PYRETHROID INSECTICIDES FOR APPLE PEST CONTROL: 1. DEVELOPMENT OF PYRETHROID-RESISTANT PREDATORY MITES

N.P. MARKWICK, C.H. WEARING and P.W. SHAW

DSIR, Private Bag, Auckland, Clyde and Appleby

SUMMARY

Field-selection of *Typhlodromus pyri* to produce synthetic pyrethroid (SP) resistance began in 1978. After 4 years of selection no resistant predators had been recovered and a laboratory programme began. By March 1984 the first SP-resistant predators were recovered from field-selection trials and SP-resistance was also detected in the laboratory colony. Continued selections raised the level of resistance in both strains of *T. pyri* until the LC50 was more than twice the field application rate. These predators were cross-resistant to other SP products and retained their organophosphate (OP)-resistance. The laboratory strain successfully established, overwintered and controlled ERM in the field. The field strain is evaluated in Walker *et al* (1990).

INTRODUCTION

Typhlodromus pyri Scheuten is a predatory phytoseiid mite which has been used in New Zealand since the mid-1970's in integrated mite control programmes (IMC) against the European red mite (ERM — *Panonychus ulmi* Koch). The success of the IMC programme depended largely on the resistance of *T. pyri* to the organophosphate (OP) insecticides used against insect pests (Wearing *et al* 1978).

It was recognised that, should insect control with OP fail and necessitate replacement with another group of insecticides, the IMC programme would be jeopardized. Synthetic pyrethroids were identified as providing extremely good control of leafrollers and codling moth and seemed the most likely group to replace OP insecticides. However, they were known to be highly toxic to predatory mites and massive outbreaks of ERM, controlled only by frequent use of acaricides, followed their use (Wearing and Thomas unpublished; Markwick 1986a).

In 1978 Wearing and Thomas began a field-selection programme for SP-resistance in *T. pyri* at the DSIR Research Orchard, Appleby, Nelson. Field-selection was chosen in the first instance since *T. pyri* had developed OP-resistance in the field after about seven seasons of spraying during the 1960's (Wearing pers. comm.). However, when no predators had been found in the SP-sprayed apple trees at Appleby by the 1981-82 season, the programme was extended to include laboratory-selection in an attempt to speed up the development of SP-resistance. This paper reports on the development of SP-resistance in field and laboratory strains of *T. pyri*.

METHODS

Field selection

Field-selection began in the 1978-79 season with nine permethrin (Ambush 50EC) sprays applied (at 15 g ai/100 litres) fortnightly to a block of apple trees (cv. Sturmer Pippin). The following season a second block of apple trees (cv. Splendour) was added to the programme, and the SP used from then on was cypermethrin (Cymbush 10EC). Spray applications were fortnightly for the first five seasons and then monthly from the 1983-84 season onwards once the field persistence of the SP deposits became known. Similarly applications rates were reduced after 2-3 years (from 11.25 ml ai/100 litres to 1.5 ml ai/100 litres) in accordance with Cymbush recommendations for leafroller control and because of the high toxicity of the EC formulation of *T. pyri* (Markwick 1986a). Excellent control of leafrollers was achieved with the monthly sprays.

Proc. 43rd N.Z. Weed and Pest Control Conf. 1990: 296-300

As no predators were recovered from the SP-sprayed trees by the 1981-82 season, *T. pyri* were introduced from other blocks (22 releases between December 1981 and February 1984). Most (14 releases) came from neighbouring apple trees (cv. Dunn's Favourite) that were subjected to SP-spray drift while eight were from blocks receiving OP-treatment but no SP-drift.

Laboratory selection

Before undertaking laboratory selection, populations of *T. pyri* from Christchurch, Nelson, Havelock North and Hamilton were screened for their response to SP insecticides (Markwick 1986b). *T. pyri* from the trees in the SP spray-drift zone at Appleby had an LC50 slightly higher than those from other areas for all three SP's tested (cypermethrin, deltamethrin, and fenvalerate).

A laboratory culture was set up from the survivors of screening large numbers of predators with cypermethrin at one-fifth field rate (0.001 ai%) (Markwick 1986b). About one fifth of this base culture originated from commercial orchards near Hamilton with no SP-spray history. The remainder came from the spray-drift zone at Appleby as it seemed likely that some selection for SP-resistance had already begun in this population.

Selections were carried out on the laboratory culture, initially every 2 to 3 months, with cypermethrin. About 1000 adult females were sprayed on leaf discs under a Potter Tower and mortality was assessed after 48 hours (Markwick 1986b). Selections began at one-fifth field rate (0.001 ai%) and when the 48-hour survival of females exceeded 50%, the rate of cypermethrin was increased (Figure 1).

Fig. 1: *T. pyri* survival in 16 selections with increasing rates of cypermethrin.

Field establishment of laboratory SP-R *T. pyri*

To bulk up numbers, after each selection of *T. pyri* the unselected part of the laboratory culture was released onto apple seedlings grown under glass. These seedlings were maintained at 21-25 °C under a 16:8 L:D photoperiod. Sprays of cypermethrin at the current selection rate were applied 3-4 times per year.

During the 1985-86 season seven releases of *T. pyri* from the glasshouse culture were made into a hedgerow of apple trees at the DSIR Research Orchard, Kumeu, Auckland and five cypermethrin sprays at full field rate (0.005 ai%) were applied at monthly intervals. No further releases were made from the laboratory culture into the

hedgerow after this first season but this population of SP-R *T. pyri* was monitored fortnightly for the following three seasons.

The SP used in the next season was cypermethrin (Cymbush 6.5DG) in accordance with both field- and laboratory-selection. In the following two seasons deltamethrin (Decis 2.5 flowable) and esfenvalerate (Hallmark 5 flowable) were used respectively.

Retention of OP-resistance in *T. pyri*

The apple trees used in the SP-selection programme at Appleby had received no OP treatment since the programme began and predators from OP-treated blocks were last introduced in February 1984 (see above). Likewise, laboratory cultures of the predator were set up in 1983 for selection with SPs and since then had received no OP-treatment. In 1986 dosage-mortality tests were carried out with azinphos-methyl (Gusathion 50WP) on both strains of SP-R *T. pyri* to ascertain if they had retained their OP-resistance.

The tests used the slide-dip technique as described by Penman *et al* (1976). Twenty adult female *T. pyri* were placed on their backs on double-sided sticky tape (Sellotape®) attached to a microscope slide. For each dip test a range of at least five concentrations of azinphos-methyl (Gusathion 50WP) was prepared with tap water, as well as control treatments of tap water. Mites were dipped for 5 seconds and then held in a humidity chamber at $25 \pm 2^\circ\text{C}$ and approximately 80% RH for 24 hours. Mortality was assessed as the failure of mites to move an appendage when touched with a fine brush. Tests were repeated on two occasions.

RESULTS AND DISCUSSION

Field-selection

Low numbers of *T. pyri* were first recorded in March 1984 and by March 1985 predators had increased to almost two per leaf in the 'Splendour' block. In March 1985 the LC50 of these predators was 0.0103 ai% (cypermethrin), which is more than twice the recommended field rate for leafroller control. By the end of that season, with the assistance of three propargite (Omite 30WP) sprays, ERM was under control in this block (ERM:*T. pyri* actives, 0.79:1).

Field-selection has continued whilst implementation of SP-based IMC programmes using SP-resistant *T. pyri* has commenced (Walker *et al* 1990). By March 1987 field-

Fig. 2: Dosage-mortality lines for *T. pyri* with cypermethrin. Comparison between two resistant and one susceptible strains.

selected *T. pyri* from the 'Splendour' block, reared through one generation in the laboratory, had an LC50 of 0.0132 ai% (cypermethrin).

Laboratory-selection

After eight selections the LC50 had increased to 0.0035 ai% (cypermethrin) (Figure 1) compared with values between 0.0003 and 0.0006 ai% for susceptible *T. pyri* populations (Markwick, unpublished). Between the 8th and 13th selections the LC50 remained constant (at 0.0035 ai%). Survival of the selection treatment did not reach 50% during this period and so the rate of cypermethrin was not increased. However, for the 14th and 15th selections, in an attempt to increase the resistance level, the rate was doubled and this was immediately followed by a substantial increase (2.66 times) in the LC50 to 0.0101 ai%. This is twice the recommended field rate for use against the target pests. Tests after the 15th selection indicated a less heterogenous resistant strain.

A comparison of the two SP-resistant strains with an SP-susceptible strain from Havelock North at the end of the 1986-87 season gave resistance factors (LC50 resistant strain/LC50 susceptible strain) of 31 for the laboratory strain and 41 for the Appleby strain (Figure 2).

Field-establishment of SP-R *T. pyri*

T. pyri established quickly on the hedgerow and was present in every sample after the first release (Figure 3). Although numbers of *T. pyri* dropped after the first cypermethrin spray, they later peaked at 2.8 predators per leaf. Thus laboratory-selected SP-R *T. pyri* were able to establish in the field and increase under an SP-spray programme even though at that time the LC50 of this strain for cypermethrin was lower than the rate of cypermethrin applied. ERM numbers were very high and two clofentezine (Apollo 50SC) sprays were applied at one-third recommended rate.

In the second season (1986-87) the SP-R *T. pyri* were able to respond to the increasing prey numbers and gained control of ERM under the SP-spray programme although some leaf bronzing by ERM still occurred. No miticides were used.

In the third and fourth seasons (1987-88/88-89) control of ERM numbers on the hedgerow by the predator was excellent (Figure 3). No miticides were applied.

Fig. 3: Numbers of SP-resistant *T. pyri* and European red mite on a hedgerow of apple trees at Kumeu Research Orchard. a & b show number of *T. pyri* actives (+ - +) and number of ERM adults (— ● —). c shows number of *T. pyri* actives (+ - +) and ERM actives (□ — □).

The dramatic improvement in ERM control over the four seasons after the release of predators in 1985-86 can be attributed partly to improved distribution of the predators and partly to increased SP-resistance in the predators. By March 1987 the LC50 for *T. pyri* from Kumeu was 0.0098 ai% (cypermethrin), almost three times that when the predators were released two seasons previously. Good cross-resistance was also demonstrated amongst the three SP's used during this period. This substantiated previous laboratory tests (Markwick 1986b).

Retention of OP-resistance in SP-R *T. pyri*

Results were compared to those given by Penman *et al* (1976) and show that both SP-R strains have retained azinphos-methyl resistance at a similar level to the Appleby-R strain tested in 1976 (Table 1). This was despite the absence of selection pressure from OP sprays for at least 2 years at Appleby and more than 3 years in the laboratory. Between 1986 and 1989 field trials undertaken at Appleby confirmed these laboratory test results (Walker *et al* 1990).

TABLE 1: Toxicity of azinphos-methyl to strains of *T. pyri*

Strain	Year tested	LC50 ai %	95% confidence limits	Slope
*Appleby-R	1971	0.07	—	—
*Appleby-R	1976	0.30	0.19 - 0.46	1.25
Appleby-SP	1986	0.40	0.24 - 0.65	2.10
Lab-selected SP	1986	0.36	0.25 - 0.50	1.95

* From Penman *et al* (1976).

CONCLUSIONS

Both field and laboratory selection produced strains of *T. pyri* which were resistant to several SP products at levels required to maintain excellent leafroller control. As well these predators retained their OP-resistance. Thus, neither SP-R strain would be adversely affected by the inclusion of OP sprays in an SP-spray programme. The high level of SP-resistance and cross-resistance, combined with OP-resistance shown by these predators has greatly enhanced their usefulness in integrated mite control.

ACKNOWLEDGEMENTS

We wish to acknowledge Pat Tibbits, Tony Greaves and Jonathan Toye for carrying out the maintenance work and spray programmes required to make the field programme at Kumeu possible and Louise Noonan and Suzanne Reid for their assistance with monitoring these mite populations. Dr Alison Hayes is thanked for her assistance with graphics.

REFERENCES

- Markwick, N.P., 1986a. Induced resistance in beneficials with particular reference to *Typhlodromus pyri* Scheuten (Acarina: Phytoseiidae). In: Insecticide Resistance Management, Proceedings of a joint CSIRO/DSIR Workshop. J.C. Daly and D.M. Suckling (Eds). pp 91-98.
- Markwick, N.P., 1986b. Detecting variability and selecting for pesticide resistance in two species of phytoseiid mites. *Entomophaga* 31: 225-236.
- Penman, D.R., Ferro, D.N. and Wearing, C.H., 1986. Integrated control of apple pests in New Zealand VIII. Azinphos-methyl resistance in strains of *Typhlodromus pyri* from Nelson. *N.Z. J. Exp. Agric.* 4: 377-380.
- Walker, J.T.S., Markwick, N.P., Wearing, C.H., Shaw, P.W. and White V., 1990. Pyrethroid insecticides for apple pest control: II Field evaluation of mite and insect control. *Proc. 43rd N.Z. Weed and Pest Control Conf.* (in prep).
- Wearing, C.H., Walker, J.T.S., Collyer E. and Thomas W.P., 1978. Integrated control of apple pests in New Zealand. 8. Commercial assessment of an integrated control programme against European red mite using an insecticide-resistant predator. *N.Z. J. Zoo.* 5: 823-837.