EFFICACY OF CARBARYL, *BACILLUS THURINGIENSIS* AND PYRETHRUM AGAINST LIGHTBROWN APPLE MOTH LARVAE ON APPLES

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SUMMARY

Field tests were conducted against inoculated larvae of lightbrown apple moth (*Epiphyas postvittana*), using conventional and novel insecticides and adjuvants. On mature apple trees, mortality caused by *Bacillus thuringiensis (Bt)* (29%) alone gave results which were not significantly different from the untreated control. Silwet L-77 increased this mortality to 53% but this was not statistically significant. Carbaryl gave c. 80% mortality of 7 and 14 day old larvae. Pyrethrum gave 66% and 54% mortality in two field tests. Two airblast applications of *Bt* and Silwet L-77 resulted in less leafroller damage than *Bt* alone. Damage at harvest after a full season of seven applications of pyrethrum, on inoculated trees, was 1.6%, compared with 13.6% in the unsprayed control. Damage after a full season of *Bt* usage in another trial was 1-2% for 'Cox's Orange' and 'Granny Smith', and 9-10% on 'Sturmer Pippin' apples.

Keywords: leafroller, insecticide, *Bacillus thuringiensis*, pyrethrum

INTRODUCTION

Leafrollers (Lepidoptera: Tortricidae) are the major target of insecticides used on pipfruit in New Zealand. The sustainability of current practices is threatened by insecticide resistance, as well as reduced acceptance of residues in our key markets. It would therefore be highly desirable for environmental and marketing reasons to develop alternatives to organophosphate and pyrethroid insecticides for leafroller control in pipfruit, with the aim of reducing insecticide applications and residues at harvest. *Bacillus thuringiensis (Bt)* has gained registration for use against leafrollers in kiwifruit, avocados, and berryfruit, where it has shown sufficient efficacy. Wigley and Chilcott (1991) reported that 90% of the *Bt* in New Zealand was used on kiwifruit. In contrast, only erratic control has been achieved on apples in New Zealand (Wearing, Suckling, Shaw, and Walker unpublished data), which is likely to be due to inactivation of the bacteria and its toxin by ultra violet light (Beegle *et al.* 1981), as well as differences in tolerance of damage. Pyrethrum could provide a solution for leafroller control with nil detectable residues on fruit and, if effective, could also provide an option for control of leafrollers. It might be limited to locations with pyrethroid-resistant *Typhlodromus pyri* (Walker *et al.* 1990), as pyrethrum is likely to be toxic to the normal strain of this predatory mite.

Carbaryl is currently registered for use on apples, with a 5 day witholding period (NZAPMB Spray Chart for 1992/93). Its' efficacy against two New Zealand leafrollers is known to be 7-10 fold less than organophosphate insecticides such as chlorpyrifos and azinphos-methyl (Suckling *et al.* 1986), and 25-fold carbaryl resistance has been reported (Suckling and Khoo 1990). However, a proportion of New Zealand apple growers have been using it at a high application rate (120 g/100 litres, usually as 3x concentrate sprayed at 1000 litres/ha), up to 5 days pre-harvest, in the absence of alternatives.

Silwet L-77 ("Pulse", a wetting agent) was included in the tests because improved distribution of the insecticides was desirable, and improvements in efficacy had been demonstrated from adding this to a conventional insecticide (Walker *et al.* 1992). Salama *et al.* (1986) reported improved efficacy of *Bt* from the addition of various inorganic salts, and a *Bt*/borax combination was also tested on *Epiphyas postvittana.*

The aim of this work was to investigate the efficacy of novel insecticides and adjuvants, such as *Bt* and pyrethrum, compared to carbaryl for control of *E. postvittana* larvae under field conditions. Screening was conducted using hand spray and airblast treatments on mature trees in the field, on candidates which might be capable of providing control of leafrollers, without causing residue problems.

METHODS

Research orchard trials

The experiment at Appleby Research Orchard, Nelson compared a single application of seven hand-sprayed treatments with an unsprayed control. Mature cv. 'Red Delicious' apple trees were treated using a hand lance applying high volume sprays to run-off (16,910 kPa, 12-15 litres/tree). Treatments (Table 1) were applied on February 4 1992, one week after leaves were inoculated with >200 *E. postvittana* eggs, designed to hatch over the next 24 h at each of two release sites per tree. In addition, an unsprayed control was compared with carbaryl, applied after larvae from the same inoculation had been allowed to develop for 14 days in the field. There were two single tree replicates of each treatment, arranged in a randomised block design, separated by guard trees. One week after inoculation, pre-treatment establishment counts were made on one release site per tree. One week after treatment, all visible nests within a c. 50 cm radius of the second release site (which was the vast majority) were picked gently into plastic bags to avoid disturbing the larvae. The number of nests, and live/dead larval counts were then made in the laboratory, including moribund with dead insects. Seven of the 10 treatments contained more than 100 larvae, with a range of 36 to 141 (Table 1).

In the second experiment, hand sprays of pyrethrum (Pyrethrum Organic Insecticide, 14 g/litre pyrethrum and 56.5 g/litre piperonyl butoxide) (as above, with 8-10 litres/tree due to smaller tree size) were compared with an unsprayed control. Each treatment had five single tree replicates, separated by guard trees. Two hundred *E. postvittana* eggs in black-head stage were put on each apple cv. 'Delicious' tree. The first spray was applied on December 12, 1992 to 'Delicious' trees one week after the hatching of the eggs. A similar assessment as in the first study was carried out. These trees then received six further c. fortnightly applications until 2 weeks before harvest on March 9 1993. Two additional releases of hatching larvae were also made (in January and Februrary), to ensure high pest pressure. At harvest, 100 fruit from each replicate were assessed for insect damage.

Air blast trials

An air-blast spray trial was performed on 'Granny Smith' apple trees at Appleby Research Orchard, to test two applications (March 30 and April 6, 1992) of either *Bt* (Thuricide HP, 100 g/100 litres) or *Bt* and Silwet L-77 (100 ml/100 litres) at 1000 litres/ha. The incidence of live insects and damage 2 weeks later was assessed by sampling 100 fruit from 15 trees per treatment on 13 April.

A season-long air-blast spray trial of *Bt* (Thuricide) was conducted on three apple varieties on a 0.5 ha block at Riverside Community, Nelson. A conventional organophosphate programme was last applied to the 'Cox's Orange Pippin' apples one year before, while the 'Granny Smith' apples had been under organic pest control for 3 years, and the 'Sturmer Pippin' apples for 5 years. Applications were made in the evenings at 10 day intervals up to the third cover spray, and fortnightly thereafter, using 1000 litres/ha. Samples of 100 fruit per tree were harvested from 15 trees of each variety, and the insect damage was recorded.

Statistical analyses

Abbott's formula was used to correct for control mortality in the field bioassays (Abbott 1925). Mortality was angular tranformed and compared using t-tests. Fisher's Exact Test (Hintze 1989) was used to compare the incidence of leafroller damage on fruit at harvest.

RESULTS AND DISCUSSION

Research orchard trials

There was no difference in the number of leafrollers established pre-treatment on all treatments (24 ± 1.0 larvae/tree, mean ± sem). Unsprayed control mortality averaged 13% (Table 1). Carbaryl, *Bt* plus pyrethrum, and *Bt* plus carbaryl treatments all had significantly higher mortality than the unsprayed control ($P<0.05$). *Bt* alone was not significantly different from the unsprayed control. Borax had no effect on *Bt* efficacy. Pyrethrum increased mortality to 66%, but high variability in the two replicates meant that this was not significantly different from the unsprayed control ($0.1>P>0.05$). The addition of *Bt* did not improve the control achieved with carbaryl or pyrethrum alone. Silwet L-77 did not significantly improve the uncorrected mortality caused by *Bt*, although the raw figures rose from 29% to 53%, which deserves further investigation. Carbaryl caused 81% mortality of 14-day old larvae.

TABLE 1: Mean percentage mortality, standard deviation (sd), sample size and Abbotts' correction) of inoculated *E. postvittana* larvae in treatments applied once by hand spray application to mature trees in March 1992.

Treatment	Rate g ai/ 100 litres	Mortality (%)	sd	No. insects sampled	Abbotts' corrected mortality (%)
7 Day-old larvae					
unsprayed	-	13	8.8	117	-
carbaryl (80 WP)	120 g	79	16	74	76
Bt (Thuricide HP)	100 g	29	6.4	141	18
Bt + carbaryl	100 g + 120 g	69	26	125	65
Bt + pyrethrum	100 g + 500 ml	69	33	124	65
Bt + Silwet L77	100 g + 100 ml	53	5.3	112	46
pyrethrum	500 ml	66	33	36	61
Bt + borax	100 g + 100 g	27	0.9	157	16
14 Day-old larvae					
unsprayed	-	8.5	0.2	73	-
carbaryl	120 g	81	1.3	122	80

In the second experiment, a similar number of larvae (dead, moribund, and alive) were recovered from the pyrethrum (31 ± 5.4 larvae/tree, mean ± sem) and unsprayed control trees (31 ± 7.4 larvae/tree) indicating neglible losses of dead larvae from the experiment. Mortality in the unsprayed control was 4.8 ± 1.4%. Mortality in pyrethrum-treated trees was 59 ± 6.4%, which was significantly different from the untreated control ($P<0.001$, $t=8.1$). Repeated applications of pyrethrum were more successful at controlling leafrollers, which were inoculated onto the trees to ensure high levels of pest pressure. Fruit damage at harvest showed a significant improvement over the unsprayed control (Table 2, $\chi^2=51.2$, $P<0.001$). Slightly improved control of woolly aphid and mealybug was also evident, although the infestation level was too low for the sample size of fruit (n=500) to indicate the significance of this. No scale insects were found.

Airblast trials

The addition of Silwett L-77 to *Bt* significantly reduced damage from 1.8% with Bt alone to 0.8% ($P<0.05$, $\chi^2=5.84$).

The level of leafroller control given with full season applications of *Bt* was very poor by export standards, where a nil tolerance for damage applies. Damage depended on variety, and was highest on 'Sturmer Pippin' (Table 3). Damage from noctuids (probably *Graphania mutans*), was also evident, and Frogatt's apple leafhopper (*Typhlocyba frogatti*) was observed to be abundant.

TABLE 2: Mean percentage of 'Delicious' fruit with insect damage sampled from fortnightly pyrethrum (500 ml/100 litres) or unsprayed treatments (n=500 fruit).

Treatments	% Fruit with:				
	Live LR[1] larvae	LR damage	Noctuid damage	Mealy bug	Woolly aphid
Unsprayed	1.0	13.6	0.4	3.4	0.8
Pyrethrum	0.2	1.6	0.8	0.0	0.2

[1] leafroller

TABLE 3: Percentage of the total fruit with insect damage, sampled from three apple varieties treated with airblast spray of *Bacillus thuringiensis* fortnightly from November to harvest.

	% Fruit with:					
	Live LR[1] larvae	LR damage	Noctuid damage	Mealy bug	Scale	Woolly aphid
'Cox's Orange Pippin'	0.2	1.5	0.6	3.4	0.2	0.7
'Granny Smith'	0.0	1.2	0.3	1.1	1.1	0.3
'Sturmer Pippin'	0.0	9.5	0.0	2.1	1.0	0.6

[1] leafroller

Hand spray trials offer the potential for a greater number of field treatments than airblast spraying, although differences in pesticide performance with air-blast spraying need to be considered. In this case, differences in deposition of *Bt* between airblast and hand spray trials could be present, although the result from the airblast treatment is in general agreement with the bioassay result. Spraying to "run-off" can reduce *Bt* efficacy when Silwet L-77 is added, at least in potted apple tree tests (Suckling unpublished). The reported half-life of *Bt* on cotton is 0.5-2 days (Beegle *et al.* 1981), which, if it is similar on apples, highlights the problem with current formulations of this insect pathogen available for use on apples. The development of an acceptable UV protection system could offer significant advantages, although the safety of adjuvants planned for use on food crops must be carefully evaluated.

Full season applications of *Bt* did not give good insect control. Pyrethrum was promising, giving 54 and 61% kill (corrected values) of larvae in the two hand-sprayed trials, and further evaluation is warranted. Use of pyrethrum might be limited to areas with pyrethroid-resistant *T. pyri* present, and is likely to be expensive. Carbaryl remains an option for leafroller control in the late season, although the measured efficacy was only 80% kill of established larvae.

In conclusion, no entirely effective alternatives for insecticidal control of leafrollers on export pipfruit were identified. Efficacy of *Bt* appeared slightly improved by the addition of Silwet L-77 in the hand sprayed and air blast trials, but the improvement was not large enough to prevent damage at harvest.

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