A NEW *BACILLUS THURINGIENSIS* PRODUCT FOR USE ON KIWIFRUIT

C.E. MCKENNA¹, P.S. STEVENS²
and D. STEVEN²

¹HortResearch, RD2, Te Puke

²HortResearch, Private Bag 92 169, Auckland

ABSTRACT

The efficacy and plant safety aspects of a new oil-based *Bacillus thuringiensis* formulation (Condor OF (BtCo)) were assessed for use against the lepidopteran pests of kiwifruit. Three rates of BtCo were compared with two standard Bt products (Dipel 2X (BtDi) and Delfin (BtDe)) and an untreated control for efficacy against leafrollers and *Stathmopoda* spp. All Bt products gave equivalent levels of control. No phytotoxicity was observed when BtCo was applied either alone or mixed with three fungicides commonly used on kiwifruit. Some fruit marking occurred when BtCo was applied in combination with mineral oil at twice the recommended rate.

Keywords: kiwifruit, leafrollers, phytotoxicity, compatibility

INTRODUCTION

Kiwifruit has two major pest groups, the armoured scale insects (Homoptera: Diaspididae) and the leafrollers (Lepidoptera: Tortricidae). Armoured scales cause little or no damage; their pest status is largely due to quarantine regulations. Leafroller and *Stathmopoda* spp. (Lepidoptera: Stathmopodidae) caterpillars, on the other hand, physically damage kiwifruit and on unsprayed vines the proportion of fruit with caterpillar chewings can exceed 50% (Steven 1991). Most feeding damage occurs during the 10 weeks immediately post-flowering and control is critical over this period (Stevens *et al.* 1995).

Leafroller control has traditionally been achieved by calendar applications of organophosphate or synthetic pyrethroid insecticides. Products derived from the bacterium *Bacillus thuringiensis* (Bt) were first used on kiwifruit in the mid 1980s. In seasons when flowering was prolonged, or if flowering on adjoining properties did not coincide, then Bt could be used to protect the new fruitlets from caterpillar feeding without harming honeybees still active on the crop. More recently there has been a significant increase in the use of Bt products on kiwifruit. Market demand for residue-free produce has led to 40% of the national kiwifruit crop being produced using a new pest control programme (Anon 1995). Under this programme growers rely solely on Bt products for caterpillar control from mid January to harvest. The small number of growers producing organic kiwifruit also depend on Bt for caterpillar control.

Currently there are four Bt products, all dry formulations, being used on kiwifruit. These products are effective but new products with improved efficacy are continually sought. The approaches used include selecting new bacterial strains with enhanced activity, such as conjugated and genetically modified strains, or changing the formulation to increase the stability and longevity of the applied product (Bryant 1994).

A field trial was carried out to compare the efficacy of a new oil-based Bt product (Condor OF (BtCo)) with two standard Bt products (Dipel 2X (BtDi) and Delfin (BtDe)). Two further trials examined the plant safety of BtCo and its compatibility with other chemicals commonly used on kiwifruit.

METHODS

Three trials were carried out in two kiwifruit blocks, one at each of the Te Puke and Kumeu Research Orchards. Both blocks comprised mature kiwifruit vines, cv. Hayward, trained on T-bar structures. Sprays were applied to runoff (approximately 6 litres per vine) using a handgun from a small-plot sprayer. All trials used a randomised block design with five replicates. Treatment plots comprised single vines for the efficacy trial and half vines for the phytotoxicity and compatibility trials.

Analyses of variance and Duncan's Multiple Range tests used angular transformed percentages of damaged fruit in order to detect statistical significance between treatments. Untransformed data are presented in the results.

Efficacy trial

Three rates of BtCo (100, 150 and 200 ml product/100 litres) were compared with BtDi and BtDe (50 g product/100 litres) and an unsprayed control. Treatments were applied without surfactants at Te Puke, but Citowett at 25 ml/100 litres was added to the BtDi treatment at Kumeu.

Treatments were applied three times. The first application was made at approximately 90% petal fall, followed by the remaining two at 12 to 15 day intervals (Te Puke 8.12.94, 20.12.94, 4.1.95; Kumeu 7.12.94, 21.12.94, 5.1.95). All sprays were applied in the morning under fast drying conditions.

Fifty fruit per plot were picked on 7.2.95 at Te Puke and 26.1.95 at Kumeu and scored for caterpillar damage. Another 50 fruit were similarly assessed at harvest on 27.4.95 at Te Puke and 2.5.95 at Kumeu. Two damage categories were used:

light = superficial damage less than a circle of 11.3 mm diameter ($<1 \text{ cm}^2$).
severe = superficial damage greater than a circle of 11.3 mm diameter ($>1 \text{ cm}^2$) and any penetrating damage.

Fruit with severe damage does not meet the export standard.

Phytotoxicity trial

Two rates of BtCo (150 and 400 ml product/100 litres) were applied in early January. Both rates of BtCo were applied twice, once under conditions which gave fast drying and once when drying was slow (Table 1). Each plot was sprayed only once.

At the end of February, 50 fruit per plot were picked and examined in the laboratory for any skin marking. The severity of damage was recorded using two categories:

light = light or dark speckles spread over $1\text{--}3 \text{ cm}^2$ and generally confined to the stamen end of the fruit.
severe = extensive speckling merging to blackening at the stamen end of fruit and/or on the side.

Fruit with severe damage does not meet the export standard.

Compatibility trial

BtCo was applied alone and in combination with benomyl (Benlate), vinclozolin (Ronilan FL), iprodione (Rovral FL), or mineral oil (Sunspray Ultra-Fine). The application dates were at times when each mix might normally be applied for disease (sclerotinia or botrytis) or armoured scale control (Table 2). All materials were applied at twice the full label rate and each plot was sprayed only once. In early February 50 fruit per plot were picked and assessed as in the phytotoxicity trial.

RESULTS AND DISCUSSION

Efficacy trial

At Te Puke the mean percentage of fruit with caterpillar damage in all Bt treatments was significantly lower ($P<0.05$) than in the untreated control at both assessment times (Table 3). At Kumeu the levels of caterpillar damage in all Bt treatments were also less than those recorded in the untreated control, but these differences were only statistically significant at the harvest assessment ($P<0.05$). Spraying Bt reduced the total amount of fruit damaged by caterpillars by at least 60% (Kumeu) or 80% (Te Puke) and severe damage by at least 67% (Kumeu) or 85% (Te Puke).

TABLE 1: Treatments, application dates and times for the phytotoxicity trial.

Treatment and rate (ml product/100 litres)	Drying rate	Application date and spraying time	
		Te Puke	Kumeu
BtCo 150	Fast	4-1-95 1100-1200	11-1-95 1320-1420
BtCo 400	Fast	4-1-95 1100-1200	11-1-95 1320-1420
BtCo 150	Slow	5-1-95 0600-0640	9-1-95 0700-0800
BtCo 400	Slow	5-1-95 0600-0640	9-1-95 0700-0800
Untreated control	-		

TABLE 2: Treatments, rates and application dates for the compatibility trial.

Treatment and rate (ml of product or g ai/100 litres)	Application date	
	Te Puke	Kumeu
BtCo 400 ml	5.12.94	6.12.94
BtCo 400 ml + benomyl 50 g	5.12.94	6.12/94
BtCo 400 ml	20.12.94	-
BtCo 400 ml + vinclozolin 100 g	20.12.94	-
BtCo 400 ml	-	9.1.95
BtCo 400 ml + iprodione 75 g	-	9.1.95
BtCo 400 ml	31.1.95	31.1.95
BtCo 400 ml + mineral oil 2%	31.1.95	31.1.95
untreated control	-	-

There was only one significant difference ($P < 0.05$) among the Bt treatments; at Kumeu there was less total damage in the BtDi treatment than in the BtDe treatment. The addition of Citowett to BtDi (Kumeu alone) may have contributed to this difference. The different rates of BtCo tested did not give statistically different results and all rates provided effective leafroller control equivalent to the standard products.

At both sites the numbers of fruit with caterpillar damage in the unsprayed control plots increased markedly between the interim and harvest assessments, while the counts of damaged fruit in the sprayed plots showed little or no increase (Table 3). Assessing the fruit mid-season and at harvest gave very similar relationships between the treatments.

Phytotoxicity trial

No phytotoxicity was observed on any fruit sprayed with BtCo, even though applications were made in early January when kiwifruit are most susceptible to speckling damage from sprays of mineral oil (McKenna and Steven 1993).

Compatibility trial

No damage to fruit was recorded when BtCo was applied either on its own or in combination with the fungicides benomyl, vinclozolin, or iprodione at twice the label rates. However, BtCo did aggravate damage caused by the mineral oil spray. At each site 4.4% of fruit sprayed with 2% mineral oil alone was damaged. Approximately twice as much fruit was damaged when 2% mineral oil mixed with BtCo was applied; 7.6% at Te Puke and 10% at Kumeu. A two-way analysis showed no significant differences between sites. The differences in fruit damage caused by BtCo alone, mineral oil alone, and mineral oil plus BtCo treatments were significant ($P < 0.05$). All damage recorded was light and no fruit had skin marking severe enough to cause exclusion from export.

TABLE 3: The mean percentages of severe and total caterpillar damaged fruit at the interim and harvest assessments.

Treatment and rate (g or ml product/ 100 litres)	Severe damage (%)		Total damage (%)	
	Interim	Harvest	Interim	Harvest
Te Puke				
BtCo 100 ml	0.0 b ¹	0.4 b	0.4 b	1.6 b
BtCo 150 ml	0.8 b	0.0 b	1.2 b	0.0 b
BtCo 200 ml	0.4 b	0.8 b	2.4 b	3.2 b
BtDi 50 g	0.4 b	1.2 b	2.0 b	2.4 b
BtDe 50 g	1.6 b	0.8 b	2.8 b	1.2 b
Untreated control	11.6 a	22.4 a	16.0 a	28.4 a
Kumeu				
BtCo 100 ml	2.0 ab	2.8 b	4.1 abc	4.4 bc
BtCo 150 ml	1.2 ab	2.0 b	3.2 abc	4.0 bc
BtCo 200 ml	0.8 ab	1.6 b	1.2 bc	2.8 bc
BtDi 50 g	0.0 b	0.4 b	0.0 c	1.2 c
BtDe 50 g	1.6 ab	4.0 b	4.4 ab	7.6 b
Untreated control	6.1 a	15.2 a	10.9 a	18.0 a

¹ at each site within a column means followed by the same letter are not significantly different at the 5% level.

During the early stages of fruit growth, increasing the concentration of an oil spray from 1% to 2% or from 2% to 4% caused a significant increase in fruit phytotoxicity (McKenna and Steven 1993). Mixing BtCo with 2% mineral oil increased the total concentration of oil applied by a maximum of 0.35%. This slight increase may be the reason for the increased levels of fruit damaged. Applications of BtCo alone did not cause damage because the oil fraction of BtCo is less than the threshold concentration at which crop damage occurs. Fruit damage is unlikely under conditions of commercial use, when chemicals are applied at the half the rates used in this trial.

CONCLUSIONS

The new oil-based Bt provided levels of control of the pest Lepidoptera of kiwifruit equivalent to those obtained with two standard Bt products. No phytotoxicity was observed when BtCo was applied either alone or in combination with three fungicides commonly used on kiwifruit. Minor fruit damage was recorded from sprays of high rates of BtCo plus mineral oil. Fruit damage is unlikely at the recommended rates of use.

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