MATING DISRUPTION FOR MANAGEMENT OF ORGANOPHOSPHATE RESISTANCE IN THE GREENHEADED LEAFROLLER *PLANOTORTRIX OCTO*

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ABSTRACT

Mating disruption was evaluated with organophosphate (OP) sprays for the control of an OP-resistant strain of the greenheaded leafroller, *Planotortrix octo,* at Dumbarton, Central Otago. Three ha plots of apples, which received the grower's 'standard' spray programme, were compared with equivalent 3 ha areas to which pheromone treatment was added. The efficacy of disruption was determined from pheromone trap catches, mating of tethered virgin female moths, and levels of leafroller damage at harvest. Two applications of pheromone were made each season (late November, end of January). The pheromone shut down trap catches, prevented mating of tethered females, and reduced leafroller damage to the crop. Mating disruption of *P. octo* offers a tool for improved control at Dumbarton and for management of the OP-resistance.

Keywords: mating disruption, resistance management, organophosphate, leafroller, pheromone

INTRODUCTION

Leafrollers are the most important pests of apples in New Zealand and the presence of damage at harvest can exclude a grower from the export market. Extensive research on apple orchards in Central Otago from 1990 to 1994 has shown that the native greenheaded leafroller, *Planotortrix octo* (OCTO), is the most important species damaging the crop, especially in the Dumbarton district (Wearing 1995a). In this area, the growers have experienced a problem with leafroller control over many years which is now known to be due to the presence of organophosphate (OP) resistance in the OCTO population (Wearing 1995b). Mating disruption was used successfully by Suckling *et al.* (1990) as part of a programme for the management of OP-resistance in lightbrown apple moth (LBAM), *Epiphyas postvittana*, in Nelson. This technique was developed and tested for the same purpose at Dumbarton against OCTO from 1991 to 1995. Mating disruption was applied to OP-sprayed orchards where the resistant OCTO were present, in an attempt to prevent mating between moths which had survived the spray programme. This should prevent or delay further resistance development and/or reduce the population density of resistant OCTO, thereby reducing crop damage.

The efficacy of disruption in a pheromone-treated area can be measured by various methods, including the level of mating by tethered virgin female moths (Suckling and Shaw 1992), numbers of males caught in pheromone traps (*loc.cit.*) and the level of crop damage. Replicated small scale trials of OCTO disruption in apricots and apples at Dumbarton in 1991-92 prevented pheromone trap catches and eliminated mating by tethered female moths (Wearing 1992). These results indicated the high potential of disruption for resistance management of OCTO. Pheromone disruption must be used on large areas (minimum 3 ha) for efficacy and this is difficult to replicate within orchards. This paper describes large scale replicated trials of OCTO disruption in the 1992-93 and 1993-94 seasons at Dumbarton, with emphasis on its impact on crop damage.

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METHODS

Trial design

The trial was replicated each season on three commercial orchards (four orchards were used over the two seasons) where problems with control of leafrollers were being experienced. Within each orchard, a 3 ha plot of apples, which received the grower's 'standard' spray programme, was compared with an equivalent 3 ha area to which pheromone treatment was added. Paired plots were 100 m or more apart to reduce the risk of pheromone drifting into the standard area and were chosen with matching apple cultivars wherever possible. However, the plots in one orchard were immediately adjacent, and blocks of some cultivars, which the growers wished to treat with pheromone, were too small to be divided between the two treatments. The results from the trials prompted one grower to treat his entire orchard with pheromone in the second season.

Pheromone dispensers

The pheromone dispensers (Shin-Etsu Chemical Co. Ltd, Japan) contained a blend of 25% Z5- and 75% Z8-14:Acetate, which has been determined by Dr J.R. Clearwater (HortResearch, Auckland) as the most promising "common" blend for the disruption of the total native leafroller complex. This is the same blend as used in the successful small scale trials at Dumbarton in 1991-92. In 1992-93 two applications of 1000 dispensers/ha were made to the orchard trees on 19-21 November 1992 and 29-30 January 1993; in 1993-94 the same density of dispensers was applied on 23-28 November 1993 but only 500 dispensers/ha on 1-11 February 1994. Dispensers were also placed in the shelter trees alongside the pheromone plots. The timing of these applications preceded the flight periods of males of each of the two generations of OCTO (Wearing 1995a). Two of the dispensers from each application in each plot were suspended vertically in the trees to enable weekly measurement of the pheromone meniscus within the dispenser capillary. This permitted the calculation of pheromone release rates using the method of Suckling (pers. comm.).

Pheromone trapping

Four traps for each of OCTO and LBAM were monitored weekly around the margins of each orchard, usually in the shelter. Similar traps had been operated at these orchards for the previous 2 to 3 years and the same trap locations, lures and procedures were used (Wearing 1995a). In addition, six OCTO traps were operated within each of the standard and standard+pheromone plots to monitor moth activity. Reduction or elimination of trap catches provided one measure of the efficacy of disruption by the pheromone when compared to the catches in the standard plot.

Tethered females

A total of >400 virgin female OCTO were tethered individually in Pherocon 1CP 'traps' and placed (half each) in either the standard+pheromone or standard plots for 3-8 days during December 1992, and March/April 1993. Recovered moths were dissected to determine the presence of a spermatophore(s) in the bursa. The level of mating provided a critical measure of the efficacy of disruption when compared to mating in the standard plots.

Harvest samples

Harvest samples of fruit were examined in the field for leafroller damage using 100 fruits per tree on at least 15 trees per cultivar per treatment on each orchard. Wherever possible, representative cultivars were selected for the early-, mid-, and late-season harvest periods, especially to include short-stemmed and late cultivars more prone to leafroller damage. Because the growers were also participating in pheromone trapping research for the second or third season, the same blocks of the same cultivars were sampled as in previous years to enable comparison between seasons. Sample bins of apples from the standard and pheromone plots were also labelled and sent to the packhouse where damaged fruit was recovered for assessment. Fruit size data from ENZA New Zealand enabled calculation of the number of fruits per bin and hence the percentage damage by pests recorded from the bins. The larger packhouse samples permitted the detection of much lower levels of leafroller damage than could be recorded in the field samples. For example in 1992-93, the packhouse

damage estimates were based on total samples of 541,000 apples from the standard plots and 775,000 apples from the pheromone plots. Only packhouse samples were obtained from most cultivars in 1993-94.

Spray programmes

Growers applied their usual insecticide programme to both the standard and standard+pheromone plots. The numbers of post-bloom OP sprays in 1992-93 varied from 4 to 8 on early-, 5 to 9 on mid-, and 6-11 on late-season cultivars. In 1993-94 the grower who applied pheromone to the whole orchard reduced the frequency of spraying and the range was 2 to 4 on early-, 3 to 5 on mid-, and 4 to 7 on late-harvested cultivars.

Statistical analysis

The percentage damage data were angular transformed before analysis of variance using Solo (Hintze 1989) to compare leafroller damage in the paired standard and pheromone plots (treating orchards and seasons as replicates) and to compare damage with that of previous seasons (treating trees or bins as replicates). The large disruption plots and experimental design limited the validity of some of these comparisons but this was compensated for by the uniformity of treatment effects.

RESULTS AND DISCUSSION

Following the first application of pheromone each year, the mean release rate rose to 20-25 mg/ha.h in December/January and declined to just below 10 mg/ha.h by the time of the second application. This brought release rates to as high as 35 mg/ha.h in February 1993 with rates exceeding 10 mg/ha.h into May; in 1994, the reduction to 500 dispensers/ha in the second application gave a more even release, with a February peak of 25 dropping below 10 mg/ha.h by the end of April.

Application of the dispensers prevented any catches of OCTO in the six pheromone traps within each of the pheromone plots in both seasons. In contrast, first (Dec/Jan) and second (Feb onwards) generation OCTO were trapped in all the standard plots and, in plots well isolated from pheromone treatment, the numbers caught were similar to those in the margin traps, reaching respectively >1.5 and 3 moths/trap/day in April 1993 and 1994.

None of the tethered females placed in the pheromone plots were mated. The percentages of mated females in the standard plots increased significantly from the first (mean = 35.1%, range 10-60%) to the second generation ($P<0.05$) when 74.3% were mated (range 40-84%). Greater mating in the second generation probably reflected the higher density of males available at that time. The total absence of mating in the pheromone plots is significant given the high mating percentages in the standard plots.

The measurement of disruption efficacy with pheromone traps and tethered females was specific to OCTO. The ultimate test of the efficacy of disruption is the level of fruit damage by the target insect. In this trial, the pheromone disruption was added to the standard spray programme which is directed at the whole pest complex, including three species of leafroller - OCTO, LBAM and the brownheaded leafroller (BHLR), *Ctenopseustis obliquana*. The mating disruption targeted OCTO and used a pheromone blend which could also disrupt mating of BHLR, but could not disrupt LBAM. There is no way of distinguishing fruit damage by different species of leafrollers. The harvest samples from the pheromone and standard plots were, therefore, as much a test of whether OCTO was indeed the source of damage at Dumbarton as they were a test of the efficacy of disruption.

The results, which are presented for three of the four orchards, gave unequivocal evidence of the benefits of disruption and confirmed that OCTO was the major source of crop damage (Table 1). Mating disruption was used on Orchard 1 for the first time in 1993-94 and harvest damage to Cox and Splendour was reduced compared to that in the standard treatment. Extreme problems were being experienced in a block of Sturmer up to 1992-93 and the inclusion of these trees in the disruption treatment in 1993-94 greatly reduced damage compared to earlier years ($P<0.01$). A similar result has been reported by the grower in 1994-95. Mating disruption consistently reduced

TABLE 1: Percentage of harvested apples damaged by leafrollers in three of four Dumbarton orchards in which mating disruption of OCTO was added to and compared with the standard spray programme in 1992-93 and/or 1993-94 (in bold). Field samples were based on a minimum sample of 1500 apples and packhouse samples on a minimum of 50,000 apples.

Orchard & Cultivar	Year	Standard		Standard +Pheromone	
		Field	Packhouse	Field	Packhouse
1. Cox	1990-91	0.47	0.093		
	1991-92	0.99	0.273		
	1992-93	0.77	0.153		
	1993-94	**0.85**		**0.12***	
Sturmer	1990-91	3.06	0.136		
	1991-92	4.22	3.191		
	1992-93	5.96	1.044		
	1993-94	**-**		**0.85****	
Splendour	**1993-94**	**2.39**		**0.73****	
2. Cox	1990-91	2.12	0.812		
	1991-92	1.06	1.279		
	1992-93	**1.43**	**1.006**	**0.33***	**0.231***
	1993-94		**0.489**		**0.205***
Red Delicious	1990-91	1.79	0.322		
	1991-92	1.86	0.257		
	1992-93	**0.32**	**0.200**	**0***	**0***
Braeburn	**1993-94**		**0.340**		**0***
Sturmer	1990-91	2.74	1.313		
	1991-92	1.92	0.845		
	1992-93	**-**	**0.261**	**0***	**0***
Granny Smith	**1992-93**	**1.05**	**0.210**	**0***	**0***
	1993-94		**0.204**		**0***
3. Cox	1991-92	0.66	0.609		
	1992-93	**-**	**-**	**0.11****	**0.041****
	1993-94		**-**		**0**
Golden Delicious	**1992-93**	**0†**	**0†**		
	1993-94		**-**		**0**
Red Delicious	1991-92	2.11	0.100		
	1992-93	0†	0†		
	1993-94		**-**		**0**
Sturmer	1991-92	0.72	0.873		
	1992-93	**-**	**-**	**0****	**0****
	1993-94		**-**		**0**

†Standard and standard+pheromone plots were adjacent with strong evidence of pheromone drift into the standard plot.
* Significantly less than in the standard treatment ($P<0.05$); ** Significantly less than in the previous season ($P<0.01$); - within season comparison not available, see text.

leafroller damage in all cultivars of both seasons at Orchard 2. No damage could be detected in the pheromone-treated trees of Red Delicious, Braeburn, Sturmer and Granny Smith. Damage to Cox was reduced by the pheromone to <0.4% in field and packhouse samples. Orchard 3 was too small to allow matching cultivars with and

without pheromone. The grower was experiencing increasing leafroller damage up to 1991-92 and this was "eliminated" in Sturmer and reduced in Cox when pheromone was applied in 1992-93. A transect of tethered female moths across the adjacent standard Golden and Red Delicious trees to the north resulted in only 10% mating, and indicated pheromone drift due to the prevailing southerly winds. Catches of OCTO in internal and margin pheromone traps were also reduced. No leafroller damage was detected in these cultivars. The efficacy of disruption was confirmed in 1993-94 when it was used on the entire orchard in combination with a seasonal spray programme which had been reduced from 8-11 applications to only 2-4. No damage was detected in any of the four cultivars and similar results have been reported for 1994-95. Mating disruption also reduced crop damage on Orchard 4 (not presented) which was used only in 1992-93 (standard and standard+pheromone treatments were compared).

Leafroller damage was monitored from 1990 to 1994 at another Dumbarton orchard not using mating disruption, where the grower had increased spraying in an effort to improve control. Packhouse damage (%) records for Cox were 0.098, 0.258, 0.085, and 0.160, and for Sturmer were 0.501, 0.452, 0.033, and 0.174 over the four seasons. This orchard provided a 'control' showing that there was no clear trend in leafroller damage over the 4 years which could account for the observed treatment effects.

The harvest results demonstrated clearly the benefit of mating disruption for control of OCTO at Dumbarton and confirmed its potential for management of OP-resistance. Crop damage within the pheromone plots was rare and occurred in three main situations: (i) on the edge of the pheromone-treated area (including the tops of tall trees), where the pheromone plume would be breaking up and where immigrant mated females might oviposit on the trees, (ii) where trees were missing within the blocks, creating gaps in the pheromone plume around isolated trees, and (iii) where blocks of small young trees were present. The results indicate that mating disruption will function most effectively in large blocks of mature trees with a uniform dense leaf canopy (see Karg *et al.* 1994). Three Dumbarton growers have again used mating disruption plus OP sprays on 3 ha blocks in 1994-95 but have deployed only 500 dispensers/ha in both the first and second applications. Good results have been reported by the growers.

The combination of mating disruption and reduced insecticide applications offers an effective resistance management programme for OCTO at Dumbarton. Mating disruption of OCTO was tested alone (ie. without OP sprays) on a neighbouring orchard in 1993-94 and this eliminated both pheromone trap catches and the mating of tethered females. However, many mated females were trapped in molasses bait traps, which showed that high levels of immigration were occurring from host plants in the orchard environs, and this resulted in crop damage. At Dumbarton, mating disruption appears to have reduced or eliminated the mating of resistant OCTO selected within the orchard, while the insecticide sprays remain toxic to susceptible immigrant mated females. This integrated programme may enable Dumbarton growers to reduce their spray applications to 3-5 as in other Otago districts (Wearing 1995a) and the grower from Orchard 3 has already achieved this. However, the principal economic benefit of combining mating disruption with spraying is the restoration of fruit quality consistent with the demands of export markets.

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