EARLY-SEASON USE OF INSECTICIDES FOR MANAGEMENT OF WOOLLY APPLE APHID (*ERIOSOMA LANIGERUM*) IN NELSON APPLE ORCHARDS

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ABSTRACT

A spray strategy to control woolly apple aphid (*Eriosoma lanigerum*, WAA) was assessed on apple orchards in Nelson. Carbaryl, applied for fruit thinning, was either sprayed alone or combined with diazinon on 'Braeburn' apples at four orchard sites infested with WAA. The diazinon plus carbaryl treatment reduced WAA levels and there were lower numbers of WAA-infested shoots with considerably fewer colonies on branches and shoots in November. Numbers of WAA colonies on shoots in January were 50% lower overall in the diazinon plus carbaryl treatment. There was an initial decline in numbers of the WAA parasitoid, *Aphelinus mali*, in both treatments, but they increased steadily during the season and high levels of parasitism were evident by harvest. The parasitoid was able to suppress the lower populations of WAA in the diazinon plus carbaryl treatment and this resulted in significantly lower levels of WAA shoot and fruit infestation and bud damage in late March. **Keywords:** woolly apple aphid, infestation, spray strategy, control, apples, carbaryl, diazinon, *Aphelinus mali*.

INTRODUCTION

Woolly apple aphid (WAA), *Eriosoma lanigerum* (Hausemann) (Homoptera: Pemphigidae), is a serious and increasing threat to the New Zealand apple industry. Growers face issues with susceptible rootstocks used for intensive plantings, a lack of Integrated Fruit Production (IFP)-compatible insecticides and unpredictable biological control outcomes influenced by seasonal temperature variations, which affect emergence and developmental rates of the parasitoid and WAA (Mols & Boers 1999; Shaw et al. 2008).

The aphids infest the aerial parts of trees and sometimes the roots, sucking sap from the plant, and heavy infestations can cause significant damage to trees, resulting in knotted and galled lumps on older wood and bud damage on shoots (Ferro 1976). Fruit contamination and infestation contributes to significant productivity losses and can cause market access problems.

The egg parasitoid, *Aphelinus mali* (Hald.) (Hymenoptera: Encyrtidae), is a specific endoparasitoid of WAA and is the New Zealand apple industry's primary control strategy for managing WAA. The parasitoid is an important factor regulating WAA populations in orchards under IFP (Shaw & Walker 1996) and is considered the most important parasitoid of WAA in apple-growing regions throughout the world (Brown & Schmitt 1994). Preferably, selective chemicals with the least disruptive effect on *A. mali* should be applied to apple trees (Bradley et al. 1997). However, carbaryl, which is widely used by growers for thinning 'Braeburn' apples, and diazinon, which is currently used for controlling WAA are both harmful to *A. mali* (Bradley et al. 1997). Diazinon is now restricted to early season use to avoid the risk of exceeding the maximum residue limit of 0.01 ppm imposed for fruit destined for the European Union (EU) market.

The lack of alternative insecticides and a very low residue limit for diazinon in the EU provided the justification for this research. This study investigates the strategy of combining a single application of diazinon with carbaryl at fruit thinning time to suppress WAA and to allow populations of *A. mali* to recover and suppress WAA to less damaging levels later in the season.

METHODS

Trial details

Blocks of mature 'Braeburn' apples on 'M.106' rootstocks infested with similar levels of WAA at four Nelson orchards were divided into two plots of approximately 0.5 ha each. One plot was sprayed with a single application of carbaryl (Sevin® FLO) (160 ml/100 litres) and the other plot was sprayed with carbaryl (160 ml/100 litres) and diazinon (Dew™ 500) (100 ml/100 litres). Sprays were applied by conventional airblast sprayers at a water rate of 1800–2000 litres/ha between 20 and 28 October 2008. During the season, the experimental areas received standard IFP fungicides and insecticides for leafroller control.

Monitoring procedures

On 27 November 2008, two lower tier branches per tree on five trees per row on four rows per plot (40 branches per plot) at each site were examined and the number of WAA colonies found was recorded. On the same 20 trees per plot at each site, five shoots per tree (100 shoots per plot) were examined and the number infested with WAA and the numbers of colonies per shoot were recorded. The same procedure was followed to record WAA infestation on shoots on 21 January 2009 and 25 March 2009. On 25 March, the number of buds damaged by WAA feeding was recorded on the same shoots monitored for WAA infestation. During harvest (7–8 April), 100 fruit from each of five bins of fruit in each plot (500 fruit per plot) at each site were examined and the number of fruit infested with WAA was recorded.

Two yellow sticky traps (180 × 190 mm) were hung from trees in each plot at each site to monitor numbers of *A. mali*. Traps were collected and changed approximately every 2 weeks between 8 October 2008 and 17 March 2009. Sticky bases were inspected with a binocular microscope and the number of *A. mali* caught was recorded.

Catches of *A. mali* from two sticky traps were also monitored in an area of 'Braeburn' with WAA at a separate site that was not treated with carbaryl or diazinon. This was used to demonstrate typical *A. mali* activity in Nelson without disruption from insecticides.

Statistical analysis

The total number of infested shoots, WAA colonies on shoots and the number of damaged buds on shoots and infested fruit was calculated for each plot. These totals were subjected to analysis of variance with orchards being considered equivalent to replicates. Residual plots were checked and no transformations were deemed necessary.

RESULTS

The addition of diazinon to the carbaryl spray significantly reduced aphid populations and this was reflected in lower shoot infestation levels in November (Table 1, $P=0.004$). Similar results were recorded for infestations of WAA on branches in November (data not shown). Aphid numbers increased during the season. However, monitoring during January and March provided consistent results that showed there were substantially lower levels of WAA shoot infestation ($P<0.05$) and bud damage in the carbaryl plus diazinon treatment than the carbaryl alone. The percentage of WAA-infested fruit in harvest samples inspected in April was also lower in the carbaryl plus diazinon than the carbaryl treatment ($P=0.01$).

Sticky trap catches showed there was an initial drop in *A. mali* numbers in both treatments after the sprays were applied (Fig. 1). However, the populations of *A. mali* continued to increase during the season, with lower numbers in the carbaryl plus diazinon treatment consistent with the lower WAA population in that treatment.

TABLE 1: Means of woolly apple aphid (WAA) infested shoots (%) and the number of colonies per 100 shoots (November 2008, January and March 2009), the number of damaged buds per 100 shoots (March) and the number of infested fruit per 100 fruit (April) for each treatment. The standard errors of the difference (SED) between the two means and P-values are shown.

Treatment	November		January		March		April	
	Shoots	Colonies	Shoots	Colonies	Shoots	Colonies	Buds	Fruit
Carbaryl	13.5	15.5	85	493	73	346	226	9.8
Carb+diaz	0.5	0.5	63	246	55	153	74	2.6
SED	1.58	2.8	5.2	59	4.3	49	54	1.38
P-value	0.004	0.013	0.023	0.025	0.026	0.03	0.067	0.014

FIGURE 1: Seasonal trend in the numbers of *Aphelinus mali* caught (catch per trap per day) on sticky traps averaged over all four orchards for the carbaryl only and the carbaryl plus diazinon treatments. Note the $\log_{10}$ scale on the Y-axis. Spray treatments were applied between 20 and 28 October 2008, as illustrated.

DISCUSSION

Carbaryl and diazinon are both toxic to *A. mali* (Bradley et al. 1997; Shaw & Wallis 2008), but they have continued to be used by apple growers, as carbaryl is a reliable fruit thinner for 'Braeburn' apples in particular, and diazinon is used to control WAA because other more selective products are unavailable. Generally WAA levels are low and colonies are less obvious in orchards during spring. However, even low populations of the pest can develop quickly and result in damaging outbreaks, which become evident during January and February. By this time, it is too late to apply a diazinon spray because of the risk of exceeding the EU residue tolerance (0.01 ppm) and the WAA population may be too high to control effectively.

The dilemma for growers is that biological control outcomes are unpredictable because they are influenced by seasonal temperatures, which affect emergence and development rates of both the aphid and the parasitoid (Mols & Boers 1999; Shaw et al. 2008). Spring temperatures during post-diapause development of *A. mali* affect emergence timing of the parasitoid (Trimble et al. 1990; Shaw et al. 2008).

Records from sticky traps operated at the same sites for the past four seasons indicated that emergence of *A. mali* in early spring was slow in 2008 and 50% emergence occurred 13 days later than the previous season (P.W. Shaw, unpubl. data). This delay would have allowed WAA, which has a lower temperature development threshold than *A. mali* (Asante & Danthanarayana 1992), to increase unchecked for a period and gain a 'head start' on the parasitoid, ultimately resulting in the elevated levels of WAA infestation recorded in these trials.

The strategy of combining diazinon with a carbaryl fruit-thinning spray in late October avoids the issue of exceeding the European Union (EU) residue restriction for diazinon and suppresses the WAA population. In both treatments, there was an initial drop in *A. mali* numbers (Fig. 1), but they recovered quickly and the parasitoid was able to reduce the build up of WAA in the combined treatment because of the initial suppression of WAA provided by diazinon. In contrast, the high levels of WAA in the carbaryl treatment resulted in significantly increased amounts of shoot and fruit infestation ($P < 0.05$) and bud damage was also higher (Table 1). The lower numbers of *A. mali* recorded in the carbaryl plus diazinon treatment throughout the season were associated with lower levels of WAA in this treatment. Apart from the trial treatments, no other insecticides that could potentially affect *A. mali* or WAA were used during the season, so this was not a factor affecting aphid and parasitoid responses in the respective treatments.

The timing of carbaryl thinning sprays in late October in the Nelson district coincides with low numbers of *A. mali* since the over-wintering generation has largely been completed and there are few adults in the population (Shaw et al. 2008). This may reduce disruption to *A. mali*. The seasonal pattern of activity of *A. mali* recorded in both treatments was similar to the typical phenology of the parasitoid in Nelson when no carbaryl or other disruptive insecticides are used (data not shown).

Trial results indicate that combining diazinon with a carbaryl thinning spray before WAA numbers increase helped Nelson growers to reduce aphid populations and infestation levels. Further assessment of this strategy for WAA management should be investigated to confirm these results and to account for the effects of varying seasonal temperatures on the interaction between the parasitoid and WAA. In order to minimise disruption to *A. mali* and other biological control agents in orchards, diazinon use should be limited to areas where WAA outbreaks are likely to occur. Ideally, alternative more selective chemicals than diazinon for controlling WAA and carbaryl for fruit thinning would be desirable in an IFP apple spray programme. To assist with WAA biological control, the possibility of introducing a species of aphidophagous hoverfly (*Heringia calcarata*) from the USA with a strong preference for WAA is being considered.

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