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Aggregation behavior in the European earwig: Response to impregnated shelters

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ABSTRACT

The European earwig *Forficula auricularia* Linnaeus (Dermaptera: Forficulidae) is a key predator of pests in pip fruit orchards; however, this insect can also cause economic damage in stone fruit crops. Pheromone-impregnated shelters may be useful to promote earwigs in orchards devoted to pip fruit and also to capture them in those used for stone fruit production. By using corrugated cardboard traps in four orchards during two years, we observed the aggregation behavior of European earwig in canopies. Under laboratory conditions, corrugated cardboard shelters impregnated by 0.2 individuals/cm^2 over one week attracted earwigs for 5 weeks within a range of 50 cm. Future field work should examine the potential of impregnated shelters to promote earwigs in pip fruit orchards and to remove them from stone fruit ones.

1. Introduction

The European earwig, *Forficula auricularia* Linnaeus (Dermaptera: Forficulidae), is an important predator in pip fruit (Asante, 1995; He et al., 2008; Lenfant et al., 1994; Nicholas et al., 2005), kiwifruit (Hill et al., 2005) and citrus (Piñol et al., 2010, 2009) orchards. However, given its omnivorous regime, this insect can damage shoots, leaves, flowers and fruits (Pollini, 2010), becoming a pest of stone fruit crops (Albouy and Caussanel, 1990; Cranshaw, 2000; Flint, 2012; Grafton-Cardwell et al., 2003; Kuthe, 1996) and vineyards, where in addition to its direct damage on berries, its frass can negatively influence the aroma and flavor of some wines (Burdet et al., 2013; Huth et al., 2011). The incidence and severity of earwig outbreaks has recently increased in peaches (*Prunus persica* (L.) Batsch var. *persica*), nectarines (*P. persica* (L.) Batsch var. *nectarine* (Aiton) Maxim. and *P. persica* (L.) Batsch var. *nucipersica* (Borkh.) Schneider), apricots (*Prunus* armeniaca L.) and cherries (*Prunus avium* L.), reaching in some cases 10–15% of damage in Mediterranean areas (Asteggiano and Vittone, 2013; Pollini, 2010; Saladini et al., 2012; Servei de Sanitat Vegetal, 2013). Therefore, earwig management practices should be adopted in accordance with the fruit crop. To control them in conventional production, growers spray orchards with commonly used pesticides such as chlorpyrifos and spinosad that have been reported to have lethal effects on European earwig (Fountain et al., 2013; Peusens and Gobin, 2008; Vogt et al., 2010). In organic production, alternative strategies such as mass trapping and exclusion by setting glue around the base of trunks are used (Alston and Tebeau, 2011; Saladini et al., 2012).

The European earwig is a thigmotactic insect that shelters during the day and forages at night (Albouy and Caussanel, 1990; Burnip et al., 2002). It is usually found in clusters across the orchard, taking refuge in shelters previously occupied by earwigs (Sauphanor and Sureau, 1993). In laboratory experiments, this insect has been observed to aggregate, which is postulated to be elicited by a pheromone (Evans and Longépé, 1996; Hehar et al., 2008; Sauphanor, 1992; Sauphanor and Sureau, 1993; Walker et al., 1993). Gregarious behavior confers protection against predators, increases mate encounters, and enhances juvenile growth and development (Antony et al., 1985; Fuchs et al., 1985; Sauphanor and Sureau, 1993; Walker et al., 1993).

Laboratory experiments revealed that females, males, and nymphs produce and respond to an airborne aggregation pheromone; however, its source and composition are still under debate (Evans and Longépé, 1996; Hehar et al., 2008; Sauphanor, 1992; Walker et al., 1993). Sauphanor (1992) suggested that the pheromone was segregated on tibial glands, while Walker et al. (1993)

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associated it with fecal excreta and cuticular lipids. Evans and Longépé (1996) reported that leg extracts were not active and pointed to the body cuticle as the source of the pheromone, whereas Hehar et al. (2008) observed that neither fresh frass extracts nor body washes elicited significant responses. Although the source and composition of the pheromone remains unclear, Hehar et al. (2008) proposed that this chemical cue is perceived by olfaction rather than by contact chemoreception, and Evans and Longépé (1996) had already determined that it was detectable by the antennae.

Evans and Longépé (1996), Sauphanor and Sureau (1993) and Hehar et al. (2008) observed that filter papers, cardboard shelters, and paper-towel disks previously in contact with European earwig individuals elicited aggregation behavior. In this regard, the use of corrugated cardboard shelters in pear orchards has been reported to increase populations of European earwig which results in a reduction of the densities of pear psylla *Cacopsylla pyri* L. (Hemiptera: Psyllidae) (Solomon et al., 1999). Suckling et al. (2006) suggested that high populations of earwigs may significantly contribute to biological control. Earwigs have been shown to be predators of pests such as woolly apple aphid (WAA) *Eriosoma lanigerum* Hausmann (Asante, 1995; Mueller et al., 1988; Nicholas et al., 2005), and green apple aphid *Aphis pomi* DeGeer (both Hemiptera: Aphididae) (Carroll and Hoyt, 1984; Hagley and Allen, 1990), apple leaf-curling midge *Dasineura mali* Kieffer (Diptera: Cecidomyiidae) (He et al., 2008) and diaspidid scale insects (Hemiptera: Diaspididae) (Hill et al., 2005; Logan et al., 2007).

In pip fruit, growers have tried with little success up to now, to enhance earwig populations (Moerkens et al., 2009). While the pheromone emitted by earwigs is not commercially available, shelters impregnated with the aggregation pheromone by maintaining earwig individuals in contact with them for some time may be useful for this purpose. Impregnated shelters might be also useful to capture individuals in stone fruit orchards. However, such applications are hindered because there is no method to ensure long-term impregnation of shelters for this purpose.

Here we evaluated the aggregation behavior of the European earwig in field conditions; determined in the laboratory the number of earwigs required to impregnate a shelter, the duration of such impregnation, and the distance at which the insect can respond to the pheromonal signal emitted by these shelters.

2. Materials and methods

2.1. Aggregation behavior in field conditions

The trials were performed in the following four apple orchards located in Catalonia (NE Spain): Les Borges Blanques (41°30′23.06″N; 0°51′05.93″E), Mollerussa (41°36′51.13″N; 0°52′22.75″E), Ivars d'Urgell (41°41′06.19″N; 0°58′06.09″E), and Miralcamp (41°36'31.89″N; 0°52'24.62″E). All orchards were under organic management. To evaluate earwig aggregation behavior, 10 cardboard traps per orchard were set up in the canopy of trees (one trap per tree). For this purpose, a piece of corrugated cardboard was rolled into a cylinder (12 cm height × 9 cm diameter) and inserted into a PVC tube (15 cm height × 9.5 cm diameter) to protect it from rain and adverse conditions. Similar traps have been used in studies of European earwigs (Burnip et al., 2002; Gobin et al., 2006; He et al., 2008; Helsen et al., 1998; Logan et al., 2007; Moerkens et al., 2009; Phillips, 1981; Solomon et al., 1999). Every week from mid March to the end of August in 2012 and 2013, we recorded the number and phenological stage of *F. auricularia* in each trap. As two earwig species were found, absence of wings in *Forficula pubescens* Gené was used to distinguish adults from those of *F. auricularia*; while to distinguish the nymphs we took into account the size, colour and setae type of the cerci (Albouy and Caussanel, 1990). The number of antennal segments and presence of wing buds on the 3rd segment of the thorax were used to distinguish nymph stages (Albouy and Caussanel, 1990). After identification and enumeration, insects were released at the base of the assessed tree.

2.2. Aggregation pheromone trials

The European earwigs used in the experiments were collected with cardboard traps from Les Borges Blanques and Ivars d'Urgell orchards in 2011. They were fed *ad libitum* on a semi-artificial diet (Eizaguirre and Albajes, 1992) and kept in colonies under a 16:8 h light/dark cycle at 25 ± 3 °C and 75 ± 5% RH.

2.2.1. Shelter impregnation by the aggregation pheromone

The shelters used in the experiments were prepared by rolling a piece of corrugated cardboard into cylinders (5.5 cm height × 3 cm diameter). Earwigs were confined with the cardboard cylinders in plastic containers (14 × 10 × 20 cm).

To determine the minimum number of earwigs needed to impregnate shelters, we performed tests with 10, 20 and 40 individuals (with equal number of males and females). The gender of earwigs was determined by dimorphism of the cerci (Albouy and Caussanel, 1990). Each group of earwigs (pheromone group, PG) was placed in a plastic container, together with a shelter, and 2 g of semi-artificial diet during one week; then the earwigs and food were removed and the shelter was considered 'impregnated'.

To evaluate the attraction of pheromone-impregnated shelters, 10 earwigs (5 males and 5 females) were used (evaluation group, EG). At 3.00 p.m. on the day before the assessment, the EG was put in plastic containers with a semi-artificial diet until 8.00 a.m. on the following day (day of assessment). The EG was used in a choice test the day of assessment. This experiment consisted of placing an impregnated pheromone shelter (P) and a non-impregnated shelter (C) at the opposite ends of a rectangular plastic container (30 × 20 × 10 cm), releasing the EG at its center.

To prevent any effect of orientation, the relative position of shelters was reversed for each replication. Seven hours later, still during the photophase, the number and the gender of earwigs in each shelter were recorded. The impregnated shelters were kept individually in plastic containers without earwigs until they were used again in the next test to evaluate duration of the effect. The first test was always performed the day after the impregnation week. The time between tests was 1 week in shelters impregnated by 10 or 20 earwigs. For 40 individuals, there were 3 weeks between the first and the second test; from this on, tests were performed fortnightly. Tests were carried out until no effect was detected for 2 consecutive tests. Before and after each evaluation, containers were cleaned with 99% ethyl alcohol. Earwigs belonging to the EG and PG were randomly obtained from laboratory colonies. We performed four replicates for each treatment.

2.2.2. Range of pheromone perception

Following the same method described in Section 2.2.1, new shelters impregnated with pheromone by 40 European earwigs over one week were used in this experiment. To evaluate the range of pheromone attraction, a P shelter and a C shelter were placed at opposite ends of a plastic channel (250 cm long × 13.5 cm diameter). The channel was set up in a room with no air current. An EG was released at an equal distance from each shelter. The number and the gender of earwigs in each shelter were recorded 15 min after their release. The earwigs were released at four distances from the shelters: 10, 25, 50 and 100 cm. Before and after each evaluation, the plastic channel was cleaned with 99% ethyl alcohol. Earwigs belonging to the EG were randomly taken from the laboratory