**RESISTANCE IN FROGGATT'S APPLE LEAFHOPPER,
EDWARDSIANA CRATAEGI DOUGLAS, TO AZINPHOS-METHYL**

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SUMMARY

A bioassay is described for testing the response of adult leafhoppers to insecticides. It was used to establish concentration-response data for a susceptible population of *Edwardsiana crataegi*, Froggatt's apple leafhopper (FAL) to both azinphos-methyl and carbaryl. A diagnostic concentration of 1400 ppm ai for azinphos-methyl was established. *E. crataegi* from six Hawkes Bay apple orchards were exposed to leaves treated with the diagnostic concentration. Resistance frequencies of 11 - 100% were found, and it was concluded that low levels of leafhopper resistance to azinphos-methyl are common in Hawkes Bay.

Keywords: leafhopper, resistance, azinphos-methyl, carbaryl, diagnostic dose.

INTRODUCTION

Froggatt's apple leafhopper, (FAL) (Homoptera: Cicadellidae), was first recorded in New Zealand in 1918 (Cockayne 1919). FAL, like almost all other species in the sub-family Typhlocybinae, feeds exclusively on leaf mesophyll, and most studies suggest that its development can be completed only on apple or hawthorn. Although it was initially regarded as a significant pest of apples (eg. Dumbleton 1934), it is now usually controlled by insecticides (Charles 1989; Teulon and Penman 1984). High populations reduce photosynthesis and tree vigour, and may occasionally defoliate trees. Additionally, leafhoppers can be a nuisance pest to pickers and their spots of excrement on fruit are sufficient to reject fruit from export.

Since 1987 in Hawkes Bay, there have been increasing reports of severe leafhopper damage occurring in some commercial orchards, despite season-long, export-led, insecticide spray programmes based on azinphos-methyl and chlorpyrifos. In the last 3 years the leafhopper problem has become widespread in the region and losses have occurred through excrement spotting, especially on the cultivar 'Granny Smith'.

This paper describes a bioassay technique developed to measure the response of FAL adults to contact insecticides, and the results of preliminary investigations into the resistance of FAL in Hawkes Bay pipfruit orchards.

METHODS

The susceptibility of adult FAL to azinphos-methyl was determined for a population at the Mt Albert Research Centre (MARC), Auckland. The host apple trees had been unsprayed for many years, and the FAL were designated "susceptible" to insecticides.

Both sides of freshly-picked apple leaves were sprayed under a Potter tower, with 2 ml aliquots of insecticide, an air pressure of 69 kPa, and a 10 second settling period. The stalk of each leaf was then inserted into a 50x10 mm diameter glass tube filled with water through a Plastazote plug. The plug was then placed in a pre-cut slot in a 9 cm diameter plastic Petri dish, so that the leaf lamina was inside, and the watering tube outside the dish. With the lid replaced, this provided a secure cage for holding leafhoppers on an insecticide-treated leaf.

Leafhoppers were collected from apple trees using an aspirator, briefly narcotised with CO₂, and transferred on to leaves in test cages, where they recovered within 2 min. Up to 30 adults were held in each cage, at 25°C under a 16:8 h photoperiod, for 24 h,

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when mortality was assessed by the lack of movement of individuals when touched with a fine brush.

Preliminary assessment of the technique showed that all the adult FAL tested (n=50) survived 24 h exposure to water sprayed leaves. In subsequent experiments, care was taken to ensure that leaf stalks were placed in water within 45 min of removing them from trees. High FAL mortality resulted if leaves were allowed to desiccate beyond c. 60 min.

FAL mortalities after exposure to seven or eight different concentrations of insecticide (n=10-56 adults per concentration) were recorded. Data were analyzed by probit analysis, using the software package POLO-PC (LeOra Software 1988) to generate and compare probit regressions, corrected for mortality in the untreated controls. With the MARC population, log concentration-mortality response regressions were estimated for azinphos-methyl (Gusathion M35) in 1993, and carbaryl (Carbaryl W80) in 1994. A concentration-response line for carbaryl, using an unsprayed population (15 years without insecticide sprays) from Havelock North Research Centre (HNRC), was also estimated in 1994.

The statistics from the MARC population were used to propose a "diagnostic concentration" of azinphos-methyl which would kill 100% of these individuals. In March 1993, adult FAL from the unsprayed block at HNRC, and from six apple orchards (four cultivars) in Hawkes Bay with reported leafhopper problems were collected and exposed to the diagnostic concentration, using the above technique. The trees in each orchard had all received a full (export) cover programme of azinphos-methyl during the season. FAL in the orchards were not easy to find, and only low numbers (13-31) of adults from each orchard were tested (Table 2).

RESULTS AND DISCUSSION

Azinphos-methyl

The calculated LC₉₉ for the MARC "susceptible" population was 584 ppm (Table 1). From this statistic, a diagnostic concentration of 1400 ppm was established which exceeded even the 99% confidence limits of the LC_{99 sus}, (383-1223 ppm). This concentration was approximately three times the recommended field rate for azinphos-methyl, acknowledging that there are major limitations in comparing Potter tower results with airblast sprayer application systems.

Although the numbers of FAL tested were low, the responses to the diagnostic concentration were sufficient to show that the leafhoppers in several orchards were tolerant of azinphos-methyl (Table 2). Mortality ranged from 89% at the unsprayed HNRC block to 0% at one property (with the lowest number of FAL tested). This implies that the frequency of resistant individuals in these populations ranged from 1-100% given the limitations of natural variation within these populations and the low numbers of leafhoppers tested.

TABLE 1: Responses of susceptible *E. crataegi* (FAL) adults to azinphos-methyl and carbaryl (ppm ai).

	MARC		HNRC
	azinphos-methyl (n ¹ =286)	carbaryl (n ¹ =263)	carbaryl (n ¹ =143)
slope ± se	2.94 ± 0.33	2.53 ± 0.38	3.19 ± 0.53
LC50	94.4	24.0	34.5
(95%CL)	(80-109)	(11-35)	(27-44)
LC99	584	199	185
(95%CL)	(416-977)	(102-1787)	(117-432)
diagnostic dose	1400	-	-

n¹ = total no. of FAL tested.

TABLE 2: Responses to azinphos-methyl of "hard to kill" leafhoppers from HNRC and six commercial (com) pipfruit orchards in Hawkes Bay.

Orchard number	Number of FAL tested	% mortality
HNRC	28	89
Com 1	13	77
Com 2	25	53
Com 3	31	16
Com 4	30	14
Com 5	19	12
Com 6	28	0

Carbaryl

The mortality response of the MARC population to carbaryl was less uniform than that to azinphos-methyl as indicated by the considerable scatter of data about the calculated line and the wider confidence intervals at both the LC₅₀ and LC₉₉ levels (Table 1). Therefore a diagnostic concentration for carbaryl was not established. Further studies on the response of FAL to this insecticide are required.

The regressions of the MARC and HNRC populations to carbaryl were not significantly different, either in slope or intercept. Thus despite some indication of resistance within the HNRC population to azinphos-methyl, both populations were equally susceptible to carbaryl, and there was no suggestion of cross-resistance. This appears to be the case in commercial orchards as well because Hawkes Bay pipfruit growers maintain or regain control of FAL with carbaryl. Furthermore, carbaryl has been reported to provide effective control of azinphos-methyl resistant white apple leafhopper (WALH), *Typhlocyba pomaria* McAtee, a closely related species, in North America (Beers 1991).

Hawkes Bay orchardists should not become complacent with this situation, or regard it as being anything more than a temporary measure for control of FAL. Although there is no way to predict how long carbaryl resistance may take to develop, it would be a mistake to assume a time span similar to that for azinphos-methyl. In fact, it is surprising that azinphos-methyl has been effective against FAL in New Zealand for so long with typically 7-10 applications applied each season since the mid to late 1960's. In the USA, WALH developed resistance to azinphos-methyl as early as 1968 (Trammel 1974).

Clearly, more data from both susceptible and 'problem' populations of FAL are required to develop a sound insecticide management programme for this pest in the immediate future. In the longer term, a strategy could be developed which relies decreasingly on organophosphate or carbamate insecticides, and more on selective insecticides such as insect growth regulators that are non-toxic to natural enemies. The egg parasitoid *Anagrus* sp., already present in New Zealand, and nymphal parasitoids which could be imported, are natural resources which have not yet been fully exploited for leafhopper control. The possibilities for incorporating them into an IPM programme for FAL control are only now starting to be explored.

CONCLUSIONS

Previous attempts to measure responses to insecticides have suffered from high control mortality. The technique described here resulted in virtually no mortality among FAL caged on untreated leaves, and is clearly suitable for testing FAL. Our opinion is that the feature that most significantly maximised adult survival was to collect the insects individually by aspiration, rather than by sweep-netting.

The levels of resistance to azinphos-methyl reported here are significant as organophosphate insecticides are failing to control FAL in many Hawkes Bay orchards. The commercial properties we sampled from are typical of many in Hawkes Bay that have experienced moderate to severe chlorosis of leaves due to leafhopper

feeding since 1987. The results of the bioassays indicate that FAL resistance to azinphos-methyl may be widespread in the important apple growing areas surrounding Havelock North, Hastings and Taradale. Although not investigated in this study, reports of FAL in crops treated with chlorpyrifos and diazinon suggests that Hawkes Bay FAL populations may also be cross resistant to other organophosphate insecticides. Currently azinphos-methyl resistance in FAL is restricted to Hawkes Bay but OP insecticide resistance could well become more widespread.

Although all the growers spoken to during this trial reported that they could still obtain good control of FAL by spraying them with carbaryl, conventional insecticides should not be relied on for long. Strategies for the future, which rely more on sustainable practices, and which maximise the potential for incorporating natural enemies into the programme, should be investigated.

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