EFFECT OF MINERAL OIL AND DIAZINON RESIDUES ON THE PREDATOR EUROPEAN EARWIG, *FORFICULA AURICULARIA*, IN KIWIFRUIT

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ABSTRACT

The European earwig, *Forficula auricularia*, is probably a key predator of armoured scale insects in kiwifruit in New Zealand, but its effectiveness may be compromised by the use of insecticides on kiwifruit vines. European earwigs are nocturnal and avoid direct contact with insecticides during application, but would be exposed to residues on leaves and bark. Earwigs were monitored after exposure to residues of mineral oil combined with Bt (*Bacillus thuringiensis*) or diazinon following commercial or experimental spray applications for scale control. Oil plus Bt residues caused no mortality of earwigs. No earwigs survived exposure to diazinon residues for 2 nights after the commercial application while half survived for 7 nights. Some mortality was recorded after exposure to diazinon residues up to 17 nights after the experimental application. As there is a single generation of earwigs each year, diazinon residues are likely to cause significant disruption to scale predation in conventional kiwifruit orchards.

Keywords: *Forficula auricularia*, insecticide residues, survival, kiwifruit, scale predator.

INTRODUCTION

European earwigs, *Forficula auricularia* L., are known to be generalist predators in apple orchards (Buxton 1974; Carroll & Hoyt 1984) and are probably a key predator of armoured scale insects in kiwifruit (D.P. Logan & B.J. Maher, unpubl. data). Hill et al. (2005) found extensive predation by earwigs when monitoring greedy scale, *Hemiberlesia rapax* Comstock, on kiwifruit leaves in greenhouse trials at the Te Puke Research Orchard. The percentage of scale insects predated rose steadily over the summer season reaching 91%. Armoured scale insects, particularly greedy scale and latania scale, *Hemiberlesia lataniae* Signoret, are pests of kiwifruit in New Zealand because of their presence on fruit at harvest, which may affect market access. No significant damage to vines or fruit occurs but the presence of scale insects can lead to down-grading of fruit during packing. Growers typically apply two to four insecticide sprays over a growing season for the control of scale insects. Natural enemies of scale insects such as parasitoids and fungal pathogens may provide limited control in kiwifruit orchards in unsprayed situations (Hill 1989; Steven 1990).

Earwigs have one generation per year. The females dig a nest in the soil or beneath logs and debris to overwinter and lay ca 30–60 eggs per batch in late winter to early spring (Fulton 1924; Carroll & Hoyt 1984). Most females lay one egg batch and some may lay a second smaller batch (Lamb & Wellington 1975). There are four nymphal instars. The first instar remains with the female and may forage outside the nest at night returning before daylight. Nymphs leave the nest after reaching second instar and enter a free-foraging stage (Helsen et al. 1998).

To control scale insects after flowering, commercial kiwifruit growers use mineral oil, often in combination with *Bacillus thuringiensis* (Bt), a biological insecticide (to control leafroller caterpillars), or diazinon, an organophosphate insecticide. Mineral oil and Bt are referred to as 'soft' insecticides and can be used on organic kiwifruit blocks. Organophosphate sprays are broad-spectrum and may have a negative impact on earwigs and other natural enemies of scale insects (Bozsik et al. 2002; Nicholas et al. 2005). Earwigs are nocturnally active, hiding during the day in cracks or in bark, and are therefore more likely to come into contact with spray residues rather than being sprayed directly. As earwigs are potentially valuable natural enemies of scale insects in kiwifruit, it is important to ascertain their sensitivity to 'soft' and 'hard' insecticides applied to vines. The objective of this study was to establish the effect of spray residues of some commonly used chemicals on earwig survival.

MATERIALS AND METHODS

Spray applications for experiments were carried out at the Te Puke Research Orchard, Bay of Plenty, on well established kiwifruit vines grown on pergola structures. Sprays were applied according to the recommended label rates and at a water rate equivalent to 2000 litres/ha.

Experiment 1: commercial spray applications

Mineral oil (1% D-C-Tron Plus[®]) in conjunction with Bt (Delfin) at a rate of 50 g/100 litres, was applied to a commercially-managed organic block of cv. Hayward kiwifruit on 19 December 2005. Diazinon (Basudin 600 EW[®]) at 80 ml/100 litres was applied to a conventional KiwiGreen block of cv. Hayward kiwifruit on 27 December 2005. Prior to spraying, 50 pieces of kiwifruit cane (100 mm long × 10 mm diameter) were suspended from support wires in the canopy so that they were at the level of the fruit on vines and were exposed to sprays. Ten of the pieces of kiwifruit cane (sticks) and ten leaves were picked at 3 hours and 1, 4, 9 and 14 days after the initial spray applications. In the laboratory on each of these days, one field collected adult earwig was added to a container (100 mm high × 100 mm diameter) with a picked leaf (n=10) or stick (n=10) and survival was recorded after 3 days. Ten unsprayed leaves and ten sticks were set up as controls each sampling time.

Experiment 2: experimental spray application

Diazinon (Basudin 600 EW[®]) at 80 ml/100 litres was applied on 2 February 2006 to two bays of conventionally-managed cv. Tomua kiwifruit (5 m × 4 m spacing, ca four vines), with a high pressure hand gun (200 psi) driven by a Comet P48 pump. Care was taken to ensure that good spray coverage to both sides of the leaves was achieved. Fifty-five sprayed leaves were picked at 2 hours and 1, 3, 5, 7, 11 and 17 days after the spray application and taken to the laboratory. A single 6 cm diameter disc was cut from each of 40 leaves. The leaf discs were placed on moistened filter paper in a plastic Petri dish (90 mm diameter) along with one field-collected adult earwig. As earwigs are active at night, small pieces of corrugated cardboard (30 mm × 15 mm) were added to dishes as a hiding place during the daytime. Dishes were split into two groups of 20. Leaf discs in group A were replaced after earwigs had been exposed for one night with a fresh unsprayed disc. Earwigs in group B were exposed to the same sprayed leaf disc for five nights. Twenty unsprayed leaf discs were set up in the same way as controls each time the bioassay was run. For each leaf sampling time, earwig survival was recorded on day one (following 1 night of exposure) and on day six after set up (5 nights of exposure).

The 15 remaining leaves, for each sampling time were packed into plastic bags (five leaves per bag) and frozen for diazinon residue testing by Hill Laboratories, Hamilton.

A representative subsample of leaves (ca 8-10) was selected for each sampling time and diazinon residues were determined by GC-ECD/NPD analysis after extraction by ethyl acetate. The detection limit for diazinon was 0.01 mg/kg (wet weight of leaves).

Data analysis

Data for analysis were percent survival for 1, 2, 4, 6, 8, 12 and 18 nights after spraying in experiment one and 1, 2, 5, 10 and 15 nights after spraying in experiment 2. A robust version of the generalised linear model analysis, available in R (Chambers & Hastie 1992; R Development Core Team 2005), was used to fit results with variance assumed to be proportional to that for a binomial distribution. The robust version of the model fitting procedure reduces the weight given to points that lie away from the main body of the data. The form of dependence of survival on time was assumed to be that given by a complementary log-log model, with time as the explanatory variable:

$$\log(-\log(1 - p)) = a + bt$$

where p = expected survival and t = number of nights after spraying.

The time required for the survival to reach 50% and 90% respectively (ST_{50} and ST_{90}) were calculated from the coefficients (i.e. a and b) given by the model.

RESULTS

Experiment 1

Mineral oil and Bt residues on sticks and whole leaves did not kill earwigs in this 3-day test (2 nights of exposure). Diazinon residues were toxic to earwigs. Survival reached 50% (ST_{50}) at 1.5 nights and 7 nights after spraying, on sticks and leaves respectively (Fig. 1). Some mortality of earwigs occurred on sticks up to 15 nights after spraying. There was no mortality of earwigs in controls.

FIGURE 1: The change in survival with time (nights after spraying) for European earwigs on kiwifruit (a) sticks and (b) leaves. Time to reach 50% and 90% survival (ST_{50} and ST_{90}) after 2 nights of exposure to diazinon residues was calculated from the fitted lines. Plots of survival use a discontinuous y-axis to enable the representation of the 0% and 100% (which would be at -infinity and +infinity respectively on the complementary log-log scale). Data points at either extreme, when present, are distinguished by a dot inside the symbol and are separated from the main part of the plot by a dotted horizontal line.

Experiment 2

Leaves picked 2 hours and 1, 3, 5, 7, 11 and 17 days after spraying retained sufficient diazinon residues to kill earwigs. In the laboratory, time to ST_{50} was shorter for earwigs exposed to leaf discs with residues for one night only (Group A) than for five nights (Group B) (Fig. 2). There was some variation in ST_{50} for earwigs exposed to leaf discs after one night, when groups A and B were equivalent (Fig. 2a & c). For assessments of group B earwigs after five nights exposure to residues, ST_{50} and ST_{90} were calculated as 10 and 16.4 nights after spraying (= natural decay in the canopy) respectively (Fig. 2d). In comparison, ST_{90} for group A (Fig. 2b) earwigs was calculated as 6 nights after spraying. All earwigs in control dishes ($n=140$) survived the experiment except one.

FIGURE 2: The change in survival with time (nights after spraying) for European earwigs, Groups A (a and b) and B (c and d). Time to reach 50% and 90% survival (ST_{50} and ST_{90}) after exposure to diazinon residues on kiwifruit leaf discs was calculated from the fitted lines. For each group, earwig survival was assessed after 1 day (1 night of exposure; (a and c)) and 6 days (5 nights of exposure (b and d)). Group A was exposed to residues on leaf discs for 1 night only. Group B was exposed to residues continually for 5 nights.

Residues of diazinon declined over time (Fig. 3). Two hours after spray application there was 240 mg/kg (wet weight of leaves) of diazinon residue on leaves. Five days after spray application the level was 37 mg/kg, but by 17 days this had dropped to 6.5 mg/kg.

FIGURE 3: Diazinon residue levels on kiwifruit leaves at seven sampling times. Day 0 was 2 February 2006.

DISCUSSION

Residues of diazinon can remain high enough to kill 50% of a European earwig population for ten days after spray application. In kiwifruit orchards, the dose an earwig receives would depend on the coverage of spray within the canopy, on leaves, bark and canes as these are all surfaces on which an earwig may wander during the night. Other factors likely to affect the level of residue to which earwigs are exposed include the time since spraying, climatic events (i.e. rainfall) and the rate of residue breakdown on different substrates. For example, in Experiment 1 the time for earwigs to reach 50% survival was shorter on sticks than on leaves. The diazinon residue level on leaves at 17 days after spraying was 6.5 mg/kg, and was still killing approximately 10% of earwigs. By using a natural substrate such as treated excised leaf discs in a bioassay rather than synthetic substrates such as plastic, a more realistic measure of toxicity from residue contact was obtained (Studebaker & Kring 2003). In this study, the first night of exposure immediately after spraying was the most lethal to earwigs with nil to very low numbers surviving. This should be similar to a dose in the field, and, as there is only one generation per year, it means a reduction in active scale predators for the season. The present results are consistent with those of Bozsik et al. (2002) who found that European earwigs were relatively susceptible to organophosphate insecticides.

Predation by earwigs may have a greater impact on scale insects in organic blocks and those where growers apply soft insecticides, such as mineral oil. This is because residues of oil and Bt combined did not kill earwigs, and presumably the exclusive use of soft insecticides allows earwig populations to increase in the long term, given that no other factors are limiting. To confirm that earwig numbers are greater in organic kiwifruit blocks compared to conventionally-managed blocks a survey of these two management systems should be undertaken as part of on-going research that aims at developing European earwigs as conservation biological control agents in kiwifruit.

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