EUROPEAN EARWIGS, *FORFICULA AURICULARIA*, AND PREDATION OF SCALE INSECTS IN ORGANIC AND CONVENTIONALLY MANAGED KIWIFRUIT

B.J. MAHER and D.P. LOGAN

HortResearch, 412 No. 1 Rd, Te Puke, New Zealand

Corresponding author: bmaher@hortresearch.co.nz

ABSTRACT

European earwigs, *Forficula auricularia* L., are potentially important natural enemies of armoured scale insects in commercial kiwifruit orchards. Earwigs are sensitive to broad-spectrum insecticides and diazinon residues can kill earwigs for up to 17 nights after spraying. Eight paired organic and conventional Kiwigreen® orchard blocks were surveyed in the summer of 2006/07 to estimate the number of earwigs present. In each block, 25 shelter traps were placed in the vine canopy for 1 month. Fewer earwigs were recorded in conventional blocks than in organic blocks (P=0.018). A sample of 800 leaves was taken from each of the blocks in March to record predation of scale insects by earwigs. There was no clear evidence that scale insects on leaves were predated by earwigs. This was attributed to the low level of mature scale insects, the preferred stage for predation by earwigs.

Keywords: *Forficula auricularia*, predation, insecticide residues, kiwifruit, scale insects.

INTRODUCTION

In New Zealand, kiwifruit crops are susceptible to infestation by armoured scale insects, particularly greedy (*Hemiberlesia rapax* Comstock) and latania scale (*Hemiberlesia lataniae* Signoret) (Hemiptera: Diaspididae). The presence of scale insects on the fruit at harvest can result in market access restrictions. On-orchard control of scale insects throughout the industry is predominantly achieved by applications of insecticidal sprays applied in response to demonstrated need using the KiwiGreen® pest management system. On organic orchards, growers use predominantly mineral oils while on conventionally managed orchards the broad-spectrum organophosphate diazinon is the most commonly used insecticide (Hill 2002). Natural biological control agents such as predators, parasitoids and fungal pathogens are present in orchards but the degree of control provided is limited (Hill 1989), probably due to the use of broad-spectrum insecticides that can reduce populations of beneficial agents.

European earwigs, *Forficula auricularia* L., are a key beneficial agent in kiwifruit orchards, acting as generalist predators. Hill et al. (2005) found that earwigs were extensively predating greedy scale in an unsprayed greenhouse trial in Te Puke. Globally, earwigs are considered important predators particularly of woolly apple aphid (*Eriosoma lanigerum* Hausmann) in apple orchards (Blommers 1994; Nicholas et al. 2005), but also as pests in some soft-fleshed fruit crops because they are omnivorous and feed on plant substrates in addition to smaller insects (Buxton 1974).

Orchardists endeavour to keep scale insect numbers to a minimum to meet market access standards, and any increase in biological control would be extremely advantageous. European earwigs are sensitive to broad-spectrum insecticides (Epstein et al. 2000; Bozsik et al. 2002). As nocturnal insects, earwigs come into contact with spray residues on the bark and leaves within the kiwifruit canopy. Maher et al. (2006) determined that diazinon residues on kiwifruit leaves are toxic to earwigs and can kill for up to 17 nights after spraying, but mineral oil (a 'soft' option for scale insect control) did not kill earwigs. This study compares the number of earwigs and the level of scale insect predation on organic and conventionally-managed kiwifruit blocks to test the hypothesis that spray regimes affect earwig populations.

METHODS

Sixteen blocks of mature cv. Hayward kiwifruit in Bay of Plenty, each commercially managed under an organic or conventional regime, were surveyed in mid January 2007 to determine the number of earwigs present, and in mid March to determine if earwigs had predated scale insects on leaves. The blocks were grouped into eight pairs consisting of one organic and one conventional block in close proximity to each other (ca 5 km with a minimum separation between two blocks of the same management regime of 0.5 km). The block sizes and number of vines were variable, with an average block size of 0.6 ha and a range of 0.4–1.5 ha. In general, on the conventional blocks, the area at the base of vines within a row had either a sparse sward of grass and weeds or bare ground where herbicides had been used. On the organic blocks the sward tended to be dense with tall plants within vine rows, and was controlled by mowing only.

Shelter traps and earwig numbers

Cardboard shelter traps, made by rolling a piece of corrugated cardboard (100 mm wide × 850 mm long) into a cylinder, similar to traps used by Burnip et al. (2002) in earwig studies in Canterbury apple orchards, were placed in the canopy on the central leader of 25 randomly allocated vines, at one trap per vine. Traps were placed in the kiwifruit canopy since more earwigs are found there than on the ground in summer months (D.P. Logan unpubl. data). Earwigs readily hide in the longitudinal corrugations of the traps, which were held in place with a wire staple and covered with a weatherproof milkshake container. Vines in the middle five rows of each block made up the sample area to eliminate any effect of block edges or block size on earwig numbers. The average spacing between rows is 4 m with an average of 14 rows per block (range 9–20) in this study. Traps were positioned in the canopy on 13–15 December 2006. The numbers of earwigs per trap were counted 1 month later, on 15–17 January 2007. Total counts of earwigs from organic and conventional blocks were log transformed by $\log(x + 0.5)$ and compared using a paired two sample t-test. Variances of earwig data from organic and conventional regimes were similar after transformation.

Leaf sample and predation

A sample of 800 leaves was taken from the sample area of each block in mid March to look for predated scale insects. This number of leaves was based on the expectation that the industry average of 2–4% of leaves with scale insects (Hill 2004) would provide an adequate sample to estimate predation levels. The sampling plan was based on first counting the number of bays (area between support posts) within the five-row sample area and then taking an equal number of leaves per bay. All leaves were picked within 1 m of the main leader of the vine, as this area tends to have a higher incidence of scale insects (Hill et al. 2006). The number of leaves with scale insects of any life stage present was recorded in the laboratory by selecting leaves haphazardly until 35 scale insect infested leaves were reached. Some samples had relatively high densities of scale insects, which meant that not all leaves were checked to reach the nominal 4% infestation level. Presence or absence of scale insect predation by earwigs on the leaves was recorded. Predation is observed as a chewed scale insect cap with the scale insect body removed, or the cap and body completely eaten leaving a white base plate where the scale insect once was. This contrasts to the earlier report by Hill et al. (2005) that predation typically resulted in the removal of the whole of the insect, leaving no sign of its former presence. Observations from this, and studies in 2006 looking at Hayward leaves, have led to the conclusion that earwig predation of scale insects results in the white base plate mark being left behind. Hill et al. (2005) studied *Actinidia chinensis* selections not Hayward, which may explain the difference. Base plate marks can also indicate senescence of scale insects and this is a possible source of error in predation estimates. The timing of the leaf sample was based on previous predation and scale insect phenology data that indicated high levels of predation at the end of summer (D.P. Logan, unpubl. data). Percentage of leaves with scale was compared for organic and conventional blocks by the Mann-Whitney U test at P<0.05.

RESULTS

Shelter traps and earwig numbers

On average, the number of earwigs found in organic blocks was higher than in the conventional blocks in mid January (P=0.018) (Table 1).

TABLE 1: Total number of European earwigs found in shelter traps in paired organic and conventional kiwifruit blocks in Bay of Plenty in January 2007.

Pair	Orchard Location	Organic	Conventional
1	Te Matai Rd, Te Puke	14	1
2	Oropi/Welcome Bay	0	0
3	Lower Te Puke	12	1
4	Kaimai area	1	0
5	Maketu	1254	61
6	Pyes Pa	61	0
7	Pyes Pa	737	2
8	No. 1 Rd, Te Puke	114	171

Leaf sample and predation

The percentage of leaves with scale insects was higher (P=0.003) in the organic blocks (average 11%) than in the conventional blocks (2.4%). The total numbers of scale insects on leaves ranged from 21–136 on organic blocks, and of these 6–41 were 3rd instars and mature adults, the stages that earwigs prefer. On conventional blocks the range was 12–43 scale insects with 3–10 of these as 3rd instars and mature adults (Table 2). Only two scale insect base plates were found on leaves at separate sites (organic orchards of pairs 4 and 7) but this is difficult to confirm as predation by earwigs because of the possibility that these two scale insects died of old age.

TABLE 2: Percentage of leaves infested with scale insects, the total numbers of scale insects and of 3rd instar and mature adult scale insects (with percentages) on paired organic and conventional kiwifruit blocks in March 2007.

	Total no. leaves		% leaves with scale		Total scale		Total 3rd and mature scale (%)	
Pair	Org.	Conv.	Org.	Conv.	Org.	Conv.	Org.	Conv.
1	320	800	10.9	2.0	91	17	37 (41)	9 (53)
2	800	800	2.4	1.9	21	20	6 (29)	5 (25)
3	400	800	8.8	1.5	64	12	9 (14)	3 (25)
4	240	800	14.6	2.4	43	23	8 (19)	3 (13)
5	160	640	21.8	5.5	136	43	38 (28)	10 (23)
6	800	800	2.4	1.8	21	15	11 (52)	6 (40)
7	480	800	7.3	2.5	55	26	27 (49)	5 (19)
8	160	800	21.8	1.25	97	20	41 (42)	10 (50)

DISCUSSION

The number of earwigs found in organic orchard blocks in mid summer was greater than in conventionally managed blocks. This may be attributed to the less toxic insecticidal sprays (mineral oils) used by organic growers. The number of earwigs found on two of the organic blocks (pairs 5 and 7) were notably higher than others, but the reason for this is unclear. Both blocks are reasonably large (0.8 and 0.5 ha respectively), have mature vines and are geographically well separated, with one at 13 m (pair 5) and the other at 90 m above sea level. The sward on the organic block (pair 5) that had the highest numbers was reasonably sparse, whereas the other was dense. Growers on conventional blocks generally use one or two broad-spectrum organophosphate insecticides, such as diazinon, after flowering (December-February) in response to KiwiGreen® monitoring where ≥4% of leaves are found with live scale insects. It is likely that the residues from these sprays kill many earwigs and other natural enemies (Maher et al. 2006). Groundcover management, such as mowing, is unlikely to reduce earwig numbers during summer months as earwigs tend to be found in the kiwifruit canopy rather than on the ground (D.P. Logan, unpubl. data), unlike in apple orchards (Burnip et al. 2002).

There was no clear evidence of scale insect predation on leaves by earwigs on either organic or conventional orchards. A preliminary study on three unsprayed blocks during late summer 2006 showed that approximately 40% of scale insects on kiwifruit leaves were predated by earwigs (D.P. Logan, unpubl. data). Scale insects were present on 20% of leaves at two organic orchards in the present study (pairs 5 and 8), and some predation could be expected at this population density. Mueller et al. (1988) found that predation on woolly apple aphids is greater at higher earwig densities, but this was not the case in this study even on the two organic orchards with high numbers of earwigs.

Predation levels are linked to prey density. One of the basic components of predation or parasitism is the functional response, defined as a change in the number of prey attacked as prey density changes (Solomon 1949). In regards to European earwigs and woolly apple aphid, Nicholas et al. (2005) found that even in conjunction with IPM control methods where aphid infestations were relatively high in apple trees, earwigs were able to suppress aphid populations to low levels. In the present study scale insects, at various life stages, tended to occur singly or in small clusters of two and three on individual leaves, and this low density is likely to have contributed to the apparent lack of predation. The number of third instar and mature scale insects was generally less than half of the total scale insects found on leaves and, since immature stages of scale are not very attractive to earwigs (D.P. Logan, unpubl. data), first and second instars were probably ignored by foraging earwigs.

Commercial orchards in general have low densities of scale insects because control practices, such as using insecticides particularly organophosphates, prevent mature scale insects building up to high densities. Levels of scale insect infestation of leaves were generally higher on organic than on conventional orchards, and the lack of evidence that earwigs were predating scale insects is disappointing. Earwigs may be contributing to control of scale insects in these blocks, but this was not apparent from checking leaves only. More scale insects can be found on the wood of kiwifruit vines than on the leaves. It is also probable that earwigs find foraging easier on the bark and wood of vines and that predation levels are higher on wood. This is difficult to measure and consequently has not yet been measured in commercial orchards, but should be addressed.

ACKNOWLEDGMENTS

We thank Patrick Connolly (HortResearch, Mt Albert) for helpful discussions on experimental design and the Foundation for Research, Science and Technology for funding this work under contract No. C06X0301.

REFERENCES

Blommers LHM 1994. Integrated pest management in European apple orchards. Annual Review of Entomology 39: 213-214.

Bozsik A, Francis F, Gaspar C, Haubruge E 2002. Effect of some insecticides on acetylcholinesterase from beneficial insects: *Coccinella septempunctata, Chrysoperla carnea* and *Forficula auricularia*. Mededelingen 67: 671-677.

Burnip GM, Daly JM, Hackett JK, Suckling DM 2002. European earwig phenology and effect of understorey management on population estimation. New Zealand Plant Protection 55: 390-395.

Buxton J 1974. The biology of the European earwig, *Forficula auricularia* L., with reference to its predatory activities on the damson-hop aphid, *Phorodon humuli* (Shrank). PhD Thesis, University of London.

Epstein DL, Zack RS, Brunner JF, Gut L, Brown JJ 2000. Effects of broad spectrum insecticides on epigeal arthropod biodiversity in Pacific Northwest apple orchards. Journal of Environmental Entomology 29: 340-348.

Hill MG 1989. Diaspididae, armoured scales (Homoptera). In: Cameron PJ, Hill RL, Bain J, Thomas WP ed. A review of biological control of invertebrate pests and weeds in New Zealand 1874 to 1987. CAB International, Institute of Biological Control, Wellington, New Zealand.

Hill MG 2002. A review of Armoured scale insect (Diaspididae) biology and control, with special reference to kiwifruit. HortResearch Client Report 2002/290. HortResearch, Palmerston North, New Zealand. 94 pp.

Hill MG 2004. Armoured scale and leafroller management on kiwifruit – a preliminary analysis of industry data. HortResearch Client Report 10490. HortResearch, Auckland North, New Zealand. 156 pp.

Hill MG, Mauchline NA, Cate LR, Connolly PG 2005. A technique for measuring growth rate and survival of armoured scale insects. New Zealand Plant Protection 58: 288-293.

Hill MG, Mauchline NA, Ramankutty P 2006. Armoured scale insect infestation on kiwifruit in relation to position on the vine. New Zealand Plant Protection 59: 47-50.

Maher BJ, Logan DP, Connolly PG 2006. Effect of mineral oil and diazinon residues on the predator European earwig, *Forficula auricularia*, in kiwifruit. New Zealand Plant Protection 59: 202-207.

Mueller TF, Blommers LH, Mols PJM 1988. Earwig *Forficula auricularia* predation on the woolly apple aphid, E*riosoma lanigerum*. Entomologia Experimentalis et Applicata 47: 145-152.

Nicholas AH, Spooner-Hart RN, Vickers RA 2005. Abundance and natural control of the woolly aphid *Eriosoma lanigerum* in an Australian apple orchard IPM programme. BioControl 50: 271-291.

Soloman ME 1949. The natural control of animal populations. Journal of Animal Ecology 18: 1-35.