SUSCEPTIBILITY OF EIGHT APPLE VARIETIES TO DAMAGE BY *FORFICULA AURICULARIA* L. (DERMAPTERA: FORFICULIDAE), AN EFFECTIVE PREDATOR OF *ERIOSOMA LANIGERUM* HAUSMANN (HEMIPTERA: APHIDIDAE)

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Summary

Overseas *Forficula auricularia* L. is recorded as a pest of apple. In Australia however it has been shown capable of providing biological control of *Eriosoma lanigerum* Hausmann in apple orchards. Laboratory, field cage and crop assessments at harvest were used to identify and determine the extent of damage caused by *F. auricularia* to varieties of apple grown commercially in Australia. In the laboratory, in the absence of alternative food sources, the varieties Golden Delicious and Sundowner were susceptible to *F. auricularia* damage and most damage occurred on or close to the calyx. No damage was recorded on Granny Smith, Jonathan, Red Delicious, Red Fuji and Smoothe. In field cages Red Delicious and Granny Smith were not damaged, and the variety Jonathan was damaged in December but not in January or February. At harvest, *F. auricularia* damage was difficult to distinguish from that caused by the Light Brown Apple moth *Epiphyas postvittana* (Walker). Damage attributed to *F. auricularia* in Jonathan was 2.48%, Red Delicious 1.77% and Granny Smith 0.39%.

Keywords: European earwig, woolly aphid, biological control, crop loss

INTRODUCTION

European earwig (*Forficula auricularia* L.), a generalist predator with a preference for aphids (Asgari 1966), is capable of controlling woolly aphid (*Eriosoma lanigerum* Hausmann) to a commercially acceptable level in apple orchards in the eastern States of Australia (Nicholas 2000). In Australia, the control of woolly aphid by earwigs has been made possible by a reduction in the use of broad-spectrum insecticides. This was facilitated by the use of pheromone-based mating disruption and the insect growth regulator fenoxycarb for control of codling moth (*Cydia pomonella* L.) and the light brown apple moth (LBAM) *Epiphyas postvittana* (Walker). Insecticides previously used to control these pests are highly toxic to *F. auricularia* (Nicholas and Thwaite 2003) and prevented the effective biological control of woolly aphid (Nicholas 2000). Now European earwigs can establish in orchards in the absence of woolly aphid and be ready to control an infestation should it occur (Nicholas 2000), however as earwigs are omnivorous, there is potential for this otherwise beneficial insect to damage fruit.

In fact *F. auricularia* in Australia is a serious pest of stone fruit, including cherries, peaches, nectarines, apricots and plums (Hely *et al*. 1982, Bower 1992). In other countries *F. auricularia* is a minor or occasional pest of apples. In the United Kingdom Phillips (1981) reported 10 % damage to the variety Lord Lambourne and minor damage to Cox's Orange Pippin, Laxton's Superb and James Grieves but none of these varieties are grown commercially in Australia. Until now susceptibility of local varieties to earwig damage was unknown. Grower acceptance of *F. auricularia* in Australian apple orchards will depend on its contribution towards woolly aphid control outweighing any crop losses. In this study we quantify the damage to fruit caused by *F. auricularia*.

MATERIALS AND METHODS

Laboratory trial

Fruit from eight apple varieties grown commercially in Australia, namely Bonza, Golden Delicious, Granny Smith, Jonathan, Red Delicious, Red Fuji, Smoothe and Sundowner, were collected immediately prior to harvest from orchards at the Orange Agricultural Institute and Bathurst Agricultural Research Station, NSW. Seven apples of each variety were washed and using a stereo-microscope, carefully checked to ensure they were free from damage and skin abrasions. Each fruit was placed in an individual cage constructed from a 1 L plastic jug covered with voile netting (0.5 mm nylon gauze). The fruit was placed on its side allowing earwig access to all parts of the fruit. Five mature male and five female earwigs that had not fed for 72 h were added to each cage. There was no earwig mortality during the trial. The fruit were examined, using a stereomicroscope, every day for seven days and any damage recorded. Beginning on Day 3 and continuing daily thereafter all damage to fruit was sealed using a non-toxic adhesive compound (Bostik Blu-Tack, Bostik Australia) in an attempt to encourage damage at new sites. On Day 7 three fruit of each variety were pricked with a dressmakers pin at one of the following sites; calyx, stalk cavity and body. Each fruit was pricked to an approximate depth of 0.5 mm and the fruit replaced in the cage. Each day the fruit were checked for damage and where present its approximate location recorded as calyx, stalk or body.

Orchard cage trial

The potential of earwigs to damage fruit at different earwig densities was examined during the 1997/98 season. Cages were deployed for the first two weeks of each month. The trial was repeated each month from December 1997 to March 1998, except for the variety Jonathan, which was harvested in February. A section of branch from three apple varieties, Red Delicious, Granny Smith and Jonathan, was caged using a bag made from voile netting (0.5 mm nylon gauze). Either 0, 2, 4, 8, 16 or 32 earwigs (equal numbers of males and females) were then introduced into each cage, which contained a single fruit and two leaves with all other potential earwig food removed. There were two replicates of each earwig density for each of the three varieties. After 14 days, the branches were pruned off and removed to the laboratory for damage assessment.

Harvest crop assessment

Using three varieties, Red Delicious, Granny Smith and Jonathan, four trees were fitted with predator exclusion bands and four left unbanded. This was replicated in four plots giving a treatment sample of fruit from 16 banded trees and 16 unbanded trees from each variety. The predator exclusion bands consisted of a 15 cm wide strip of green plastic sheet coated on both sides with polybutene (Tree Tanglefoot Pest Barrier, Tanglefoot Co. USA) and were fitted prior to earwigs ascending the trees. The polybutene was cleaned and replenished as required. A minimum gap of 15 cm between the foliage of adjacent trees was maintained to prevent inter-tree movement of earwigs. Damage was assessed at harvest.

Data analysis

Analysis of variance (ANOVA) was used to determine differences in European earwig damage to fruit between treatments and varieties. Multiple pair-wise comparisons were used to separate treatment means using LSD ($P<0.05$). Statistical analysis was carried out using Genstat 5 Lawes Agricultural Trust, Rothamsted Experimental Station (Genstat 2000).

Table 1. Nature of damage to apples by caged *Forficula auricularia* (five males and five females/cage).

Variety	No. fruits	Day damage observations						
		1	2	3[1]	4	5	6	7
Bonza	7	B[2]	B,B	B,B	-	-	-	-
Golden Delicious	7	C	C	C	B,C	-	C,C	B,C
Granny Smith	7	-	-	C,S	-	-	-	-
Jonathan	7	-	-	-	-	-	-	-
Red Delicious	7	-	-	B	-	-	-	-
Red Fuji	7	-	-	-	-	-	-	-
Smoothe	7	-	-	-	-	-	-	-
Sundowner	7	B	B	B	S	-	-	-

1. Damage up to Day 3 was disregarded. From Day 3 onwards all damage sealed daily.
2. Region of fruit incurring damage: B - body, C - calyx, S - stalk. Each letter represents damage to an individual fruit (multiple damage to a single fruit did not occur).

RESULTS

Laboratory trial

The damage to fruit observed in these trials consisted typically of a small circular or oblong hole, usually just sufficient to allow earwig entry. A smooth rounded depression approximately 7-10 mm deep was formed and with further feeding a tunnel was often created beneath the skin. The tunnel rarely exceeded the feeding earwig's body length. Occasionally earwigs were found sheltering inside the fruit during the day.

The number of feeding points and their location on the fruit of each variety is given in Table 1. In the first three days of exposure, when the daily damage was not sealed, only one Golden Delicious, Red Delicious and Sundowner, and two of the Bonza and Granny Smith apples were damaged. The Bonza, Red Delicious and Sundowner apples sustained damage only to the body of the fruit, Golden Delicious to the calyx region and Granny Smith to both the calyx and stalk region. There was no damage to the varieties Jonathan, Red Fuji and Smoothe. After Day 3, when all previous damage had been sealed, the earwigs initiated damage to the variety Golden Delicious six times and once to Sundowner. There was no earwig-initiated damage to Bonza, Granny Smith, Red Delicious, Jonathan, Red Fuji or Smoothe (Table 1). Despite being checked thoroughly, it is possible that the visual inspection prior to the start of the trial did not detect all the minute damage that could potentially be exploited by the earwigs. For this reason damage that occurred in the first three days was disregarded when assessing if earwigs could initiate damage. On Day 8, after fruit pricking on Day 7, earwigs had extended the damage by feeding at all sites in all varieties.

Orchard cage trial

No damage to fruit occurred in Granny Smith. All Red Delicious apples were free of damage until March, when one apple caged with 16 earwigs was damaged on the body of the fruit. In December the variety Jonathan was damaged around the calyx in cages containing four (one replicate), eight (both replicates) and 32 (both replicates) earwigs. Jonathans were not damaged in January or February (Jonathans were harvested prior to the March assessment). Earwigs caused minor leaf damage in nine (8.2%) of the 110 cages but there were no earwig density, or variety trends.

Harvest crop assessment

Results of the harvest crop assessment are given in Table 2. There were significant differences ($P<0.05$) in damaged fruit, assessed as being caused by earwigs, between Jonathan and Granny Smith. Differences between Jonathan and Red Delicious and between Red Delicious and Granny Smith were not statistically significant. There was no significant difference ($P<0.05$) in fruit, assessed as damaged by earwigs, between trees fitted with predator exclusion bands (1.67%) and unbanded trees (1.42%).

DISCUSSION

The laboratory cage trial results show that *F. auricularia* is able to initiate damage to Golden Delicious and Sundowner fruit. Golden Delicious was the more susceptible variety with most damage occurring around the calyx of the fruit. The results suggest that there was undetected physical damage (not observed in pre-trial examination) on Day 1 in Bonza, Golden Delicious, Red Delicious and Sundowner because these varieties did not incur damage after this initial damage was sealed on Day 3.

Table 2. Number of fruit assessed as damaged by *Forficula auricularia* harvested from trees banded to prevent earwig access to fruit and from unbanded trees during the 1997/98 season.

Variety	Total no. fruit harvested	No. fruit harvested from banded trees	Total no. damaged fruits	No. damaged fruits from banded trees	Mean % damaged fruit[1]
Jonathan	12911	6993	248	145	2.48 a
Red Delicious	18189	9152	361	156	1.77 ab
Granny Smith	9297	4504	37	24	0.39 b

[1.] after transformation and statistical analysis.
Means followed by different letters are significantly different ($P<0.05$) by LSD.

After Day 7 when fruit were pricked with a pin to simulate damage initiation, the earwigs consistently enlarged the holes to gain access to the flesh within 24 hours at all three sites, in all varieties. This feeding usually occurred at night and demonstrates how earwigs are quick to exploit and extend damage initiated by other sources. The orchard cage trial showed that of the three varieties tested, only Jonathan was susceptible to earwig damage and only early in the season. Mature fruit remained undamaged. There was no apparent relationship between earwig density and the incidence of damaged fruit. The one Red Delicious apple damaged by earwigs in the field cage was damaged on the body, not near the calyx or stalk. It was also in close proximity (within 13 cm) to a limb. As laboratory trials indicated that Red Delicious was not susceptible to earwig damage until pricked with a pin, this damage may have been initiated by limb rubbing. Damage observed in the laboratory and field cages occurred in the absence of alternative food sources.

At harvest Jonathan, Red Delicious and Granny Smith sustained 2.48%, 1.77% and 0.39% fruit damage by earwigs respectively (Table 2). Codling moth and LBAM had damaged up to 30% of fruit. LBAM larvae web leaves to the fruit and feed by grazing on the skin of the apple underneath. For further protection they often burrow into the fruit, usually close to, or in the stalk cavity (Hely *et al.* 1982). These burrows can resemble earwig damage, however, fresh earwig damage can be distinguished from that of LBAM as earwigs cause the skin to be turned in around the edge of the hole. As the fruit decays over time, however, the differences become less distinct and it is possible that some damage may have been wrongly attributed. At harvest, earwigs were found occupying fruit from unbanded trees that had previously had leaves webbed to the skin and thus had clearly been damaged previously by LBAM. It is therefore likely that the actual level of damage initiated by earwigs was lower than that quoted above. Based on the assumption that earwigs rarely fly (Phillips 1981) and that the exclusion bands were effective (as shown by Nicholas 2000), the lack of significant differences in fruit damage between banded and unbanded trees suggests that earwigs initiated little, if any, damage to fruit under open field conditions.

In the field cage trial Jonathan fruit were damaged in December. This is consistent with this variety having the highest level of damage at harvest. It is likely Jonathans are more susceptible to LBAM damage than other varieties because the short-stalked and tightly clustered fruit provide a better refuge from natural enemies and insecticides than where the fruit grow singly on longer stalks. For a similar reason Jonathan fruit may be more susceptible to damage by earwigs. *F. auricularia* is nocturnal and varieties with short-stalked, clustered fruit also provide suitable daytime refuges. However in long-stalked, non-clustered varieties daytime refuge takes place on the orchard floor, in cracks and crevices and under bark. Taking refuge in clustered fruit during the day may increase the opportunity for earwigs to initiate damage. Frass deposited in the stalk cavity may also result in the fruit being downgraded and may require fruit to be washed prior to storage.

Our results demonstrate that *F. auricularia* can damage the fruit of some varieties of apples grown commercially in Australia and growers will need to know how susceptible their varieties are before utilising earwigs to control woolly aphid. Earwigs are most likely to initiate damage early in the season when alternative food sources are not readily available, and after harvest if fruit is left exposed in the packing shed. As earwigs feed extensively on fruit initially damaged by other agents (eg. insects, birds or limb-rubbing), caution must be exercised when identifying and attributing the source of damage.

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