CONTROL OF CODLING MOTH WITH COMMERCIAL PREPARATION OF GRANULOSIS VIRUS

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SUMMARY

A commercial formulation of the granulosis virus of codling moth (*Cydia pomonella*) was investigated to determine whether Nufilm-17 could provide sufficient UV-protection to enable control using two-weekly sprays on apple. Nufilm-17 at 50 g/100 litres increased the efficacy of the virus equivalent to that with the standard protectant, milk powder at 250 g/100 litres. Total larval mortality was 98-99%, including improved mortality of neonate larvae before fruit damage (up to 73%). The addition of *Bacillus thuringiensis* to the virus/Nufilm sprays provided good control of leafroller larvae.

Keywords: codling moth, granulosis virus, UV-protectant, biological control, leafroller

INTRODUCTION

Codling moth granulosis virus was first investigated for control of codling moth in New Zealand in Nelson in the 1970's (Wearing 1990). Using a locally-prepared virus spray, the mortality of codling moth was very high (up to 92% reduction in the overwintering population) and indicated the potential of the virus for control. Larval mortality was enhanced by the addition of a UV-protectant. Codling moth granulosis virus is now available in various commercial formulations and trials were conducted from 1990-92 with Madex-3 (Andermatt Biocontrol AG, Switzerland; Key Industries Ltd, Auckland). Standard spraying practices for this product include the use of milk powder as a UV-protectant (250 g/100 litres) and sugar as a feeding stimulant (500 g/100 litres) for the larvae, which must ingest the virus.

The susceptibility of granulosis virus to UV degradation has resulted in recommendations to spray weekly during peak larval hatching, particularly if this period is sunny. Although univoltine in the South Island, codling moth has a long period of larval hatching from November to February and this is accompanied by high sunlight hours. Weekly spraying over this period would be expensive. Nufilm-17 (Miller Chemical and Fertiliser Corporation, U.S.A.; Key Industries Ltd, Auckland) was evaluated as a UV-protectant for Madex-3 (CMGV) sprayed two-weekly during the period of larval hatching in Central Otago. Nufilm-17 is also used to improve the rainfastness of spray deposits. *Bacillus thuringiensis* (Bt) (Thuricide, Yates N.Z. Ltd) was included in the 1991-92 experiment and its effects on fruit damage by codling moth and leafroller were evaluated.

MATERIALS AND METHODS

Trial site

The trials were conducted at the DSIR Earnscliffe Nursery, Alexandra, in two blocks of mature apples of mixed cultivars planted 5.4 m x 5.4 m. Each cultivar constituted a replicate, with treatments (see below) allocated at random to individual trees of the cultivars Oregon Red (1 replicate in 1990, 1 replicate in 1991), Goldstrike (1, 1), Granny Smith (3, 1), Lord Lambourne (2, 2), Ballarat (2, 1), and Spartan (1, 1). The trees had been unsprayed for about 10 years prior to 1990 and had a known high resident codling moth population. There were sufficient untreated trees in the blocks in addition to the 1990-91 trial to maintain the high codling moth population into the 1991-92 season. Each treatment in 1991-92 included two trees which had been unsprayed in 1990-91.

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CMGV Application

The sprays were applied by hand lance from a tractor-drawn PTO sprayer operating at 1800-2000 kPa and 7-10 litres per tree (Table 1).

TABLE 1: Treatments - materials, rates (/100 litres), combinations and dates of application.

1990-91	CMGV (ml)	Sugar (g)	Milk powder (g)	Nufilm-17 (g)	
1.	15.7-17.1 ¹	50	100		
2.	15.7-17.1	50		50	
3.	15.7-17.1	50			
4.	Untreated Control				
Dates: 16.11., 29.11., 15.12., 28.12., 11.1., 25.1., 7.2., 21.2., 8.3 (late harvest cultivars only).					
1991-92	CMGV (ml)	Sugar (g)	Milk powder (g)	Nufilm-17 (g)	Thuricide (g)
1.	17	500	250		
2.	17	500		50	
3.	17	500		50	100
4.	Untreated Control				
Dates: 23.11., 4.12., 19.12., 2.1., 15.1., 30.1., 12.2., 29.2 (late harvest cultivars only)					

¹ 15.7 ml of product/100 litres up to 11.1., 17.1 ml/100 litres from 25.1.

The concentrations of sugar and milk powder were increased for the 1991-92 season in accordance with recommended rates. No other chemical treatments were applied to the trees.

Sampling methods

Two pheromone traps for codling moth were operated throughout the trials (15.10.90-30.4.91; 21.10.91 - 23.3.92), one in block 1 and the other in block 2. Moth catches were recorded weekly, pheromone caps renewed every 4 weeks, and bases every 6 weeks.

Larval sampling was undertaken to determine the contribution of the treatments to the mortality of codling moth in the period from egg hatch to completion of larval development in the fruit. Larval mortality was assessed both before fruit damage (pre-entry) and after (post-entry) using the methods of Wearing (1979). A minimum sample of 100 hatched eggs and the associated larval entries to fruits was obtained in late January from at least four trees per treatment to assess pre-entry mortality. Egg viability was also assessed at this time. Post-entry mortality and the number of surviving larvae per tree were determined by examining all windfall fruits and a known proportion of the crop at harvest. Larval entries to fruits can be interpreted to assess larval population density and mortality (Wearing 1979). Harvest dates were: Lord Lambourne 21.2.91, 17-18.2.92, Goldstrike 13.3.91, 17.3.92, Oregon Red 13.3.91, 17-19.3.92, Spartan 19.3.91, 19-20.3.92, Ballarat 12.4.91, 14.4.92, and Granny Smith 24.4.91, 14.4.92.

The level of fruit damage by leafroller larvae was also recorded on the harvest samples. Surface damage by leafrollers was categorised as being <5 mm or >5 mm diameter on individual fruits and the percentages of damaged fruits were calculated.

Mortality data were subject to angular transformation before analysis of variance and the application of Fisher's Least Significant Difference Test using Solo (Hintze 1988).

RESULTS

Pheromone trap catches

The catches of codling moth males in the two pheromone traps (1990-91 total 347, 1991-92 total 241) confirmed high populations of codling moth in both blocks. Flight was bimodal with peak catches in December and late January.

1990-91 trial

All three virus treatments significantly increased pre-entry larval mortality and protected the fruit when compared to the untreated control ($P < 0.001$) (Table 2).

TABLE 2: Larval mortalities of codling moth on apple trees sprayed with different treatments in 1990-91 and 1991-92. Means followed by the same letter in the same season are not significantly different ($P < 0.05$ or lower).

Year/ Treatment	Pre-entry		Mortality	
	% ¹	n	% ¹	n#
1990-91				
1. CMGV+Sugar+Milk	54.3 b	105	95.2 ab	2136
2. CMGV+Sugar+Nufilm	73.6 a	113	97.5 a	2664
3. CMGV+Sugar	47.3 b	101	93.5 b	2155
4. Untreated	18.6 c	101	31.8 c	3783
1991-92				
1. CMGV+Sugar+Milk	49.7 a	123	96.9 a	1024
2. CMGV+Sugar+Nufilm	59.7 a	102	97.3 a	576
3. CMGV+Sugar+Nufilm +Bt	49.1 a	126	97.2 a	1577
4. Untreated	18.9 b	118	28.2 b	2336

¹backtransformed percentages #infested fruits

The inclusion of Nufilm-17 (Treatment 2) increased pre-entry larval mortality compared to both Treatments 1 and 3 ($P < 0.001$). The slight increase in mortality when milk powder was added was not significant (Treatment 1 v. Treatment 3).

Post-entry mortalities exceeding 90% were achieved by the CMGV in most replicates compared to untreated mortalities which ranged from 17% to 53%. This variation was attributed in part to spray drift because virus-infected larvae were found in fruit from the untreated control trees. All CMGV treatments resulted in higher mortalities than that in the untreated control ($P < 0.001$). In addition, the use of Nufilm-17 increased larval mortality compared to Treatment 3 ($P < 0.05$).

The CMGV could not prevent significant fruit damage by such a dense codling moth population within a single season. All CMGV treatments halved the damage from 48% to 25-27%. However, the percentages of fruits with deep (live) entries were greatly reduced and resulted in few surviving larvae per tree (Table 3).

1991-92 trial

All three virus treatments again increased pre-entry larval mortality compared to that in the untreated control ($P < 0.001$). However, neither of the Nufilm treatments increased pre-entry mortality compared to that of Treatment 1, in which the concentration of milk powder had been raised to 250 g/100 litres (Table 2).

Post-entry mortalities exceeding 90% were achieved by the CMGV in most replicates compared to untreated mortalities of 12% to 42% ($P < 0.001$). There were no significant differences between the virus treatments, indicating that milk powder at 250 g/100 litres was as effective in UV protection as Nufilm-17 at 50 g/100 litres, with or without Bt. The Bt did not increase either pre- or post-entry mortality.

TABLE 3: Percentages of fruit with deep entries and the numbers of live larvae of codling moth surviving in different treatments in 1990-91 and 1991-92. Means followed by the same letter in the same season are not significantly different ($P < 0.01$).

Year/Treatment	Deep entries % ¹	n	Mean no. of live larvae/tree
1990-91			
1. CMGV+Sugar+Milk	1.5 a	6509	5.3 a
2. CMGV+Sugar+Nufilm	0.7 a	7009	5.6 a
3. CMGV+Sugar	2.2 a	6843	9.7 a
4. Untreated	35.9 b	6133	240.1 b
1991-92			
1. CMGV+Sugar+Milk	0.6 a	4711	3.9 a
2. CMGV+Sugar+Nufilm	0.2 a	3241	1.3 a
3. CMGV+Sugar+Nufilm +Bt	0.5 a	5914	6.3 a
4. Untreated	30.7 b	5263	221.1 b

¹backtransformed percentages

The percentages of fruit with deep (live) entries and the numbers of surviving larvae per tree in the CMGV treatments were even lower (Table 3) than in the previous season. This was achieved despite the similar high density of codling moth in the trees, as indicated by the population of larvae in the untreated control. The percentages of damaged fruits remained high in all treatments due to the dense codling moth population, although the CMGV treatments significantly reduced damage compared to that in the unsprayed trees (reduced from 38% to 17-27%). There were no surviving larvae found on four of the seven trees in Treatment 2, indicating a very high level of efficacy of the CMGV.

The addition of Bt to the CMGV substantially reduced leafroller damage (Table 4).

TABLE 4: Percentage fruit damaged by leafroller larvae on apple trees sprayed with different treatments in 1991-92. Means followed by the same letter are not significantly different ($P < 0.05$).

Treatment	<5 mm	>5 mm	Total damage
1. CMGV+Sugar+Milk	7.1 a ¹	11.0 b	18.0 ab
2. CMGV+Sugar+Nufilm	5.4 a	14.9 b	19.5 b
3. CMGV+Sugar+Nufilm+Bt	5.9 a	0.8 a	7.3 a
4. Untreated	9.2 a	18.7 b	28.5 b

¹backtransformed percentages

Leafroller damage greater than 5 mm was reduced from 11-19% to less than 1% by the Bt. Larvae collected at harvest were almost all greenheaded leafroller (*Planotortrix octo*) and no live leafroller larvae were found at harvest in the Bt treatment.

DISCUSSION

The pheromone trap data and egg/larval sampling confirmed a very high population of codling moth in this trial, and indicate the levels which can occur in Central Otago in the absence of control measures over 10 years. Using the estimates of the

larval population density, pre-entry mortality and egg viability, it was calculated that the population density was between 500 and 1000 eggs per tree, or 10 to 20 mated pairs per tree in 1990-91 and about 400 eggs/tree or eight mated pairs per tree in 1991-92. There was significant variation in population density between trees and replicates.

In these circumstances, the slow-acting CMGV could not protect the fruit from all damage. The level of crop damage was governed primarily by population density and secondarily by the virus. However, the level of crop damage in this short-term trial using single-tree replicates is no guide to the efficacy of the virus for codling moth control (Wearing 1990). The important results for population management are the numbers of larvae surviving to overwinter and emerge as adults in the following spring. The commercial formulation Madex-3 demonstrated greatly improved pre-entry mortality of codling moth (which provides fruit protection) compared to early trials with a local virus preparation (Wearing 1990). When this is combined with its very high post-entry mortality, Madex-3 applied fortnightly by hand is able to reduce larval survival by 98 to 99%, provided Nufilm-17 or milk powder (at 250 g/100 litres) is added for UV protection. Life tables for univoltine codling moth on mature 'Delicious' apple trees in Nelson indicate that this level of mortality would rapidly reduce codling moth populations to very low levels in the absence of immigration (Wearing 1979).

The recommended rate of use for Madex-3 is 100 ml/ha at 600 litres of spray per hectare which is equivalent to 17 ml/100 litres as used in these trials. However, the hand spraying of the trees used higher volumes of water (and hence virus) per hectare. Brain and Glen (1989) have shown that the time taken by granulosus virus to kill codling moth larvae is inversely related to virus concentration, and it is therefore important to ensure high concentration of the virus to protect the fruit from damage. Many apple growers in New Zealand spray at 2000-2500 litres/ha but it would be essential to reduce this to the recommended 600 litres/ha (or lower volumes) for Madex-3. Each application would then cost approximately \$130/ha for the virus.

As a result of trials in Canada and Europe, granulosus virus has been recommended for control of univoltine codling moth using just three to four sprays at two week (or 130 day degrees) intervals (e.g. Wildbolz 1988; Charmillot 1989; Jaques 1990; Helsen *et al.* 1992). This has been found to provide control equivalent to conventional chemical sprays. This result could be expected in New Zealand with low-volume high-concentration spraying against the levels of codling moth experienced in conventional orchards. The long emergence period of codling moth in New Zealand may require more spray applications or the use of more frequent sprays of lower dosage (Helsen *et al.* 1992). However, the current results indicate that UV protection would assist in reducing the number of sprays needed. In organic orchards with established high codling moth populations, the slow action of the virus would not protect the fruit from damage in a single season. The trial results indicate that CMGV is an outstanding candidate for long-term management of codling moth in New Zealand orchards using biological methods.

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