THE EUROPEAN EARWIG: GETTING THE BEST OF BOTH WORLDS?

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Abstract—The European Earwig (*Forficula auricularia*) is considered to be a pest in urban gardens, and also of fruit, ornamentals and a contaminant in mechanically harvested fruit. However earwigs are also efficient predators of fruit pests such as aphids, mites, scale and insect eggs, and are probably exerting a degree of biological control of pests in gardens as well as orchards. Electrophysiological and behavioural studies have confirmed the role of a volatile pheromone in aggregating earwig distributions. The potential use of the aggregation pheromone in controlling earwigs in an urban situation and in maximimising their potential for biocontrol of insect pests is discussed.

INTRODUCTION

The European earwig, *Forficula auricularia* L., is a common sight in urban gardens and is distributed throughout the world (Behura, 1956). Earwigs occasionally enter houses in large numbers, and due to their ferocius-looking cerci, and widespread mistaken belief in being prone to enter the human ear and eat their way into the brain (hence its common name), often causes alarm. The damage that earwigs may cause to fruit and flowers in urban gardens is outweighed by their beneficial value as predators of a range of pests such as aphids, mites and caterpillars. Recently these benefits have been exploited for the control of pests in orchards (Carroll and Hoyt, 1984; Mueller *et al.*, 1988; Lenfant *et al.*, 1994) and vineyards (Buccholz and Schruft, 1994) where earwig predation plays an important role in the natural control of many pests especially aphids.

So should earwigs be considered as friend or foe? Recent research (Sauphanor, 1992; Walker *et al.*, 1993) and the results presented in this paper confirms the presence of an aggregation pheromone in the European earwig. The aggregation pheromone may allow us to manage earwigs to get the best of both worlds: utilising them as renewable biocontrol agents, which can be removed from crops, gardens and other urban areas, and replacing them when they can no longer cause damage or offence.

MATERIALS AND METHODS

Source of earwigs

Earwigs (nymphs and adults) were collected from nests at Blackford Hill, Edinburgh during February-March 1995. This site was cited by Behura (1956) as an excellent breeding area for earwigs, and the nests were found under stones, logs and leaf litter. The earwigs were sexed, segregated and kept in plastic cups (i.e darkness) with moist soil and pieces of apple for food at a temperature of 20–25°C.

Preparation of aggregation pheromone extracts

Previous studies (Sauphanor, 1992; Walker *et al.*, 1993) suggested that the pheromone was associated with the cuticle of earwigs. Pheromone extracts were obtained by immersing 10 earwigs of each sex in 1 ml of hexane for one hour. Extracts were also made of the abdomen and legs of earwigs to identify which part of the body releases the pheromone.

Earwigs (males or females) were also kept in a glass container in the dark with no food for 15–24h along with 2.5×6.25 cm strips of Chromatography paper (Fisher Scientific) in an attempt to impregnate the filter paper strips with the pheromone. No distinction was made between adult and nymph stages of earwigs.

Proceedings of the Second International Conference on Urban Pests.
K.B. Wildey (editor) 1996

Electrophysiology

Electroantennograms (EAGs) were obtained from excised earwig heads with silver electrodes using a standard method (Evans and Allen-Williams, 1992). The EAGs were recorded on an IBM PC for analysis (Syntech, Hilversum, the Netherlands). The responses were expressed as a percentage of the response obtained from a standard stimulus of cis-3-hexen-1-ol (10% in hexane) applied before and after each pheromone extract stimulus. Between 7–11 individuals of each sex were tested.

Behavioural studies

A choice chamber made from three plastic petri dishes (8.7 cm diameter) glued together (Nagel and Cade, 1983; Walker *et al.*, 1993) was used to measure aggregation of earwigs to pheromone extracts (Fig. 1). Chromatographic filter paper strips impregnated with pheromone (100 l of hexane extract, or exposed to 10 earwigs for 15–24 h) folded into a W-shape to provide shelter for the earwigs, were placed on one side of the chamber, and a control strip of filter paper placed on the other side (Fig. 1). Ten earwigs (males or females) were introduced into the central area of the chamber, and released after 5 minutes of acclimatisation. The position of the earwigs within the chamber was recorded after 1 hour, all experiments being conducted in the dark. Chi-square analysis of the data was used to determine whether earwigs expressed a preference for pheromone treated or untreated filter papers. An aggregation index (Roth and Cohen, 1973) was used to determine the level of aggregation; 0 representing random distribution within the chamber, positive values suggesting a tendency towards aggregation/attraction, and negative values suggesting a tendency towards dispersal.

Due to an inadequate supply of earwigs, most tests were carried out on female earwigs, with only a few tests on male earwigs.

RESULTS

Electrophysiology

The EAGs obtained from male and female earwigs to various hexane body extracts are shown in Fig. 2 and Fig. 3. There are significant differences between the response to hexane and to whole body extracts of male or female earwigs, but not to leg extracts (Figs. 2 and 3). Dilution of the extracts led to reduced EAGs, not significantly different from that to hexane (not shown).

Behavioural studies

The results from the choice chamber tests are summarised in Table 1. Significant aggregation of female and male earwigs occurred to filter papers that had been exposed to male or female earwigs

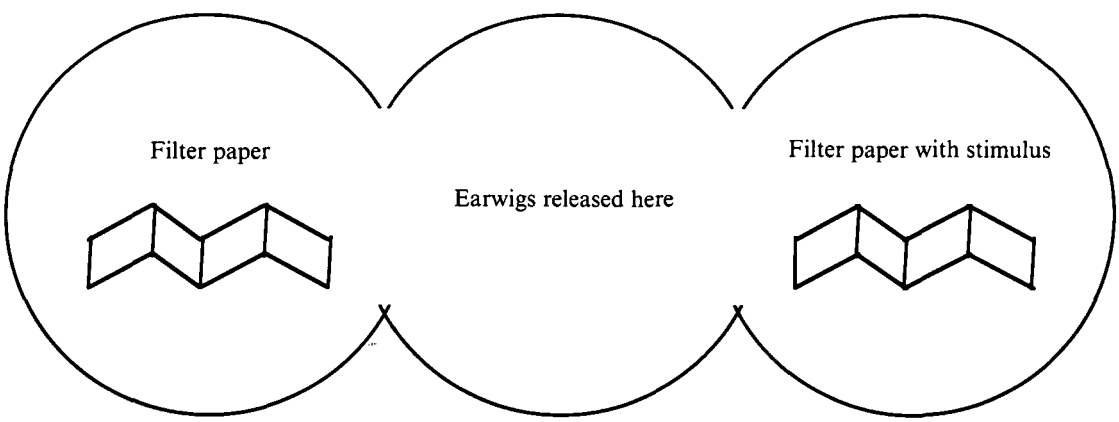

Fig. 1. Petri dish choice chamber used to measure aggregation of earwigs to filter papers exposed to earwigs or treated with hexane extracts of earwigs.

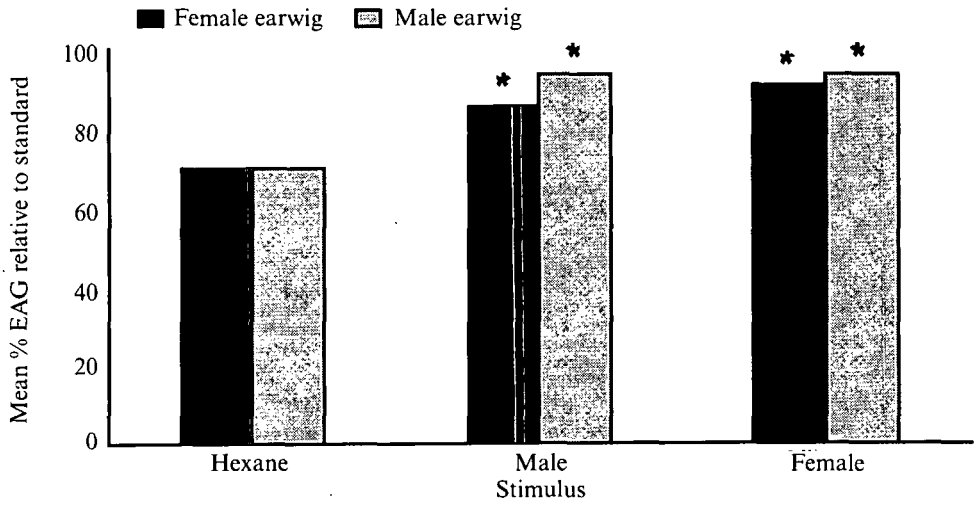

Fig. 2. EAGs obtained from female and male earwig antennae to hexane extracts of whole male and female earwigs. * indicates significantly different response from that to hexane alone ($p < 0.05$, Analysis of Variance)

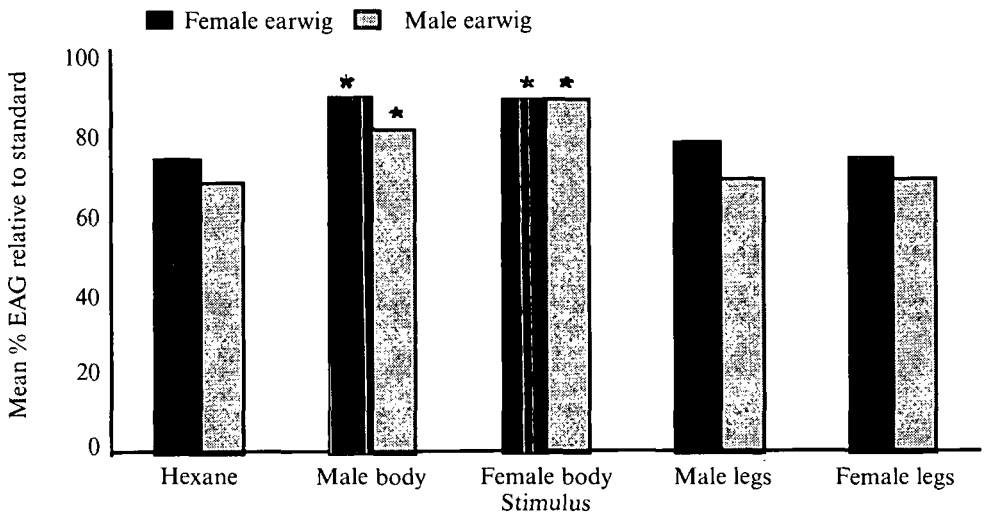

Fig. 3. EAGs obtained from female and male earwig antennae to hexane extracts of bodies (minus legs) of male and female earwigs, and extracts of male and female legs. *indicates significantly different response from that to hexane alone ($p < 0.05$, Analysis of Variance)

(Table 1). Hexane extracts of male and female earwigs also elicited significant levels of aggregation. Hexane extracts of male or female legs did not elicit any behavioural response, but female abdomen extracts did elicit aggregation in female earwigs (Table 1).

DISCUSSION

Both male and female earwigs produce a volatile stimulus, detectable by earwig antennae, which is produced within the body of the insect. Hexane extracts from as few as 10 earwig bodies elicited significant EAGs from earwig antennae and caused aggregation in behavioural studies. A hexane extract of female abdomens elicited aggregation in female earwigs, suggesting that the abdomen may be the source of the aggregation pheromone. These results confirm the observations of

Table 1. Response of earwigs to impregnated filter paper in a choice chamber

Sex	Stimulus	No. treated:untreated	Aggregation index
Female	Control	17:17	0
Female	Male	23:6	+ 0.59[a]
Female	Female	20:9	+ 0.38[a]
Female	Hexane control	12:13	+ 0.04
Female	Male body extract	25:3	+ 0.79[a]
Female	Male legs extract	12:12	0
Female	Female body extract	20:5	+ 0.60[a]
Female	Female legs extract	11:9	+ 0.10
Female	Female abdomen extract	17:7	+ 0.41[a]
Male	Male	23:4	+ 0.704[a]
Male	Female	24:4	+ 0.714[a]
Male	Female body extract	15:7	+ 0.36[a]
Male	Female legs extract	10:11	- 0.04

[a]Significant aggregation to stimulus, $p < 0.05$ (Chi-square test)

Sauphanor (1992) and Walker *et al.* (1993) that earwigs produce an aggregation pheromone, however the data also contradicts some of their observations. Walker *et al.* (1993) found that male earwig extracts alone elicited aggregation behaviour, whereas our results, both from an electrophysiological and behavioral perspective, demonstrate that both sexes produce compounds that elicit aggregation. Walker *et al.* (1993) only tested adult earwigs, whereas in our studies, earwigs were not segregated into adult or nymphal stages. Sauphanor (1992) suggested that the source of the pheromone may be the tibial glands of the legs, as extracts of amputated legs caused aggregation to occur. Our data agrees with results obtained by Walker *et al.* (1993) that the cuticle of the body is the source of the pheromone, as leg extracts were not active either electrophysiologically or behaviourally.

The aggregation pheromone would explain the reported clumped distributions of European earwigs (Behura, 1956; Lamb, 1975) and why they are found in broods overwinter. Their aggregating behaviour would also explain their perceived status as a pest both in urban and crop situations. However this aggregation is also beneficial in terms of their role as predators of aphids, mites, insect eggs and young caterpillars, as they will aggregate in areas of higher prey density rather than low prey density. Earwigs have been shown to play a major role in limiting pest populations in orchards (Carroll and Hoyt, 1984; Mueller *et al.*, 1988; Lenfant *et al.*, 1994) and vineyards (Buccholz and Schruft, 1994), and Asante (1995) found that the European earwig was a more efficient predator than two coccinellid beetles commonly thought of as effective natural predators.

Identification of the earwig aggregation pheromone may allow us to exploit the earwig as a biocontrol agent, and also to limit its potential as an urban pest. Traps baited with aggregation pheromone and a food source could be placed in urban areas and collected after a few days. The pheromone traps (without the food source) may then be placed in orchards, vineyards, glasshouses to allow enhancement of the earwig population in those areas and subsequent predation on pests such as aphids. As earwigs seek shelter during the day, the pheromone baited traps will also act as a refuge for the earwigs, keeping them within that area. During the growth stage of the crop (such as apple blossom) when the earwigs could be damaging, the refuges can be removed until the crop has been harvested, after which the earwigs can be released back into the crop. If necessary, earwigs trapped in urban areas could be destroyed, but re-deploying them in orchards where they may be of great benefit is a more environmentally friendly use of this misunderstood insect.

ACKNOWLEDGEMENTS

Many thanks to Karen Walker of Virginia Tech, for her help and advice. V.L. was funded as an ERASMUS exchange student.

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