kiwifruit was investigated. This involved applying an insecticide to PVH and cicada egg sites in the dormant kiwifruit canopy, using a new type of adjuvant that allows sprays to penetrate into egg nests laid in canes and old fruit stalks. Five treatments of bifenthrin at 100 g/ha (1 litre/ha Talstar® 100EC) and preferred combinations of nozzle type, spray application volume and Engulf™ adjuvant rate were applied to dormant canes of Hayward kiwifruit in early August 2011. Water soluble blue dye added to all spray treatments penetrated into nests and stained PVH and cicada eggs when assessed shortly after application. All treatments significantly reduced hatch of PVH relative to the untreated control, by 85-99.5%. One treatment significantly reduced cicada hatch by approximately 80% relative to the control.

Keywords *Scolypopa australis*, *Amphipsalta zelandica*, kiwifruit management, super-penetrant adjuvant, sooty mould.

INTRODUCTION

Sooty mould, which is commonly associated with feeding by nymphal and adult passionvine hopper (PVH, *Scolypopa australis* Walker), significantly reduces kiwifruit production in some years (Steven 1990). Zespri estimated post-harvest fruit losses of $15-20 million mainly due to PVH infestation in the 2009-10 season (Logan et al. 2011a). Within kiwifruit orchard blocks, PVH lays eggs in old fruit stalks, which are well protected from the external environment and virtually impossible to target with sprays. Chorus cicada (*Amphipsalta zelandica* Boisduval) egg-nests present a similar problem (Logan & Maher 2009) and preliminary studies on that insect indicated that a specialised adjuvant could enhance the penetration of sprays into intact cicada egg nests laid in live kiwifruit canes and improve spray contact with live eggs (R.E. Gaskin, unpublished data; Logan et al. 2011b). This technology has the potential to control both cicadas and PVH without contributing to residues

in fruit at harvest, by targeting eggs with insecticide sprays applied in winter.

The work reported here was undertaken to determine the spray and sprayer prescriptions required to kill PVH and cicada eggs on dormant canes, using bifenthrin sprays containing a super-penetrant adjuvant. Dye was added to treatments to monitor initial spray penetration into egg nests, and egg hatch was monitored to confirm efficacy of treatments. This paper reports on the effect of spray treatments on the control of PVH and cicada.

MATERIALS AND METHODS

Sprayer setup and treatment application

The trial was undertaken on 1 August 2011, on a commercial 'Hayward' kiwifruit orchard on Te Matai Rd, Te Puke. The dormant, unpruned pergola canopy was on a row spacing of 4.25 m with 6 m long bays. Because of the limited availability of infested canes, the size of the trial site was constrained and treatment plots were separated by only a single buffer row. In the absence of foliage to prevent spray drift, the plots were sprayed down the centre of the treatment bay in one direction of travel only. Rows on either side were not sprayed in the opposite direction, as would occur in normal practice for good spray coverage. This reduced any chance of cross-contamination of treatments, but as a result, egg nests in canes and fruit stalks were sampled from the central section (2 × 4 m) only of the treated (4.25 × 6 m) bays.

Treatments (Table 1) were each replicated on three randomly selected bays. They were applied with a trailed Vortex 2000 axial fan airblast sprayer travelling at 5.5 km/h, in light wind conditions (0-1.2 m/s) with temperatures of 12-13°C. The sprayer was fitted with three different nozzle setups (Table 1) to compare a high volume conventional spray application, a low volume application delivering fine droplets (ATR), and a low volume application delivering coarse air inclusion (AI) droplets as developed for low-drift hydrogen cyanamide applications to dormant canes (Gaskin et al. 2008).

All treatments contained bifenthrin at 100 g/ha (1 litre/ha Talstar® 100EC, FMC Corporation, USA) and Brilliant Blue food dye (Bayer, 6 kg/ha). A super-penetrant, organosilicone adjuvant, Engulf™ (Etec Crop Solutions Ltd), was added at varying rates and concentrations (Table 1), which were modified as required (by <10%) to compensate for dye antagonism of the superspreading properties of the adjuvant (data not presented).

Assessment of spray coverage and penetration

Water sensitive papers (WSP) were wrapped around canes in two different canopy zones, on canes tied down and on unpruned canes above the pergola, to monitor spray deposits. After treatments had dried, the WSP were collected and assessed. Canes were also visually assessed for dye coverage on their top and bottom edges, and on the "leading" face directly exposed to the sprayer, and the "trailing" edge shaded from the sprayer.

Penetration of sprays into PVH egg nests was not measured, but sliced fruit stalks containing PVH eggs were examined in all treatments. Penetration into the more difficult-to-access cicada egg nests was quantified. A total of 12 nests per treatment were collected (4 samples per treated bay, 3 replicates per treatment), from both low- (in canopy zone) and high-positioned

Table 1 Treatments and nozzling for spray applications (all treatments contained bifenthrin at 100 g/ha).

Treatment #	Spray volume (litres/ha)	Sprayer nozzling	Engulf adjuvant	
			litres/ha	% concentration
1	1000	Standard tips & cores	1.0	0.1
2	1000	Standard tips & cores	2.0	0.2
3	600	ATR hollow cone	1.2	0.2
4	600	Air induction	1.2	0.2
5	600	Air induction	1.5	0.25

(above canopy) canes. Nests were also sampled from two positions on the cane: either on the sides or on the underside (facing down) of canes. At least four cross-section slices per nest were made with a sharp blade. Sections were examined with a Leica $MZ12_5$ Microscope, at 10× or 20× magnification, and photographed with a Leica DFC290 camera. Penetration into cicada egg nests was assessed on a 1-3 scale: (1) no penetration of the dye into the nest cavity, (2) penetration of the dye into the nest cavity but no contact with eggs, and (3) full penetration into the nest and contact with eggs. The mean score of four nests per cane site was used for treatment comparisons and analysed by ANOVA. The number of nests examined that did not have eggs present (i.e. egg shells were evident but they had already hatched) was also recorded.

Assessment of spray efficacy

Old fruit stalks with PVH eggs were removed from the centre of each treatment plot in early November 2011. After hatching was complete in December 2011, the fate of approximately 100 (n=101-116) dissected eggs per replicate plot was assessed as dead or hatched based on Cumber (1967). To assess efficacy for treatments against cicada eggs, blue sticky-traps (Bug-Scan®) were secured around 10 egg-nests in the centre of each replicate plot 2 days after sprays were applied. Traps were removed in late November 2011 and first instar cicada nymphs counted.

A negative binomial model in the MASS package (Venables & Ripley 2002) was used in R (R Development Core Team 2011) to model the differences between the treatments. The model was used to calculate the probability of finding no difference between the numbers of hatched cicada nymphs or PVH eggs in sprayed treatments and the untreated control.

RESULTS

Assessment of spray coverage and penetration

All sprays covered the underside of canes well, but the leading and trailing edges and tops of canes were not always well-covered with spray. In practice, the adjacent rows would be sprayed from the opposite direction and overspray would land on the treated bay, resulting in overall improved coverage relative to this study. The visual assessment of WSPs and canes indicated that the high volume treatments (1&2) and the low volume/fine droplet application (Treatment 3) covered the sides and tops of canes markedly better than the coarse droplet AI sprays (Figure 1).

The score of dye penetration into cicada nests indicated that 1000 litres/ha with 0.2% Engulf (Treatment 2) produced the greatest contact of spray with cicada eggs (Table 2). The other treatments penetrated egg nests less well and there were no differences between them.

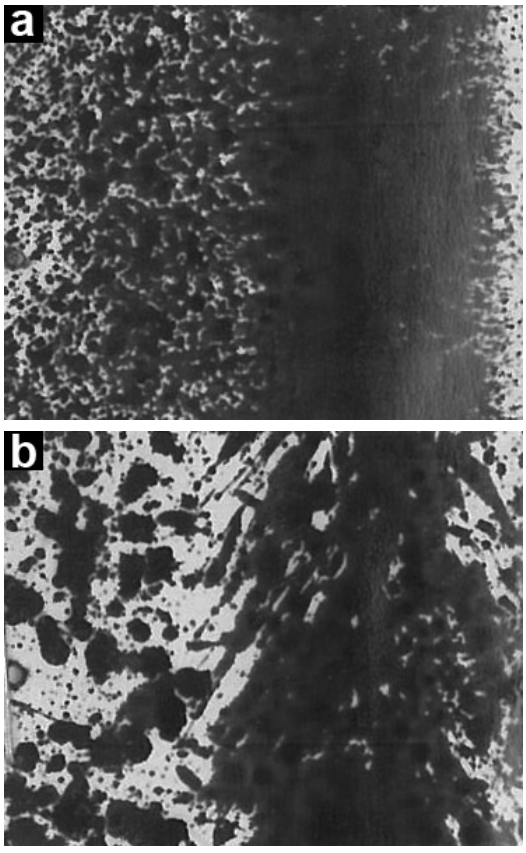

Figure 1 Coverage of water sensitive papers wrapped on canes from sprays applied by (a) fine ATR nozzles (Treatment 3) and (b) coarse AI nozzles (Treatment 5). Both sprays contained 1.2 litres Engulf/600 litres/ha.

Table 2 Penetration of cicada egg nests by sprays and unhatched egg-nests present.

Treatment #	Spray volume (litres/ha)	Mean dye penetration score[1]	% of nests with eggs present
1	1000	1.54 b[2]	54.2
2	1000	2.00 a	62.5
3	600	1.31 b	66.7
4	600	1.46 b	41.7
5	600	1.29 b	64.6

[1]Score 1= nil penetration, 3= total penetration.
[2]Means sharing common postscripts are not significantly different (LSD test, P=0.05).

There were no differences in dye penetration into nests laid in the high and low cane positions (P=0.40), nor in the nests laid on the sides of canes compared to the undersides (P=0.23). The cicada egg-hatch was more advanced than expected at the start of August, when this study was undertaken, with up to 58% of nests examined having already hatched (Table 2).

The effect of treatments on the penetration of sprays into PVH egg nests laid in old fruit stalks was not quantified at the time of spray application. However, visual examination of stalk samples indicated that (blue) spray contacted eggs in all treatments.

Assessment of spray efficacy

All treatments reduced PVH egg hatch relative to the untreated control by 85-99% (Table 3). However, only one of five spray treatments reduced cicada egg-hatch significantly, by approximately 80% relative to the untreated control (Table 3).

DISCUSSION

Eggs of PVH and chorus cicada occur in kiwifruit canopies from autumn until late spring and present a possible target for insecticides when vines are dormant. However, the eggs of both species are inserted into woody tissue and are relatively well protected from the surrounding environment. The use of a super-penetrant adjuvant to aid penetration of insecticide is an innovative approach to the control of these cryptic life-stages. In this trial all combinations of adjuvant rate, water rate and nozzling had equivalent high efficacy against PVH. In contrast only one of the five spray treatments significantly reduced hatch rate of chorus cicadas, but efficacy is likely to be improved if adjacent rows are sprayed in the opposite travel direction.

PVH eggs are more exposed to the atmosphere than are chorus cicada eggs and this may have contributed to the difference in efficacies. PVH eggs are typically laid in a short series of individual

Table 3 Expected values for percent PVH egg hatch and cicada nymphs/sticky trap and probability of those values under the null hypothesis of no treatment effects.

	% PVH egg hatch		Cicada nymphs/trap	
Treatment	Expected treatment mean ± SE	P-value	Expected treatment mean ± SE	P-value
1	0.3 ± 3.0	<0.0001	1.88 ± 1.60	0.015
2	3.6 ± 1.7	<0.0001	4.90 ± 1.51	0.339
3	1.8 ± 1.8	<0.0001	4.05 ± 1.63	0.241
4	7.5 ± 1.6	0.0010	6.62 ± 1.51	0.660
5	9.9 ± 1.6	0.0038	5.33 ± 1.58	0.441
6 (untreated)	65.6 ± 1.6	NA	8.55 ± 1.51	NA

holes cut into dying and dead plant stems and leaf petioles of ≤3 mm diameter. According to Fletcher (1978) a sawdust plug covers the hole after the egg is deposited. This plug may frequently fall off as many eggs are partly visible on close inspection of the egg site during winter. Chorus cicadas, and other species, lay eggs in stacks of 2-10 in alternating left and right slits cut through the epidermis and sapwood of kiwifruit canes. Eggs of chorus cicadas are completely covered by a layer of macerated epidermal tissue.

Visual examination of treatments indicated that higher volumes provided better spray coverage and smaller droplets covered canes better. Larger droplets from AI nozzles such as those used for bud break sprays provide a low spray drift option, but the AI spray coverage of canes was inferior to finer droplet sprays. Efficacy results endorsed this observation, but AI nozzles are still likely to provide control, particularly of PVH egg-hatch. Increasing the adjuvant concentration increased the penetration score for cicada egg-nests, but it did not improve spray coverage or efficacy on cicada and PVH egg nests. The lower rate of adjuvant is preferable to minimise spraying costs.

The date of spray application may be important for control of cicada eggs. Hatching of chorus cicada occurs between May and December (D.P. Logan, unpublished data) with a peak typically in September-October. In warm winters, hatching may be advanced and hence late applications of insecticide increase the risk of reduced efficacy. In this trial, hatching at the time of spray application (1 August) was relatively advanced (33-58%) compared with records from previous years (ca 10-20%, D.P. Logan, unpublished data). Advanced hatching may not have affected relative treatment efficacy as hatching phenology would be expected to be consistent throughout the orchard block and for all treatments. Hatching of PVH nymphs in the Bay of Plenty occurs between mid-October and mid-December with little variation between years (D.P. Logan, unpublished data). Providing it occurs prior to the start of hatching in October, date of spray application is less critical for PVH eggs than for cicada eggs.

Sprays applied to dormant canopies are a potential new option for growers to reduce PVH and cicada populations within kiwifruit orchard blocks. However, due to the cicada's multi-year lifecycle, a reduction in numbers of adult cicadas may not be observed for several years. As an additional benefit, bifenthrin products have a label claim for use against armoured scales (*Hemiberlesia* spp.) on kiwifruit and some control of these pests is also likely to result. The numbers of PVH and cicadas invading orchard blocks from boundary vegetation also need to be minimised. A winter application of bifenthrin and adjuvant may be an effective way to treat shelter trees and other boundary vegetation, in addition to other control measures, such as boundary host-plant removal and insecticides targeting PVH nymphs and adults in summer. Cost-effective control measures are not currently available for cicadas and sprays applied to the dormant canopy may be an attractive option for growers.

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