CAN BUPROFEZIN CONTROL FROGGATT'S APPLE LEAFHOPPER, *EDWARDSIANA CRATAEGI* ?

J.G. CHARLES

HortResearch, Private Bag 92 169, Auckland

ABSTRACT

Buprofezin was an effective insecticide against nymphs of Froggatt's apple leafhopper (FALH) at commercial rates (125ppm ai) in a laboratory bioassay. However, spring emergence of many nymphs in a Hawke's Bay orchard occurred after the final permissible application date for buprofezin (at the "pink" stage of flowering). Resistance to azinphos-methyl in Motueka was detected, emphasising the need for alternative control agents. The ability of buprofezin to control the spring generation of FALH depends on the persistence of pre-flowering applications, and cannot be determined without further field trials.

Keywords: Froggatt's apple leafhopper, *Edwardsiana crataegi,* phenology, resistance

INTRODUCTION

Froggatt's Apple Leafhopper, (FALH), (*Edwardsiana crataegi* (Douglas), Homoptera: Cicadellidae), was an important pest of apples from 1918 (when it arrived in New Zealand) until the advent of DDT (Charles 1989). It became a minor pest of commercial apple orchards during the post-World War II insecticide era, but has recently developed resistance to azinphos-methyl in Hawkes Bay (Charles *et al.* 1994). The advent of insecticide resistance in FALH coincided almost exactly with that of the obscure mealybug, *Pseudococcus affinis* (Homoptera: Pseudococcidae), to chlorpyrifos (Charles *et al.* 1993). The insect growth regulator buprofezin (Applaud) has become an important weapon in the fight against OP-resistant *P. affinis* (Walker *et al*. 1993). Because minimum residue levels for buprofezin have not been set in many of our export markets, its use in apples is currently restricted to pre-flowering applications.

Although buprofezin is known to be effective against some planthopper and leafhopper pests of rice (Anon. 1989), its effect on FALH has not been investigated previously. This paper reports on (a) laboratory experiments to determine whether buprofezin kills FALH, and (b) field data on the spring phenology of FALH in Hawke's Bay to determine whether buprofezin is likely to be effective in the field. In addition, a "hard-to-kill" population of FALH from Motueka was assessed for resistance to azinphos-methyl.

METHODS

Effectiveness of buprofezin against *E. crataegi*

Because of the inherent difficulties of measuring the effects of insect growth regulators, FALH nymphs were exposed to buprofezin residues on leaves in order to simulate the conditions under which they would normally encounter the insecticide. Buprofezin is a persistent material, which appears to be active against planthopper (Delphacidae) and leafhopper (Cicadellidae) pests of rice for only a relatively short time towards the end of each nymphal stage (Anon. 1989). We assumed that similar activity would occur against FALH.

Tests were carried out only on nymphs which were less than 24h into their respective instar when initially exposed to the insecticide. To achieve this, all nymphs from an unsprayed population of FALH on apple trees (cv. 'Royal Gala' and 'Granny Smith') at the Mount Albert Research Centre (MARC), Auckland, were collected by

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aspiration into a glass tube. They were then placed on fresh apple leaves in cages (Charles *et al.* 1994), with each cage containing only one instar. Newly moulted nymphs were subsequently removed each morning for testing. Tests were carried out against 2nd, 3rd, 4th and 5th instars. It was initially planned to test first instars as well, but it proved too difficult to collect neonate nymphs known to be less than 24 h old.

Freshly picked, undamaged and disease-free apple leaves were dipped in a fresh, agitated solution of Applaud at a concentration of 125 ppm ai buprofezin (which is the recommended field rate for mealybug control) for 10 seconds. Leaves were then dried in the laboratory at ambient temperature (approx. 20°C), with their stems submerged in water in a 50 x 10 mm tube to prevent desiccation. Newly moulted FALH nymphs were then caged in 9 cm diameter petri-dishes (only one instar per dish with the treated leaf for food), as described by Charles *et al.* (1994). Other nymphs were allocated to "control" dishes, with leaves dipped for 10 seconds in water, but otherwise treated in the same way as the experimental insects.

The FALH nymphs were held at 22°C ($\pm$1°C) with a 16:8 photoperiod, and examined daily. The tests were terminated when all test insects had died or moulted.

Emergence of *E. crataegi* from hibernation in spring

If buprofezin is to be effective against FALH in commercial apple orchards, the pre-flowering applications must contact, or provide residual activity against, nymphs emerging from overwintering eggs. In 1989-1990, as part of an insecticide trial on apples at the Havelock North Research Orchard in Hawkes Bay, the FALH population structure was assessed every 2-3 weeks from the 1 cm green to tight cluster stage. On each occasion, 36 leaf and fruit "cluster" samples were removed from 8 trees (cv. 'Red Delicious'), examined under a microscope, and all FALH instars recorded. Carbaryl was applied to the block on 3 November. Azinphos-methyl was applied on 22 November, 8 and 12 December 1989.

Resistance to azinphos-methyl in Motueka

A population of FALH at the Nelson Research Centre at Motueka survived applications of azinphos-methyl in early summer 1995. Adults were collected from the field on 12 December 1995 and arrived at MARC on 13 December. Fifty-eight apparently healthy individuals were narcotised with CO_2 and transferred into petri-dish cages with apple leaves previously dipped in a diagnostic concentration of 1400 ppm azinphos-methyl (Charles *et al.* 1994). A similar number were caged with untreated leaves. Mortality was assessed after 24 h.

RESULTS

Effectiveness of buprofezin against *E. crataegi*

Adults dominated the population structure of feral FALH when the tests were carried out from 22-30 March 1995. The later instars were the most common nymphal stages present, so most test insects were 4th and 5th instars.

TABLE 1: Developmental and mortality data for FALH nymphs caged on leaves treated with buprofezin or water.

Treatment	Instar	No. tested	% killed	Mean no. days to death or next instar (SE)
buprofezin	2nd	1	100	5
	3rd	2	100	5.5
	4th	14	100	5.6 (0.25)
	5th	41	100	6.5 (0.13)
control	2nd	-	-	-
	3rd	3	0	4
	4th	6	0	3.8 (0.17)
	5th	10	0	5.2 (0.16)

All nymphs (n=19) exposed to water-treated leaves survived until at least the next moult (Table 1). Such high survival had previously also been recorded when using the same cages and technique to rear neonate FALH through to adults (Charles unpublished data), and for holding adult leafhoppers (Charles *et al.* 1994). These data allowed the allocation of a higher proportion of the limited number of available nymphs to the experimental treatments.

All of the 58 nymphs exposed to buprofezin died before the next moult (Table 1). Longevity of treated 4th and 5th instars was significantly greater than in the control insects (*t*-tests: t=5.8, P<0.001; Table 1). Control nymphs moulted about 1.5 days before treated nymphs died (Table 1).

For the first few days after initial exposure, nymphs on the buprofezin-treated leaves appeared as healthy and as mobile as the controls. However, at about the time that nymphs on the water-treated leaves began moulting to the next instar, the buprofezin-treated insects became sluggish. Typically, the abdomen turned brown, wing-buds swelled away from the thorax, and/or the whole insect appeared distended. Some nymphs appeared to have developed successfully to the next instar within (and visible through) the old cuticle. However, in none of the insects did the cuticle show any visible sign of rupture. All of the treated nymphs died within the old nymphal skin, in contrast to the brown planthopper, *Nilaparvata lugens,* which died during emergence from the old cuticle (Anon. 1989). In other respects, the results and observations reported here are quite consistent with those of Nihon Nohyaku in trials against other leafhoppers (Anon. 1989).

The above data led us to conclude that buprofezin would also have killed first instar nymphs, had they also been tested.

Emergence of *E. crataegi* from hibernation in spring in Hawkes Bay

The numbers of FALH recorded, and their respective instars, are given in Table 2.

TABLE 2: Early season phenology of Red Delicious and FALH, 1989 -1990.

Date	Tree phenology	No. FALH	Age distribution of FALH 1st	2nd	3rd	4th	5th	adult
25 Sept 1989	1cm green	1	1					
9 Oct	full bloom	12	6	4	2			
24 Oct	fruitlet	32	12	5	10	5		
6 Nov	1cm diam.	3*		1	1		1	
20 Nov	3cm diam	0						
4 Dec	4cm diam.	1*	1					
18 Dec	4-5cm	1						1(male)
3 Jan 1990	5-6cm	0						

* dead nymphs

FALH hibernates in apple trees as dormant eggs laid under the bark of young wood (Dumbleton 1934). Neonate nymphs emerged from budburst until at least early-December. The high numbers of first instars found at the fruitlet stage (24 October) indicated that peak emergence may not have occurred until after the end of flowering. The carbaryl application on 3 November was clearly very effective against FALH, and the population did not rebound, at least in spring and early summer when there were repeated organophosphate applications; there were no indications of organophosphate resistance at this time.

Resistance to azinphos-methyl in Motueka

Only 21 (36.2%) of the 58 adults died after exposure to the diagnostic concentration of azinphos-methyl. This concentration exceeded the 99% confidence limits of the LC_{99} of a susceptible population of FALH (Charles *et al.* 1994), so it is extremely unlikely that 63.8% of the insects would have survived without resistance being present. This is despite the relatively high control mortality of 9%, which was attributed to travel-induced stress. The survival rate was about mid-range of those recorded in Hawke's Bay by Charles *et al.* (1994).

DISCUSSION

E. crataegi and *P. affinis* are two insects, which, after being under effective insecticide control for nearly 5 decades, have re-appeared in the past few years as significant pests of the New Zealand apple industry. This is partly due to development of resistance to organophosphate insecticides reported previously from Hawke's Bay, and here from Motueka. Insect growth regulators such as buprofezin are emerging as key components of modern, commercial pest control strategies, and it is imperative that their activities against the full spectrum of pests they are likely to encounter are understood.

The laboratory bioassay showed that buprofezin is an effective insecticide, at the recommended rate for mealybug control, against nymphal stages of FALH. However, use of buprofezin after the "pink" stage of flowering (usually during the last week in September) is not yet permitted, and neonate FALH may emerge from hibernation in Hawke's Bay for several weeks after the last permissible application date. Similar emergence data and dates were recorded for FALH in Canterbury (Teulon and Penman 1986). The subsequent decay of buprofezin residues and/or the natural dilution of spray deposits by rapid plant growth, may mean that later emerging nymphs only contact non-lethal residues, or avoid contact with the insecticide altogether.

With these constraints, it cannot be assumed that the insecticide will act as effectively in commercial apple orchards as in the laboratory. However, it does seem probable that early emerging FALH nymphs will come into contact with, and be killed by, pre-flowering sprays of buprofezin applied for mealybug control. Buprofezin is a persistent material, and there may remain sufficient insecticide on twigs and older leaves also to kill later emerging nymphs. The proportion of the spring generation of FALH nymphs killed by buprofezin, and hence the actual level of control of FALH achievable in commercial orchards, cannot be determined without field trials.

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