GRANULOSIS VIRUS CONTROL OF CODLING MOTH IN NELSON

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SUMMARY

Field trials on the control of codling moth with granulosis virus were conducted on 'Delicious' apples in Nelson between 1969 and 1975. The virus gave limited but statistically significant protection of the fruit from damage but resulted in high mortality of larvae after fruit entry, particularly when assisted by a UV protectant. Population studies in 1974-75 measured a 92% reduction in overwintering cocoons after virus control compared to an unsprayed population. Life table analysis established that virus applications should routinely reduce univoltine codling moth populations from year to year and, in the absence of immigration, control such populations at the levels tolerable commercially.

INTRODUCTION

Codling moth, *Cydia pomonella*, is a key pest of pipfruit and, in the absence of insecticides, causes 30 to 95% of fruit to be damaged in New Zealand depending on locality. Control of this pest is critical to the development of 'organic' pipfruit production, in which synthetic chemical pesticides are not permitted. While some management techniques, such as removal of unsprayed trees in the environs of the orchard (Wearing 1979), make essential contributions to limiting codling moth infestation, this pest requires one or more specific controls to be administered in the orchard to produce fruit sufficiently free of damage for both the domestic and export markets.

Mating disruption with the sex pheromone (J.R. Clearwater, pers. comm.) and sprays of granulosis virus (e.g. Jacques *et al* 1981) are promising specific non-chemical methods for control of codling moth. This paper describes the results of field trials with the granulosis virus (CMGV) at DSIR Appleby Research Orchard, Nelson, from 1969 to 1975.

MATERIALS AND METHODS

CMGV production and preparation

CMGV was produced by infecting codling moth larvae reared on artificial diet (Brinton *et al* 1969). CMGV suspension (2×10^9 capsules/litre) was sprayed onto the surface of the diet when most of the codling moth larvae had grown to the third instar. At fifth instar, they were removed from the diet and stored at -90°C . In preparation for field application of the virus, the larvae were homogenized and the suspension was filtered through muslin, sedimented at 10000 g, and resuspended in distilled water. The capsules were then purified by sucrose gradient centrifugation, washed, and resuspended at 4 mg/ml in distilled water.

CMGV application

In 1969-70 the CMGV was applied by hand to four large apple trees cv. 'Delicious' using a knapsack sprayer (about 14 litres/tree to run-off) on 19.12, 31.12, 15.1, 30.1, 13.2, and 27.2.70. The spray in this first trial was a crude preparation of unknown concentration. It was subsequently estimated, on the basis of larval equivalents, to contain about 2×10^8 CMGV capsules/litre.

A Turbomist concentrate air-blast sprayer was used to apply CMGV to a block of 38 mature trees cv. 'Delicious' in 1970-71 (25.11., 9.12, 18.12, 23.12, 30.12, 8.1, 14.1, 20.1, 3.2, timed for larval hatching). Each spray contained 1.7×10^9 capsules/litre (x 3 conc.) and applied 4.9×10^{12} capsules/ha.

In 1974-75 the CMGV was applied dilute by Konig air-blast sprayer to a block of 50 trees cv. 'Delicious' (3.12, 17.12, 26.12, 14.1, 29.1, 11.2). Each spray contained 1.7×10^9 capsules/litre and applied 5.4×10^{12} capsules/ha. A proprietary UV screen (Trade name IMC) was added to the sprays at a concentration of 50 g/100 litres.

The only other pesticides applied to the trees were colloidal sulphur (Colsul) and dodine (Melprex 40) for disease control. In each year, a neighbouring block of 'Delicious' trees was sprayed only with these fungicides as a 'control' treatment. The IMC UV screen was also applied (50 g/100 litres) to the 'control' block in 1974-75.

Sampling methods

The objective of sampling was to determine the contribution of CMGV to the mortality of codling moth in the period from hatching of eggs through to completion of larval development. The following mortalities were assessed: egg infertility and inviability, pre-entry mortality (larval mortality before fruit entry), and post-entry mortality (i) in the first and second instars, (ii) while entering the core, and (iii) after reaching the seeds. The rationale for this and the methods used are described in Wearing (1979). A minimum sample of 100 hatched eggs from at least four trees per treatment was required for assessing egg and pre-entry mortalities. Post-entry mortalities were determined from examination of the entire crop and windfalls from four (10 in 'control'), 12, and six trees in each treatment respectively in 1970, 1971 and 1975.

Percentage mortalities were subject to arc-sin transformation before analysis of variance, using trees as replicates.

RESULTS

1969-70 Trial

The results are summarised in Table 1.

In this first trial the CMGV was slow-acting and failed to protect the fruit from damage, with no significant increase in egg mortality and pre-entry mortality. Larval mortality was significantly increased by the CMGV in first and second instar larvae both immediately after fruit entry ($P < 0.001$) and at the core ($P < 0.001$). Mortality was very consistent between trees (e.g. total post-entry mortality: 82.8%, 76.9%, 77.0%, 76.2% before transformation). Only 12 larvae completed development and left the fruit from each 100 eggs laid on the trees sprayed with CMGV compared to 50 survivors in the 'control' treatment. A search for cocoons in the winter of 1970 revealed some larvae infected and/or dead with the virus.

TABLE 1: Egg and larval mortalities of codling moth on apple trees cv. 'Delicious' sprayed with CMGV compared to those in a 'control' treatment in 1969-70.

	CMGV by hand		Control	
	% ($\pm$ SE)*	n	% ($\pm$ SE)*	n
Egg mortality				
Infertility	1.4 ($\pm$ 1.4)	110	1.3 ($\pm$ 1.0)	132
Inviability	8.4 ($\pm$ 7.2)	108	5.4 ($\pm$ 2.1)	130
Larval mortality				
Pre-entry	34.0 ($\pm$ 10.3)	100	21.5 ($\pm$ 3.5)	123
Post-entry 1-2nd instar	69.5 ($\pm$ 1.3)	589	27.3 ($\pm$ 1.4)	2561
At core	22.7 ($\pm$ 2.8)	178	2.5 ($\pm$ 0.4)	1843
At seeds	8.0 ($\pm$ 3.2)	137	1.6 ($\pm$ 0.4)	1798
Total	78.3 ($\pm$ 2.5)	589	30.2 ($\pm$ 1.3)	2561

*Detransformed mean and standard error.

1970-71 Trial

The results are summarised in Table 2.

The virus provided significant protection of the fruit in 1970-71 by increasing pre-entry mortality ($P < 0.05$). In addition, the mortality of larvae reaching the seeds (third instar and older) was increased by the virus, compared to both that in the 'control' treatment ($P < 0.001$) and that in the CMGV treatment of the previous year ($P < 0.001$). These two improvements resulted in a significant increase in overall larval mortality compared to the previous trial ($P = 0.05$). While the higher volume of the hand spraying (first trial) would be expected to provide improved efficacy compared to concentrate machine spraying, this was apparently more than offset by the greater number and improved timing of applications in 1970-71.

There was evidence in the CMGV treatment that larvae died in their eggs after perforating the chorion during hatching (recorded as inviability). When the variable number of eggs from different trees were removed from the analysis by bulking the samples, the inviability of eggs exposed to CMGV was higher than that of the 'control' treatment ($P < 0.01$). Only 10 larvae completed development and left the fruit from each 100 eggs laid on the trees sprayed with CMGV compared to 65 survivors in the 'control' treatment.

TABLE 2: Egg and larval mortalities of codling moth on apple trees cv. 'Delicious' sprayed with CMGV compared to those in a 'control' treatment in 1970-71.

	CMGV by Turbomist		Control	
	% ($\pm$ SE)*	n	% ($\pm$ SE)*	n
Egg mortality				
Infertility	0.0 ($\pm$ 0.0)	116	2.8 ($\pm$ 1.1)	114
Inviability	9.7 ($\pm$ 4.2)	116	2.4 ($\pm$ 1.4)	111
Larval mortality				
Pre-entry	32.2 ($\pm$ 6.6)	103	12.7 ($\pm$ 3.3)	109
Post-entry 1-2nd instar	65.6 ($\pm$ 4.6)	1465	21.7 ($\pm$ 2.9)	1241
At core	24.4 ($\pm$ 3.0)	470	1.7 ($\pm$ 1.1)	990
At seeds	33.7 ($\pm$ 3.9)	340	2.3 ($\pm$ 1.7)	972
Total	83.1 ($\pm$ 3.1)	1465	24.9 ($\pm$ 2.3)	1241

*Detransformed mean and standard error.

1974-75 Trial.

The results are summarised in Table 3.

Only six sprays of CMGV were applied, as in the first trial. Nevertheless, the mortality of codling moth larvae in 1974-75 reached the highest levels of the three trials; pre-entry mortality was maintained at the significant ($P < 0.05$) level of 1970-71 and post-entry mortality was increased significantly at all three stages ($P < 0.05$ to $P < 0.001$). Total post-entry mortality was almost 95%. Since the number of applications and total CMGV applied was less in 1974-75 than in 1970-71, the greater efficacy can be attributed to the inclusion of the UV screen (IMC). Only three larvae completed development and left the fruit from each 100 eggs laid on the trees sprayed with CMGV + IMC compared to 48 survivors in the IMC 'control' treatment.

The inviability of eggs sprayed only with the UV screen was 17% (Table 3). These data and those from studies of codling moth over 7 years at this location (Wearing 1979) indicate that the UV screen increased egg inviability in both the 'control' and CMGV treatments.

The CMGV-sprayed and 'control' blocks were adjacent to each other in 1974-75. Some spray drift occurred between the blocks as shown by the presence of virus-infected larvae dying within the fruit of the 'control' treatment. This may explain the higher level of mortality at this stage in the 'control' treatment compared to that of the previous two trials.

TABLE 3: Egg and larval mortalities of codling moth on apple trees cv. 'Delicious' sprayed with CMGV compared to those in a 'control' treatment in 1974-75.

	CMGV + IMC by König		Control (IMC only)	
	% ($\pm$ SE)*	n	% ($\pm$ SE)*	n
Egg mortality				
Infertility	1.7 ($\pm$ 1.7)	206	0.6 ($\pm$ 0.6)	182
Inviability	18.3 ($\pm$ 2.1)	202	16.8 ($\pm$ 3.9)	181
Larval mortality				
Pre-entry	36.8 ($\pm$ 5.2)	165	14.9 ($\pm$ 3.3)	150
Post-entry 1-2nd instar	75.1 ($\pm$ 3.5)	2115	29.4 ($\pm$ 2.2)	1473
At core	41.0 ($\pm$ 3.1)	536	6.6 ($\pm$ 1.1)	1046
At seeds	61.9 ($\pm$ 3.2)	318	10.3 ($\pm$ 1.9)	977
Total	94.5 ($\pm$ 1.4)	2115	40.8 ($\pm$ 2.9)	1473

*Detransformed mean and standard error.

Life table studies on 'Delicious' trees in Nelson, which included this CMGV Trial (Wearing 1979), have shown that a mortality of 50-55% can be expected between larvae leaving the fruit and completing their overwintering cocoons on the trees. The density of larvae leaving the fruit after the CMGV + IMC treatment was estimated, using life table methods, to be 16 larvae per tree. A thorough search of five trees in this treatment on 28-29 April 1975 revealed a total of only ten cocooned larvae, of which at least two were infected with the virus. Even allowing for some inefficiency in the searching, the population was much lower than projected, suggesting that the virus may continue to affect larval survival long after fruit feeding has finished.

DISCUSSION

These trials were deliberately established on trees with a high population of codling moth in order to measure virus efficacy in terms of insect mortality. At such densities and within one season, the slow-acting CMGV could not protect the fruit from all damage, the levels of which were more dependent on the initial population than the efficacy of the CMGV treatment. The percentages of fruit damaged in the three trials were 10, 9 and 41 but these results provide no guide to CMGV efficacy. As part of either an integrated pest management or 'organic' programme, CMGV must be evaluated in terms of its ability to provide long-term control of codling moth. Life tables provide one means of assessing this which would need to be confirmed in long-term field trials.

Life table analysis of codling moth on 'Delicious' trees in Nelson, which incorporated these trials, has shown clearly that CMGV is able to reduce a univoltine codling moth population dramatically from year to year provided measures are taken to minimise immigration of adults from unsprayed fruit trees in the orchard environs and from contaminated fruit boxes or packaging (Wearing 1979). For instance in 1974-75, the resident population in the 'control' treatment increased 4-fold whereas that in the virus treatment reduced by 80% (Wearing 1979). The combined effect was an overwintering population in the CMGV-treated trees 92% lower than that in the 'control' trees. This result compares favourably with those obtained in similar trials overseas (e.g. Huber and Dickler 1975). However, the virus in these New Zealand trials failed to protect the fruit from damage at the high levels of efficacy reported by Huber and Dickler (1975, 1976).

A wide range of rates and frequencies of spraying have been used in evaluation of CMGV overseas. The rates used in the 1970 and 1974 trials were similar to those reported by Falcon *et al* (1970) to be the most effective of the various regimes tested, but were lower than those used in some recent trials (e.g. Glen and Payne 1984). Work has begun (J.T.S. Walker, pers. comm.) to determine the appropriate rates of CMGV for codling moth control in New Zealand using well timed sprays of a standardised commercial product. In view of the results reported here, it would be essential to include a UV screen as a routine additive. Skim milk is often used overseas (e.g. Glen and Payne

1984; Charmillot 1989) but would need to be evaluated for effects on fruit finish. The presence of the milk may enhance the growth of other pests (Glen *et al* 1984).

The larval mortality achieved with CMGV was consistently higher than with ryania (Wearing 1979), and while the virus provided only limited direct protection of the fruit from damage, the trial results and life table analyses show that it should be able to maintain codling moth populations at the extremely low levels required commercially. This confirms the positive potential of CMGV in New Zealand organic apple production, at least in areas with a univoltine codling moth population. Records of natural enemies of the apple pest complex during these trials showed no measurable detrimental effects of CMGV on beneficial species.

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