Augmentation of European Earwigs (Dermaptera: Forficulidae) for Biological Control of Apple Aphid (Homoptera: Aphididae) in an Apple Orchard

DEVIN P. CARROLL AND STANLEY C. HOYT

Tree Fruit Research Center, Washington State University, Wenatchee, Washington 98801

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ABSTRACT European earwigs, *Forficula auricularia* L., reared on dogfood in an insectary, were released five to six per tree in an experimental block of prebearing apple trees and provided with artificial retreats on the trees and straw spread on the ground. The number of apple aphids, *Aphis pomi* DeGeer, on these trees declined in 3 weeks from near 500 per tree to less than 50, compared with over 3,000 per tree in an adjacent block kept free of earwigs and nearly 2,000 in a control block.

THE EUROPEAN EARWIG, *Forficula auricularia* L., although often viewed as a minor pest of apples, can be a useful aphid predator. In the Netherlands, earwigs have been credited with preventing outbreaks of woolly apple aphid, *Eriosoma lanigerum* (Hausmann) (Ravensburg 1981). They are also regarded as important predators of apple aphid, *Aphis pomi* DeGeer, (Asgari 1966, Carroll and Hoyt 1984). Other earwigs including *Labidura riparia* Pallas are effective predators of lepidopteran eggs, larvae, and pupae (Strandberg 1981, Buschman et al. 1977). Subjective field observations in north-central Washington suggest that European earwigs are present on most trees with adequate hiding places, and that these trees generally have fewer aphids than nearby trees without earwigs.

We report here on a pilot project to determine the feasibility of using European earwigs to provide enhanced control of apple aphid in a young, preproducing apple orchard.

Materials and Methods

A laboratory earwig colony was initiated with 44 female and 58 male earwigs collected on 27 October 1982 from beneath boards and in sifted dirt and soil litter at field sites around the grounds of the Washington State University Tree Fruit Research Center, Wenatchee. These earwigs were divided among five rearing cages consisting of plastic, draining-type pots (28 cm deep by 33 cm in diameter) covered on top with nylon chiffon fabric tied with string. Each pot was provided with damp potting soil 5 to 10 cm deep, a square of carpet (20 by 20 cm), and several wadded paper towels as a dry refuge. The cages with earwigs were placed in a greenhouse with temperatures kept above 10°C but otherwise not controlled. After eggs were first noted on 10 December, the pots were watered from the top and a small amount of Gaines Puppy Choice dogfood was added to each cage. More water and dogfood were added on 6 January, and most of the male earwigs were removed to prevent cannibalism. On 14 January, all pots were placed in trays filled to a depth of several centimeters with water to keep the soil continuously damp, and the chiffon coverings were replaced with tightly fitting lids made of cardboard disks with foam rubber stapled around the edges. Dogfood was added once or twice monthly thereafter as needed. Most of the remaining P_1 earwigs were removed on 23 March. Between 19 and 25 April, the F_1 earwigs, now mostly mature, were removed and placed in small ice cream cartons (9 by 9 cm) filled with wadded, damp paper toweling and a few crumbs of dogfood. The cartons were kept refrigerated at 10°C, with occasional addition of water, until the earwigs were needed.

On 13 June we selected three blocks of nine 'Red Delicious' apple trees in a 3-year-old orchard at the Research Center. In the "earwig block," we scattered straw on the ground around each tree and stapled an "earwig retreat" on each tree trunk. These retreats were made of thin cardboard ca. 20 cm wide and 60 cm long, folded around a wad of paper toweling (Fig. 1). Five or six laboratory-reared earwigs were placed in each retreat. In the "barrier block," a strip of two-sided, transparent carpet tape with a thin strip of Stikem Special applied to its outer surface was wrapped around each tree trunk. In the "control block" the trees were left undisturbed. Approximately 500 apple aphids on apple shoots clipped from infested trees were added to each of the 27 experimental trees. All aphids on each tree were then counted on days 2 and 7 after infestation and weekly thereafter until mid-July in all three blocks, and for 3 extra weeks in the "earwig block." Data were analyzed by analysis of variance.

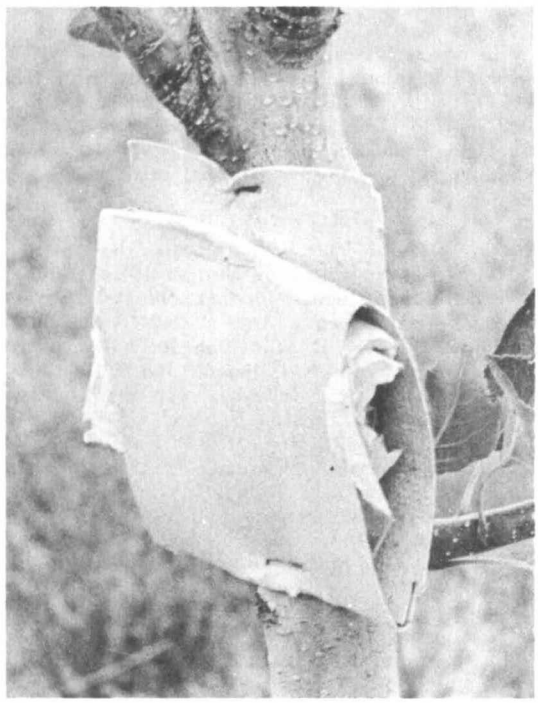

Fig. 1. Earwig retreat stapled to apple tree trunk.

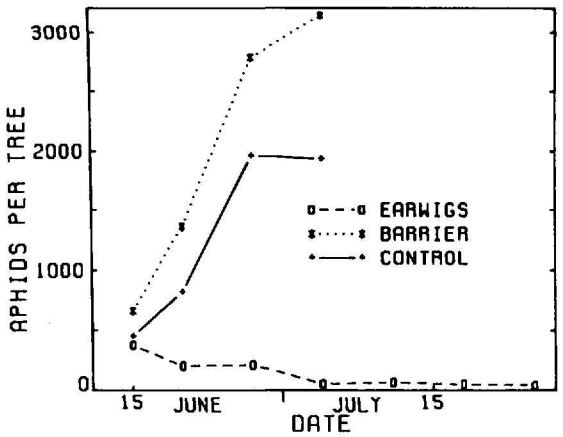

Fig. 2. Average numbers of apple aphids on experimental apple trees provided with earwig retreats after release of earwigs, compared with trees kept free of earwigs and control trees with no treatment.

Results

Three hundred and twenty earwig progeny were reared from the original 44 females, giving a yield of 7.3 progeny per female. The reared earwigs appeared healthy and near the size of field-collected specimens. In addition to the dogfood, the earwigs apparently fed on mold growing on paper toweling and probably also on collembola and mites found in most of the pots. Negligible mortality occurred during 6 months of refrigerated storage in the cartons.

The number of apple aphids in the "earwig block" declined to less than 50 per tree after 3 weeks, compared with over 3,000 per tree in the "barrier block" and nearly 2,000 in the control block (Fig. 2). These differences were significant ($P < 0.01$). Earwigs were found in all nine retreats on every aphid count day, and although we did not count them, there appeared to be more than the initial five to six per tree, indicating that the retreats were attractive to native earwigs. Additional earwigs were usually present under the straw, where the ground was moist. Earwigs were observed at night on all trees in the earwig block, but none were observed in the barrier or control blocks. Earwigs remained on the augmented trees in spite of low prey numbers and prevented reinfestation by preying on immigrating alate aphids. Small numbers of other predators including Syrphidae, Chamaemyiidae, Coccinellidae, and Chrysopidae were found in the "barrier" and control blocks.

A few holes chewed in apple leaves were attributable to the earwigs, but these were clearly insignificant to apple production.

The earwigs did not control an infestation of leafrollers, *Pandemis pyrusana* Kearfott, which occurred on some trees in the "earwig block."

Discussion

The results indicate that an augmentation project using earwigs would meet four criteria required for practical use. Insectary rearing methods were inexpensive and convenient. The earwigs remained in the orchard after being placed there. They consumed enough aphids to provide control. Finally, the earwigs did not cause significant damage to the trees.

The polyphagy of earwigs gives them some advantages over most aphid predators for use in augmentation programs. Although many predators require living prey and close supervision for insectary rearing, we reared earwigs with minimal labor, using unmodified dogfood. More importantly, earwigs will remain on apple trees even when prey are scarce if alternate food items and daytime retreats are available.

However, earwigs have only one to two generations per year and produce relatively few progeny. Under natural conditions earwigs may produce 40 to 60 eggs per female (Fulton 1924), and fecundity under insectary conditions is probably less. Thus, mass rearing will require a relatively large initial collection of earwigs. Although our yield was only 7.3 reared earwigs per female parent, this could be increased by avoiding our early rearing errors. For instance, many young nymphs and some adults died from desiccation before the addition of tray irrigation, and dozens more es-

caped around the lids. We recommend the use of smaller rearing cartons with more tightly fitting lids.

The smaller numbers of aphids in the control block compared with the "barrier" block may have been due to low levels of predation by native earwigs and other ground level predators that occasionally climb trees (Carroll and Hoyt 1984).

Although further tests using bearing trees will be necessary before we can recommend general use of earwig augmentation, we have seen little evidence of earwigs feeding on apple fruit. Earwigs apparently harm apple production primarily by their repugnance to orchard and packing-house workers. The latter may occasionally cull apples with earwigs in the calyx cavity. However, we have observed earwig damage to soft fruits such as peaches and apricots. The natural diet of earwigs is mixed, and includes significant proportions of pollen, aphids and other insects, and fungi and plant parts (Skuhravy 1960). In controlled experiments earwigs preferred aphid prey over plant material incuding apple and other leaves, flower petals, and fruit slices (apple, pear, cherry) (Asgari 1966).

Many north-central Washington apple orchards have abundant native earwig populations, especially where retreats such as mouse guards are available on the trees. These earwigs are undoubtedly providing significant natural biological control of aphids. The advantages of augmentation are that the earwigs could be introduced earlier in the season than they would normally be present, and they could be maintained more consistently in the orchards.

Acknowledgment

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