INVESTIGATING THE IMPACT OF PROTECTANT FUNGICIDES ON INTEGRATED MITE CONTROL. I. A MODELLING PERSPECTIVE

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SUMMARY

Integrated control of European red mite, *Panonychus ulmi*, has been disrupted in recent years by the use of protectant fungicides for black spot control. Laboratory tests with metiram and mancozeb were carried out to determine any direct effects of these chemicals on both the European red mite and the predatory mite *Typhlodromus pyri*. These and other published effects were incorporated into a predator-prey model but they could not explain the disruption to IMC observed from use of these compounds in the field. The model has assisted in understanding when disruption to integrated mite control occurs.

INTRODUCTION

The disruption to integrated mite control (IMC) in apple orchards resulting from the use of the fungicides metiram and mancozeb, has been recognised for some time. (Collyer 1980; Wearing and Profitt 1982; Wearing and Wilton 1984; Walker *et al* 1988). These materials have been shown to suppress predator populations (Hagley and Biggs 1989) and result in European red mite (ERM) reaching damaging levels in mid to late summer (Walker *et al* 1989).

The mechanism of the disruption to *T. pyri* has been investigated in the laboratory, using the slide dip technique (Baynon and Penman 1987) and the results indicated that both metiram and mancozeb reduced the hatch rate of young *T. pyri* eggs, but that adult and nymphal survival 24 hours after a spray application were not affected. In the present study further laboratory tests were carried out to investigate in more detail the effects of mancozeb, metiram and captan on both ERM and *T. pyri* life cycle parameters. A simulation model of ERM and *T. pyri* (Hayes 1989) was used to investigate the impact of laboratory-determined effects on seasonal changes in mite numbers, and to assist in the understanding of the results of field trials.

METHODS

Laboratory experiments were carried out on unsprayed apple leaf discs (cv. 'Sturmer Pippin'), placed on wet cotton wool in petri dishes. Predator and prey mites were obtained from the DSIR Research Orchards in Appleby or Havelock North and were placed onto the discs using a fine paintbrush. Each petri dish was sprayed with 2 ml of the test fungicide at 68.9 kPa pressure and 10 seconds settling time in a 'Potter Tower' (Potter 1952).

The fungicide treatments compared were field rates of mancozeb, 1.3 g/litre (Dithane M45, 80% ai), metiram, 1.3 g/litre (Polyram 2000, 80% ai), and captan, 1.3 g/litre (Orthocide). Controls were sprayed with distilled water. The leaf discs were held in a controlled temperature room at 20 °C (± 1 °C), 60% (± 5%) relative humidity and 18L:6D photoperiod. After spraying, the mites were examined daily and predator mites were supplied with an excess of ERM larvae.

Direct toxicity of the fungicides to the following predator and prey mite stages was assessed: ERM larvae, ERM nymphs, ERM adult females, *T. pyri* eggs (>24 h old), *T. pyri* nymphs and adult males. Assessments were made 5 days after application when it

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was possible to determine for the juvenile stages whether moulting had occurred successfully. In these experiments, each leaf disc contained 5 or 10 mites, and the total number of mite stages tested in each treatment was 100 for ERM and 50 for *T. pyri*. During the experiment, some mites were lost when they walked off the leaf discs and drowned in the wet cotton wool.

To investigate any effects on predation rates, adult female predators were placed on individual leaf discs and provided with six ERM larvae per day. Their daily consumption and oviposition rates were then recorded over a 10-day period. A total of 24 mites were used for each treatment and they were sprayed with test chemicals, once at the start of the experiment and again 5 days later. Any eggs laid were transferred daily to unsprayed leaf discs to determine their hatch rate.

RESULTS

The percentage survival of the different predator and prey stages after spraying with field rates of fungicides was similar to control survival. The only significant effect ($P < 0.05$) of fungicide treatments on ERM survival was a reduction in adult female survival from treatment with captan (39.2% survival compared with 58.6% in the control). There were no significant effects of any of the fungicides on *T. pyri* survival, although all captan-treated *T. pyri* stages had slightly lower survival than those in the control treatment, as did metiram-treated nymphs and eggs.

A summary of the results from the experiment on adult female *T. pyri* predation and oviposition rates is shown in Table 1. Captan and mancozeb did not reduce daily predation and oviposition rates compared with the control, whilst metiram reduced daily predation rates by 8% and oviposition by 13% compared with the control. The reduction in oviposition was not significant ($P > 0.05$). The reduced predation rate in the metiram treatment was significantly different from the control at the 90% level ($0.1 > P > 0.05$) and was significantly lower than in the captan treatment ($P < 0.05$).

TABLE 1: The effect of fungicide treatments on daily predation and oviposition by adult female *T. pyri* at 20°C over a 10-day period, and the hatch rate of eggs laid in the experiment.

Treatment	N	Daily predation ERM larvae/female/day	Daily oviposition eggs/female/day	Hatch rate %
water	22	4.23 ab	0.573 a	87 a
captan	22	4.31 a	0.545 a	93 a
mancozeb	23	4.44 a	0.609 a	89 a
metiram	21	3.98 b	0.5 a	83 a

Results followed by the same letter are not significantly different ($P > 0.05$).

Since there is a linear relationship between consumption of ERM larvae and predator egg production (Hayes 1988), the same percentage reduction would be expected in both, and would be somewhere between 8-13%. Predation rates were affected by metiram throughout the experiment with no apparent effect immediately after the spray. There was little evidence of a delayed effect of any of the fungicides on the percentage hatch of eggs from sprayed females. Egg hatch was similar in all treatments but slightly lower in the metiram treatment. Mortality of adult females in all treatments was negligible during the experiment.

These short term laboratory experiments revealed little evidence for suppression of *T. pyri* by mancozeb or captan. Metiram, however, reduced predation rates of *T. pyri* adult females feeding on ERM larvae, and subsequent egg production. Survival of *T. pyri* treated with metiram was similar to those treated with captan, the fungicide which is considered to be most compatible with IMC. There was a suggestion that captan may suppress ERM populations by reducing adult survival.

USE OF SIMULATION MODEL

A simulation model of ERM and *T. pyri* (Hayes 1989) was used to determine whether the laboratory measured effects can explain the disruption to IMC observed in the field. This model accurately simulates changes in predator and prey mite densities during the growing season. The inputs required to run the model are the predator and prey densities on leaves in spring, and the daily maximum and minimum temperatures throughout the season. In order to simulate mite populations under a particular fungicide regime, model parameters were changed for the period of fungicide use according to the information obtained in this and another laboratory study (Baynon and Penman 1987).

To investigate the impact on IMC of the apparent toxicity of captan to adult female ERM, the parameter for adult mortality was increased by 50% to simulate the use of captan. This change had only a very slight effect on simulations, and therefore disruption of IMC by mancozeb and metiram could not be explained by removal of suppression of European red mite when captan is omitted.

To simulate the effects of metiram use, predation rates were reduced by 13% (this study) and egg hatch was reduced to 51% (Baynon and Penman 1987). To simulate use of mancozeb, egg hatch was reduced to 73% (Baynon and Penman 1987). These changes in model parameters represent an overestimate of the observed fungicide effects, since the reductions in egg hatch were determined for young predator eggs (<24 h) which were sprayed directly and the reduction in predation rates was the upper expected value.

The impact of changing these model parameters was investigated with respect to a field trial (Walker *et al* 1988), in which the fungicides mancozeb and metiram were used on two different apple blocks between 18 November and 28 January. Control simulations (Figs. 1 and 2) were used to show the expected population changes if the fungicides had not been used. They predicted that, with the levels of predator and prey mites present in spring, adequate mite control should have occurred, with ERM active stages not exceeding 5/leaf. However, in both the field trials the actual ERM population densities departed from the control simulation after late January, and reached levels in excess of 20/leaf (Figs. 1 and 2).

When the simulation incorporated the effects of metiram, it predicted some disruption to IMC with ERM reaching densities of more than 10/leaf in late January, but with populations under control by late February (Fig. 1). Clearly this did not happen in the field where ERM populations peaked later and higher. The simulation mimicking mancozeb use differed very little from the control simulation, and predicted no disruption to IMC (Fig. 2). The predator populations in both field trials were lower than predicted during December and January (Figs 1 and 2) and resulted in the high ERM numbers in February and March.

Whilst the observed effects of metiram may go some way to explaining the disruption to IMC, the observed effects of mancozeb in the laboratory (Baynon and

Fig. 1: Comparison of field populations of ERM and *T. pyri* (—●—) with a control simulation (—) and a simulation incorporating the effects of metiram (---).

Fig. 2: Comparison of field populations of ERM and *T. pyri* (—●—) with a control simulation (—) and a simulation incorporating effects of mancozeb (---).

Penman 1987) did not explain the disruption to IMC observed in the field.

In these trials, metiram and mancozeb were used after the russet sensitive period. It is normal commercial practice to use these compounds during the russet sensitive period (from September until about the third week in November) when fungicides such as captan may lead to problems with fruit finish. Examination of data from five field trials, carried out over three separate seasons (Wearing and Shaw unpublished data) at Appleby Research Orchard showed that, where mancozeb or metiram was used during the russet sensitive period, the number of predator mites on the leaves in late October (the earliest suitable time for assessing mite density) was between 50 and 90% lower than on blocks where an IMC-compatible fungicide programme or no fungicides had been used. Simulations starting in late September and incorporating metiram or mancozeb use during the russet sensitive period did not predict this observed reduction in predator numbers by late October. However, in all cases, simulations using as inputs the densities of predator and prey mites in late October showed that the high numbers of ERM in mid to late summer could be attributed wholly to the reduced predator numbers in early spring (see Figs. 3 and 4 for an example of simulations using prey and predator densities from control and treatment blocks).

The effect of reducing predator densities in spring whilst ERM densities remain the same is further demonstrated in the simulations in Fig. 5. The important thing to note is that a small reduction in predator density in late October can lead to large increases in ERM levels later in the season.

Fig. 3: Control simulation (---) compared with field data (—●—) from a block of Gala apples at Appleby Research Orchard, treated only with IMC compatible fungicides.

Fig. 4: Control simulation (— —) compared with field data (—●—) from a block of Gala apples at Appleby Research Orchard which had been sprayed with metiram during the russet sensitive period.

Fig. 5: Simulations demonstrating the effect of reducing predator density in spring. Predator input densities are as follows: a = 0.65 actives, 0.29 eggs; b = 0.55 actives, 0.24 eggs; c = 0.45 actives, 0.2 eggs; d = 0.35 actives, 0.16 eggs; e = 0.25 actives, 0.12 eggs.

DISCUSSION

Laboratory experiments have shown very few detrimental effects on predator mites resulting specifically from use of the fungicides metiram and mancozeb in the laboratory. Moreover, in simulations these effects did not explain the disruption to IMC observed in the field. It appears that further disruption occurs in the field which has not been identified in the laboratory. Laboratory tests can only reveal short term toxicity to mites and disruption in the field may be due to either chronic effects resulting from repeated applications, or factors which have not (or cannot easily) be investigated

in the laboratory, such as distributional effects, delayed effects (not manifest until the next generation) or effects on predator stages that have not been tested (e.g. overwintered females).

Where protectant fungicides are used during the russet sensitive period, disruption of IMC appears to have already occurred before the first leaf sample is usually taken in late October. Leaf samples taken earlier than this do not accurately reflect changes in mite numbers, because of movement of mites from other parts of the trees and because of new leaf growth. A more detailed examination of mites on individual leaf and flower clusters (Walker *et al* 1989) has identified the mechanism of this disruption.

It was originally hoped to use the model to investigate the period of black spot fungicide use which would be least disruptive to IMC. However, detrimental effects on the predator determined in the laboratory were insufficient to explain the field disruption, and it is therefore not possible to argue for optimum use patterns on the basis of this information alone.

ACKNOWLEDGEMENTS

This work was partially funded by the New Zealand Apple and Pear Marketing Board. The fungicides were provided by Rohm and Haas, New Zealand, BASF and Nufarm Ltd. We should like to thank Ms Madeleine Cox for technical assistance and Dr Chris Triggs for statistical advice.

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