**INSECTICIDE RESISTANCE IN THE LIGHTBROWN
APPLE MOTH:
A CASE FOR RESISTANCE MANAGEMENT**

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SUMMARY

The status of azinphos-methyl resistance in the lightbrown apple moth (*Epiphyas postvittana*) present at Mariri and Moutere Bluffs, Nelson, is described. The history of the problem and research since 1981 indicates little change in the distribution or level of resistance for 10 years. Close definition and monitoring of the restricted distribution of the resistant insects was achieved through the collection of pheromone-attracted males, which were then topically dosed with azinphos-methyl. Field trials and cross-resistance studies evaluated the response of the resistant strain to various chemicals. A chlorpyrifos spray programme is currently giving excellent control. A resistance management programme in progress is outlined.

INTRODUCTION

Insecticide resistance is one of the most difficult problems facing chemical companies, growers, and scientists around the world. The number of insect species exhibiting resistance to agricultural chemicals continues to rise. In most cases it has not been possible to delay or halt the spread of resistance, because by the time resistance was detected in a population it was usually too late for it to regress significantly, even if selection pressure was removed. Early detection of resistance in pest populations might permit manipulation of biological and operational factors influencing resistance development.

In this paper we review the current status of insecticide resistance in the lightbrown apple moth (LBAM), one of the major pests of fruit crops in New Zealand. Azinphos-methyl was registered for control of leafrollers in apples in 1959. Tests on LBAM at that time resulted in reports of variation in the dosage-mortality responses of different populations to azinphos-methyl, and even reports of "resistance" in New Zealand (Smith 1961) and Australia (Georghiou 1981). Despite these reports, which were not supported by comprehensive data, azinphos-methyl has provided effective commercial control of LBAM and other leafrollers in fruit crops throughout the country.

Leafroller control problems with azinphos-methyl were first reported by orchardists at the Moutere Bluffs area of Nelson in the early 1970's. Although some of the difficulties may have been attributable to inadequate spray coverage, limited testing was carried out (see Fig. 1) and recommendations were made for locaused sprays or aminocarb (Matacil), which provided effective short-term control. Control problems at Moutere Bluffs have recurred. Growers and advisors from the Mariri area have reported that they too have experienced control difficulties, for up to 10 years. At both localities these difficulties amounted to fruit damage by leafrollers of the order of 1% or less with little change from year to year.

Proc. 37th N.Z. Weed and Pest Control Conf.

METHODS

Several methods were used to collect leafrollers for resistance testing. In 1981 light traps were used to collect adult moths for establishing laboratory colonies of LBAM, the dominant leafroller species in the Nelson area. Subsequently (1982) larvae were collected to initiate colonies for testing. In later surveys (1983, 1984) LBAM pheromone lures were used around dusk during peak flight periods to attract males in the field; these were netted in large numbers for direct dosing experiments in the laboratory the next day. Several different dosage-mortality methods using various insect stages were developed to assess resistance and cross resistance (Suckling 1983; Suckling *et al* 1984).

Extensive replicated field trials of leafroller control were conducted in the 1982-1983 and 1983-1984 season, at the Mariri orchards and at DSIR's nearby Appleby Research Orchard. The trials evaluated a wide range of chemicals alone and in combination, in the organophosphorus, carbamate and pyrethroid groups, as well as triflumuron (Alsystin) and *Bacillus thuringiensis*.

The long history of the LBAM control problem at Mariri, its restriction to a few orchards and the consistent low level of pest damage (and resistance) all contributed to the decision to attempt resistance management, rather than to immediately switch to alternative chemicals. The extreme importance of organophosphates for insect control in horticulture, and the role of organophosphate-resistant predators in integrated mite control also influenced this decision. However, in adopting the policy of attempting resistance management, procedures were necessary for very close monitoring of resistance level and spread, and contingency plans were made to allow a rapid response to any increase in either of these.

RESULTS

Resistance of LBAM from Mariri to azinphos-methyl was demonstrated by comparison with a Canterbury strain of LBAM (Suckling *et al* 1984) and with seven colonies originating from light traps in the Nelson district. Results indicated that the resistant population was of very limited distribution. However, the detection of a single resistant population from Mariri did not provide sufficient information on the exact distribution of resistance, nor preclude the existence of other undetected resistant populations. The novel application of female sex pheromone to the resistance survey problem in April 1983 gave considerably more detail on the distribution of resistance in the field at Mariri and Moutere Bluffs (Suckling 1983). Male moths collected from sites separated by distances as short as 500m showed quite different dose-mortality responses but fitting an overall pattern of resistance distribution. In April 1983 resistant individuals were most abundant in the centre of the orchards at Mariri. These were surrounded by a band of mixed resistant and susceptible moths in the outer apple blocks, with a large zone of susceptible moths surrounding the whole area (Fig. 2). Very similar results were obtained from surveys in October 1983, January 1984 and May 1984.

For the 1983-84 season a spray programme comprising pre-bloom dialiphos (Torak 400E, 60 g ai/100 litres) and post-bloom chlorpyrifos (Lorsban 50WP, 25-37.5 g ai/100 litres) in place of azinphos-methyl was recommended to the affected orchardist. This recommendation was based on both cross-resistance studies and field trials of insecticide efficacy at Mariri. By January 1984, this spray programme had substantially reduced both the number of moths caught in sprayed orchards, and the crop damage compared to previous seasons (this result was confirmed at harvest). Samples of moths collected from patches of scrub within the boundaries of the sprayed zone contained some resistant individuals, showing that resistance was effectively confined to these patches. Resistance was also detected at two sites near the Bluffs packhouse, but the chlorpyrifos spray programme reduced LBAM to very low levels in the nearby sprayed orchards. No resistance was detected in samples taken from other Nelson orchards, including several with previous export rejections for leafrollers. It is suggested that the resistant LBAM populations from the Bluffs and Mariri share a common origin, because fruit from Mariri were taken to the Bluffs for grading and packing (P. Cheeseman pers comm). Resistant LBAM could have escaped from reject fruit.

Fig. 1. The 95% confidence limits of LC₅₀ values obtained by workers using slide dipping of lightbrown apple moth larvae from Nelson and Christchurch in azinphos-methyl. Asterisks indicate LC₅₀ values for which no confidence limits could be calculated.

Fig. 2: Schematic representation of the distribution of azinphos-methyl resistance in light brown apple moth at Mariri in April 1983, after a 'calendar' schedule of azinphos-methyl sprays. (Zone codes: R = resistant individuals, M = mixed resistant and susceptible individuals, J = susceptible individuals)

Recent tests using slide dipping indicated that the level of resistance has not changed significantly for 10 years (Fig. 1).

Of the twenty different spray programmes evaluated for leafroller control in 1982-83 and 1983-84, none possessed all the desirable characteristics, namely, high control efficacy against LBAM, no cross-resistance, low toxicity to predatory mites, no phytotoxicity, and residues acceptable for international trade. Schedules of pyrethroids, prothiophos, methomyl plus azinphos-methyl, or acephate were highly effective in controlling resistant LBAM, but destroyed the OP-resistant predator *Typhlodromus pyri*. Dialifos, though effective, was limited to pre-bloom application because of residues. Chlorpyrifos met most of the requirements, although it had exhibited a very low level of cross-resistance in laboratory studies. *Bacillus thuringiensis* and triflumuron gave poor leafroller control.

DISCUSSION

The objectives of resistance management are to prevent the spread of resistance from its currently narrow distribution, and to reduce its impact within this area. Certain organophosphates are highly desirable chemicals for orchard pest control, because of their internationally accepted residue tolerances, lack of environmental persistence, and proven efficacy against other orchard pests. Hence it is likely that insecticides like azinphos-methyl and chlorpyrifos will remain the chemicals of choice of some time, and this programme aims to maintain their efficacy for as long as possible.

The results indicate a restricted distribution of an apparently stable, low level of azinphos-methyl resistance in LBAM. It is surrounded by a large population of susceptible LBAM potentially capable of diluting the genes for resistance, and there is strong circumstantial evidence that this is a major factor in helping to prevent the spread of resistance. Theoretical models of resistance development support this view (Georghiou and Taylor 1977).

The programme for resistance management involves maintaining the susceptible population as a source for dilution and containment of the resistant population. The dilution ratio may be improved if the resistant population can be reduced to a very low level, and in February 1984 this was attempted. The patches of scrub at Mariri and the Bluffs identified as containing resistant individuals were treated with cypermethrin (Cymbush 10EC, sprayed to runoff with 5 mls ai/100 litres). To avoid toxicity to predatory mites from cypermethrin, chlorpyrifos was applied by helicopter and hand-held sprayer to other scrub areas where the risk of drift onto the orchards was high. This tactic was accompanied by post-harvest chlorpyrifos sprays in the orchards, to prevent re-establishment of resistant moths after harvest. In addition, orchardists were asked to clean up LBAM host plants within the orchards, by burning, spraying herbicide, bulldozing, or tree topping. Improved management practices aimed at maximising spray penetration and coverage (e.g. replacing spray nozzles, heavier pruning, re-calibration of sprayers, etc.) have been recommended to improve spray efficacy.

The resistance management strategy is continually evolving as results are obtained but the present plan comprises the following procedures in the areas of resistance:

1. Close monitoring of the level and distribution of resistance using pheromone-collected males.
2. Autumn 1984: post-harvest chlorpyrifos applied to orchards to minimise overwintering larvae.
3. Winter 1984: destruction of scrub containing resistant individuals, inside the areas designated M and R in Fig. 2.
4. Spring 1984: intense application of pyrethroid to the remains of this scrub, and simultaneous chlorpyrifos sprays in orchards.
5. Conservation of azinphos-methyl susceptible LBAM reservoirs.
6. Enhanced immigration of susceptible males into the resistance area by using female sex pheromone.
7. Continuing to seek non-organophosphate chemicals with high efficacy for leafroller control, but low toxicity to predatory mites.
8. The apple spray programme for 1984-85 will be determined in spring 1984 based on latest research data.

9. Promoting further economic analysis of the resistance management option and other alternatives, begun by Hide (1984).

Items 2-4 and 8 are intended to minimise and contain the resistant population.

Detection of azinphos-methyl resistance in LBAM, while it is still low in level and restricted in distribution, presents an important and unique opportunity for resistance management. The progress of these measures will continue to be monitored very closely.

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ACKNOWLEDGEMENTS

Research by the senior author from March 1980 to August 1983 was carried out in the Entomology Department, Lincoln College, under DSIR Research Contract No. UV1/30. Grants received from Bayer (NZ) Limited, NZ Fruitgrowers Federation Ltd, N.Z. Apple and Pear Marketing Board and the NZ Kiwifruit Authority are gratefully acknowledged. Special thanks to Mr D.J. Rogers (contract technician), P.W. Shaw (Entomology Division) and MAF Advisory Services Division personnel for technical assistance, to colleagues in Horticulture Group, Entomology Division, for valuable discussion and to Dr P.D. King, Dr D. Steven and Mr P. Ellis for the use of their slide-dipping data.