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Original Article

The potential of *Labidura riparia* and *Euborellia annulipes* (Dermaptera) as predators of house fly in livestock

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Abstract

The potential of the predatory earwigs *Labidura riparia* (Pallas) and *Euborellia annulipes* (Lucas) (Dermaptera) as biological control agents of house fly was assessed. Host preferences and effects of feeding depth were evaluated. The results indicated that both earwig species preferred house fly larvae rather than pupae. Host preference experiments indicated that *L. riparia* and *E. annulipes* preferred first larval instar followed by second and third larval instars, respectively. Feeding depth studies from 0 – 20 cm in cattle manure found that *E. annulipes* consumed more larvae than *L. riparia* and that more larvae were consumed at a depth of 0 – 5 cm than at 10 – 20 cm below. In summary, two species of earwigs have the potential for controlling immature stages of house fly in the livestock.

Keywords: earwig, biological control, Muscidae, livestock, predator

1. Introduction

House fly (*Musca domestica* L. Diptera: Muscidae) is a major pest of livestock and urban areas. Although, it is not a biting insect, it is a major carrier of diseases such as enteric infections (dysentery, diarrhea, typhoid, anthrax and cholera) viral infections (poliomyelitis, hepatitis) and certain helminth infections in livestock. It can cause contamination of animal products such as milk and meat (Kettle, 2000) and population outbreaks in the summer season can cause nuisance and stress to animals, which diminishes the economic value of animal-derived products. Additionally, an abundance of house flies can cause nuisance to livestock farmers and to people in their neighborhood area (Dogra & Aggurwal, 2010).

Livestock areas are the most important breeding sites for house flies because livestock manure provides food for the development of their immature stages. The high quantities of manure produced in poultry farms and by nursing calves provide especially ideal environments for the house fly (Khan *et al.*, 2012). Insecticides such as the synthetic pyrethroid, cyromazine, and the neurotoxic 2,2-dichlorovinyl dimethyl phosphate (DDVP) have been applied to reduce house fly infestation in some areas (Acevedo, Zapater & Toloza, 2009). However, this solution has resulted in the development of insecticide resistance and has adverse health effects on farmers and livestock animals as non-target organisms (Scott *et al.*, 2013).

Biological control is an environmentally friendly method. Some natural enemies of housefly have been reported, for example, pupal house fly parasitoids (including *Spalangia cameroni* Perkins, *S. endius* Walker, and *Pachycrepoideus vindemmiae* Rondani), (Apiwathnasorn, 2012), fungi, *Entomophthora muscae* Fresen (Zurek, Watson, Krasnoff & Schal, 2002) and entomopathogenic nematodes (Taylor, Szalanski, Adams, & Peterson, 1998). Most of the natural enemies are imported to new areas of infestation and some are specific for individual developmental stages of the house fly (e.g. pupal house fly parasitoids). Furthermore, some natural enemies have limitations; for example, attacks by most house fly parasitoids are most effective with hosts at a depth of 1 – 5 cm (Geden, 2002) although many host pupae are found at depth up to 10 cm.

Two species of earwigs, *Labidura riparia* (Pallas) and *Euborellia annulipes* (Lucas) are commonly found in livestock manure in Thailand. They are polyphagous predators (Bassal *et al.*, 2001), which occur buried inside the manure

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where they find food and deposit their eggs. They can complete their life cycle entirely within the livestock area. Both these earwigs are efficient predators of many insect pests. *Labidura riparia* has been reported as a predator of maize aphid (Asin & Pon, 1998), *Thrips tabasi* Lind., *Empoasca* sp. (Ahmed & Darwih, 1991), *Bemisia tabaci* (Gennadius) (Darwish & Farghal, 1990), *Drosophila suzukii* (Matsumura) (Gabarra, Riudavets, Rodrı´guez, Pujade-Villar, & Arno, 2015), and red palm weevil (*Rhynchophorus ferrugineus*, Olivier) (Abdel-Salam, EL-Bana, & El-Rehewy, 2014). *Euborellia annulipes* is also an important predator that has been reported as a natural enemy of Lepidoptera pests in sugarcane, immature caterpillars, cotton boll weevil (Lemos, Ramalho, & Zanuncio, 2003) and *Plutella xylostella* (L.) (Nunes *et al.*, 2019). Earwigs are able to penetrate through small holes in plants in search of prey and for this reason they are interesting predators of insect pests. Some larval and pupal stages of house fly are found underneath the manure. Therefore, earwigs may play an important role consuming hidden prey.

In a recent study, Guimaraes, Tocci, and Gomes (1992) reported that *L. riparia* and *E. annulipes* were having a biological control effect at a poultry farm. However, some aspects of their behavior in animal manure, especially their prey preferences for different house fly stages and their potential for finding prey in the manure have not been reported. The objectives of this study were to 1) evaluate the potential of two earwigs species, *L. riparia* and *E. annulipes* as house fly predators in livestock, 2) to compare the prey preferences for the different house fly stages, and 3) to investigate the vertical distribution of predaceous earwigs seeking prey inside the manure.

2. Materials and Methods

2.1 Experimental insects

The experiments were conducted at the National Biological Control Research Center (NBCRC), Upper North eastern Regional Center, Khon Kaen University, Thailand. The experimental insect was maintained in the laboratory at room temperature, 28±5°C, and relative humidity of 60±10%. The house flies studied were from a colony (10th generation) and *L. riparia* and *E. annulipes* were from a colony (5^{th} generation) maintained at NBCRC, Upper Northeastern Regional Center.

2.2 Host preferences

2.2.1 Larva and pupa

The experiments were conducted in plastic cages of 15 cm x15 cm x 15 cm size with wire mesh on top. Ten house fly larvae and 10 house fly pupae were separated into 2 boxes (5 cm x 5 cm x 1.5 cm) containing cattle manure. The choice tests of prey preference were designed to include 20 trials for each earwig species. Before starting the experiments, adults of both earwigs species were not provided food for 12 hr. Then, one individual adult was transferred to the cage. Eating behavior was observed, and number and type of preys consumed were recorded after 24 hr. Data were analyzed by paired t-test (SAS Institute, 2001). Manly's preference index (Manly, 1974; Nunes *et al.*, 2019) was used to confirm the prey stage preference by the predator.

$$\beta 1 = log(\frac{e_1}{A_1})/\left[log(\frac{e_1}{A_1}) + log(\frac{e_2}{A_2})\right]$$

where β_1 is the preference for prey type 1 (larva),

e_1 is the number of prey type 1 (larva) remaining after study,

e_2 is the number of prey type 2 (pupa) remaining after study

A1 is the initial number of prey type 1. A2 is the initial number of prey type 2

The value of the preference index can range from 0 to 1. β_1 close to 1 indicates a preference for prey type1, whereas, β_1 close to 0 indicates preference for prey type 2. β_1 = 0.5 indicates no preference.

2.2.2 Larval instars

Eight each of 1^{st}, 2^{nd} and 3^{rd} instar larvae were randomly placed in a plastic tray with 24 circular wells. Cattle manure was placed on the top of the wells. Each plastic tray was transferred to a plastic cage (15 cm x 15 cm x 15 cm) and the tray was covered with cattle manure (to a depth of 2 cm). Adults of *L. riparia* and *E. annulipes* were starved for 12 h before the experiment. One individual adult was transferred into each experimental cage. After 24 h, the number of each larval instar consumed by each individual earwig was recorded. The experiments were conducted with 20 replications for each earwig species.

Data on larval instars consumption by earwig species were analyzed by ANOVA using PROC GLM (SAS Institute, 2001) to determine significance. Results with significance in the ANOVAs were post-tested by Duncan's Multiple Range Test (P=0.05) using SAS (SAS Institute, 2001).

2.2.3 Effects of depth on predation

Ten first instar house fly larvae were embedded in cattle manure in cylindrical glass tubes (20 cm height x 10 cm diameter) at depths 0, 5, 10, 15 and 20 cm in separate tubes. One individual 12 h-starved adult earwig was transferred into each tube and the behavior of the earwig observed. After 24 h, number of prey items consumed by each individual earwig was determined. The experiments included 20 replicates for each earwig species and prey consumption at different depths was analyzed by ANOVA using PROC GLM (SAS Institute, 2001) to determine significance. Results with significance in the ANOVAs were post-tested by Duncan's Multiple Range Test (P=0.05) using SAS (SAS Institute, 2001).

3. Results and Discussion

3.1 Host preferences

3.1.1 Larvae and pupae

There was significant differences in consumption of larvae between *L. riparia* and *E. annulipes* (Table 1). Manly's indexes of 0.92 and 0.98 confirmed that *L. riparia*

Table 1. Comparison of average prey consumption of house fly larvae and pupae by *Labidura riparia* and *Euborella annulipes*

Earwig species	n	House flies consumed (mean±SD)[a, b]		Manly's index
		larva	pupa	
Labidura riparia	20	7.40±2.11bA	0.85±0.96aB	0.92
Euborella annulipes	20	9.25±0.99aA	1.15±1.28aB	0.98

[a] Within each row, values followed by the same capital letter are not significantly different (P>0.05)
[b] Within each column, values followed by the same small letter are not significantly different (P>0.05)

and *E. annulipes* preferred larvae over pupae. Even though *E. annulipes* are smaller than *L. riparia*, the daily food consumption of *E. annulipes* was greater. A significant difference was found between consumption of larvae and pupae with both earwig species preferring larval rather than pupal house flies. These data are similar to the results for *L. riparia* when feeding on the dipteran *Drosophilla suzukii* (Gabarra *et al.*, 2015), in which the number of *D. suzukii* larvae consumed by adults of *L. riparia* (9.1 – 9.6 larvae) was higher than of *D. suzukii* pupae (6.1 – 7.7) in different experimental trials. In contrast *L. riparia* preferred pupae rather than larvae of the lepidopteran *Galleria mellonella* (Abd-Elgayed and Owayss, 2007). Unlike the pupae of Lepidoptera, puparia of house flies are coarctate (enclosed in a hardened cuticle) which may be an important factor determining different prey preferences of earwigs.

3.1.2 Larval instars

Statistical analysis showed significant differences among consumption of 1st, 2nd, and 3rd larval instars by earwig species. The first larval instar of house fly was preferably consumed by *L. riparia* and *E. Annulipes*, followed by 2nd and 3rd larval instars in rank order (Table 2). The mean numbers of individuals consumed of 1st, 2nd and 3rd larval stages of house fly by *L. riparia* were 6.4, 4.95 and 2.5, whereas *E. annulipes* consumed 8.25, 6.2 and 2.4, respectively. These results were different from those of *L. riparia* feeding on *Rhynchophorus ferrugineus* (red palm weevil), in which case all immature stages were equally preferred (Abdel-Salam *et al.*, 2014). Langston and Powell (1975) reported that tropical species of earwigs are predaceous insects, especially favoring soft larvae. Soft-bodied newly-hatched larvae may be easier to catch and consume than hardened ones.

3.1.2 Effects of depth on predation

E. annulipes consumed more prey items than *L. riparia* at various depth from 0 –20 cm in cattle manure (Table 3). More larvae at depths of 0 – 5 cm from manure surface were preyed upon by both species of earwigs than at depths of 10 – 20 cm. The efficiency of *L. riparia* finding prey was significantly decreased at the depth of 20 cm, whereas that of *E. annulipes* at the depth of 10 – 20 cm was not significantly affected. Xiuqin, *et al.* (2010) found that Muscidae larvae are a common group of soil macrofauna observed in 0 – 10 cm soil depth. Tahir and Ahmad (2013) reported that third instar immature housefly could be collected at up to 60 cm depth of soil, depending on moisture content and soil compaction. Therefore, earwigs may not eradicate house flies from deep soil. However, they are effective for controlling house fly larvae near the soil surface.

Both species of earwigs, *E. annulipes* and *L. riparia* are usually found in cattle farm areas and they are natural predators of house fly in an immature stage. From the results of this current study, they are efficient in consuming young larvae and in finding prey at the various depths of manure, especially *E. annulipes*. Therefore, these predators can enable good biological control in a farm area.

Table 2. Average consumption of different house fly larval instars by *Labidura riparia* and *Euborella annulipes*

Earwig species	n	House fly instars consumed (mean±SD)[a, b]		
		1st	2nd	3rd
Labidura riparia	20	6.4±1.27bA	4.95±1.95aB	2.50±1.10aC
Euborella annulipes	20	8.25±1.89aA	6.20±2.69aB	2.40±2.80aC

[a] Within each row, values followed by the same capital letter are not significantly different (P>0.05)
[b] Within each column, values followed by the same small letter are not significantly different (P>0.05)

Table 3. Average consumption at various depths in cattle manure of larvae of house fly by *Labidura riparia* and *Euborella annulipes*

Depth (cm)	n	*Labidura riparia* (mean±SD)[a, b]	*Euborella annulipes* (mean±SD)
0	20	7.05±1.47aB	8.9±1.02aA
5	20	6.80±2.14aA	8.0±2.45aA
10	20	2.65±2.18bB	6.05±2.14bA
15	20	3.00±1.45bB	6.20±1.77bA
20	20	1.30±1.13cB	5.05±1.57bA

[a] Within each row, values followed by the same capital letter are not significantly different (P>0.05)
[b] Within each column, values followed by the same small letter are not significantly different (P>0.05)

4. Conclusions

Two species of earwigs, *L. riparia* and *E. annulipes* have the potential for controlling immature stages of house fly. They could provide positive reinforcement for decreasing house fly numbers in the larval stage by releasing them alongside pupal house fly parasitoids. *E. annulipes* is more suitable as a biological control agent to control house fly larvae than *L. riparia* because of its more efficient consumption of larvae and its ability to find prey at various depths of manure. Earwig release may help larval control during high density of houseflies in the summer.

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