

## Impact of host food plant on parasitization behaviour in a larval parasitoid of *Heliothis armigera* (Hubner)

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**Abstract.** The sequence of host seeking and stimuli involved in them for the larval parasitoid was *Eriborus argentipilosus* and its host *Heliothis armigera* are discussed through a series of experimental observations. In such a sequence of behaviour the step-by-step release of the different responses tending to contribute to the efficiency of host finding are explained.

**Keywords.** Parasitization behaviour; larval parasitoid; *Heliothis armigera*; Parasitoid-host-plant system; insect-plant relationship.

### 1. Introduction

As parasitoids are important for the regulation of host populations and their use in the biological control of insect pests, there is a strong and persistent interest in the population dynamics of parasitoid-host-plant systems. Various stimuli aid entomophagous parasitoids in finding and recognizing hosts. In the host selection of parasitic hymenoptera, usually visual and/or chemotactile stimuli (Vinson and Lewis 1965; Arthur 1966; Corbet 1971) are involved.

The role of chemicals in insect-plant relationship has received much attention, the importance of other cues and sensory modalities has gone relatively unexplored (Herrebut 1969). Very few workers have published the data concerning the chemical stimuli that elicit parasitization behaviour. Noteworthy among them are Dethier (1947), Arthur (1969), Arthur *et al* (1972), etc. The chemical stimuli in such behaviour have been identified (Vinson *et al* 1975). Vinson (1976) outlined specific mechanisms whereby parasitoids may be able to utilize oligophagous hosts on only a part of their food plant range. However, these chemicals have usually not been behaviourally assayed as a part of the host finding sequence, notwithstanding that they are assumed to be not merely attractive but also to play a part in controlling different steps of the behaviour.

The specificity of behavioural response exemplified by oligophagous insect species for odours typifying their host plants, suggests some specialized tuning of their olfactory receptors located in the antennae. The evidence has been presented indicating that the oligophage responds to a specific blend of green leaf volatiles, released by potato (Richerson and Borden 1972). Jones *et al* (1973) have reviewed earlier work on host odours. The kairomones are transpecific chemical messengers, the adaptive benefits of which favour the recipients rather than the emitters (Brown *et al* 1970). Literature on the role of kairomones in host finding of entomophagous parasitoids is accumulating.

The visual stimuli are the most important factors in host selection and the parasitoid attacks, if the host is moving and is red or black (Richerson and Deloach 1972). Some species can recognise a suitable host by piercing it with the ovipositor (Salt 1935; Jackson 1928; Weseloh 1974; Wylie 1965). While, some species detect

their hosts by perception of sound or vibrations produced by host larvae (Deleon 1935). The host finding is also related with thermal (temperature) or infrared radiation stimulus (Richerson and Borden 1972).

The subcortical and wood boring insects find and oviposit into or on hosts through plant tissues. However the mechanisms are little understood (Richerson and Borden 1972).

Generally, the female parasitoids are attracted by the food plant leaf of their host and are stimulated by it to start searching; further stimulation from new damage by host larvae releases excitement behaviour and continued intensive searching (Sato 1979). In the close vicinity of a host, orientation of antennae occurs and finally stabbing. In such a sequence of behaviours, the step by step release of the different response may contribute greatly to the efficiency with which hosts are found. The present study analyses both, the sequence of host seeking and the stimuli involved in them for the parasitic wasps, *Eriborus argenteopilosus* (Cameron) and its host, *Heliothis armigera*.

## 2. Materials and methods

The laboratory cultures of *E. argenteopilosus* was used. The experiments were conducted in glass cages and test tubes (19 × 2.5 cm) at room temperature (25 ± 1°C and 60 ± 6% RH). In each experiment 20 mated female parasitoids were exposed. Because of the diverse nature of the experiments, methods and results of each of the foregoing experiments are presented separately wherever appropriate. The adult parasitoids were fed with 50% honey and host larvae with respective food plant parts. The main food plants of the *Heliothis* was grown out of doors. Other food plants were tested as indicated in the text, either cultivated in the laboratory or collected from the field during the experiments. The leaf pieces measuring 1.5 × 1.5 cm were used in the experiments.

## 3. Results

### 3.1 Behaviour of female on food plant: sequence of host seeking behaviour

The young pigeon pea plant (1-month old) was kept in a glass cage and observations on the seeking behaviours of 20 mated females were made.

Firstly, she came in contact with the leaf, further performed walking movements over the leaf and tapped the leaf surface 2–3 times with antennae. Then raised the wings and performed movement of third pair of legs. When she came across the food plant leaves damaged by host larvae, has performed intensive searching and stabbing intention movements. The presence of a 2nd instar host larva immediately brought about oviposition. When landed on a healthy leaf she searched for about 22" and then flew away.

### 3.2 Food plant factors eliciting searching behaviour

3.2a Responses to different food plant leaves (Expt. 1): For the experiment chick pea, pigeon pea, lady's finger, cabbage, cauliflower and tomato were used as host

food plants. Pieces of respective food plant leaf (about  $1.5 \times 1.5$  cm except for chick pea  $1 \times 0.5$  cm) were kept in each test tube with a female parasitoid and observations were noted. With pigeon pea leaves maximum (100%) females have performed searching movements (mean search:  $34.75 \pm 6.77''$ ) while, with cabbage leaf piece minimum searching (45%) was recorded (mean search:  $10.44 \pm 2.72''$ ). None of the parasitoids have performed searching movements on chick pea leaf (table 1).

3.2b *Responses to females to food plant parts (Expt. 2)*: To find out the favourite searching site of female parasitoids, pigeon pea leaf, flower bud and pod were cut into same size ( $1.5 \times 1.5$  cm) and exposed to them. The results (table 2) indicate that 100% females have searched on leaf piece while 75% of them have searched on flower bud and 60% on pod. As the optimum searching was noted on leaf pieces (mean search:  $34.75''$ ) hence, used in further experiments to observe the behavioural responses.

3.2c *Responses to cellophane wrapped leaves (Expt. 3)*: Pieces of pigeon pea leaf ( $1.5 \times 1.5$  cm) were wrapped with cellophane and exposed to female parasitoids. The parasitoids have not responded to them. The wrapped leaf was neither attractive nor repulsive. It seems that females were unable to locate a food plant leaf by visual stimuli.

3.2d *Responses to collodionized leaves (Expt. 4)*: With the exposure of collodionized leaves, 25% female parasitoids have performed searching movements. When these leaves were washed with ether and their further exposure resulted in searching in 80% of the parasitoids (table 3). These parasitoids have searched for a mean period of  $10 \pm 2.19''$  and  $21.65 \pm 2.79''$ . After removing the ether the females have shown orientation of antennae, vigorous movements of third pair of legs,

**Table 1.** Responses of female, *E. argenteopilosus* to different food plant leaves of *H. armigera*.

Food plant	n	Females searched (%)	Mean search $\pm$ SE
Pigeon pea	20	100	$34.75 \pm 6.77''$
Chick pea	20	0	—
Tomato	20	80	$25.15 \pm 4.77''$
Lady's finger	20	80	$17.85 \pm 4.67''$
Cauliflower	20	70	$12.6 \pm 4.66''$
Cabbage	20	45	$10.44 \pm 2.72''$

**Table 2.** Responses of female, *E. argenteopilosus* to host food plant parts.

<i>C. cajan</i>	n	Females searched (%)	Females performed stabbing intention movements (%)	Mean search $\pm$ SE
Leaf	20	100	—	$34.75 \pm 6.77''$
Flower bud	20	75	—	$21.4 \pm 3.53''$
Pod	20	60	—	$14.08 \pm 3.45''$

**Table 3.** Responses of female, *E. argenteopilosus* to collodionized pigeon pea leaf.

Leaf	n	Females searched (%)	Mean search $\pm$ SE
Clean (control)	20	100	34.75 $\pm$ 6.77"
Collodionized	20	25	10.0 $\pm$ 2.19"
Collodion ether removed	20	80	21.65 $\pm$ 2.79"

**Table 4.** Responses of female, *E. argenteopilosus* to filter treated variously with ether extracts of pigeon pea leaf.

	n	Females searched (%)	Females performed stabbing intention movements (%)	Mean search $\pm$ SE
Paper with extract of intact healthy leaf	20	100	85	24.55 $\pm$ 4.7"
Paper with ether alone	20	0	0	—

followed by flying movements toward the leaf. Further, they performed vigorous searching movements, but did not exhibit stabbing intention movements.

3.2e *Responses to leaf extracts on filter paper (Expt. 5):* The results (table 4) showed that all females (100%) have performed searching movements (mean search: 24.55  $\pm$  4.7") by orientation of antennae and vibrating the wings. Eighty five per cent of them have shown excited behaviour and followed by stabbing intention movements. Females did not show response to filter paper treated with ether alone. The factors responsible here for bringing the intensive searching and stabbing intention movements were chemical.

### 3.3 Damaged leaf factors eliciting responses

3.3a *Responses to leaves damaged by H. armigera larvae (Expt. 6):* With the leaves of pigeon pea, chick pea, lady's finger, cauliflower, cabbage, tomato damaged by host, females have performed absolute searching (100%) and stabbing intention (100%) movements on pigeon pea leaf (mean search: 50.5  $\pm$  12.02"). The minimum searching and stabbing intention movements were recorded with tomato leaves (mean search: 20.2  $\pm$  6.71"). Whereas, female parasitoids did not show searching and stabbing intention movements on chick pea leaves (table 5).

3.3b *Responses to damaged leaf extracts on filter paper (Expt. 7):* All females have performed intensive searching movements by orienting and drumming movement of antennae, vigorous leg movements, vibrating the wings (mean search: 41.75  $\pm$  3.76"). Eighty per cent have performed stabbing intention movements by performing up-and-down movements of abdomen, vigorous vibration of wings, etc. With the exposure of extract of an intact leaf cut into the filter paper size, only 70% females

**Table 5.** Responses of female, *E. argenteopilosus* to leaves damaged by larvae, *H. armigera*.

	n	Females searched (%)	Females performed stabbing intention movements (%)	Mean search $\pm$ SE
Pigeon pea	20	100	100	50.5 $\pm$ 12.02"
Chick pea	20	0	—	—
Lady's finger	20	80	45	33.65 $\pm$ 7.98"
Cauliflower	20	85	30	42.35 $\pm$ 4.63"
Cabbage	20	60	25	32.1 $\pm$ 4.31"
Tomato	20	40	15	20.2 $\pm$ 6.71"

**Table 6.** Responses of female parasitoids to damaged leaf extracts on filter paper.

	n	Females searched (%)	Females shown stabbing intention movements (%)	Mean search $\pm$ SE
Filter paper + ether extracts of damaged leaf	20	100	80	41.75 $\pm$ 3.76"
Filter paper + ether alone	20	—	—	—
Extract of cut leaf	20	70	45	25.2 $\pm$ 7.39"
Cut leaf	20	100	—	18.4 $\pm$ 4.20"

have performed searching movements (mean search: 25.2  $\pm$  7.39") and 45% of females have shown stabbing intention movements (table 6). The chemical stimuli that released from damaged leaf extract were responsible in bringing the searching and stabbing intention movements in female parasitoids.

**3.3c Responses to objects treated with saliva of host larvae (Expt. 8):** The females have shown 100% searching and 85% of them exhibited stabbing intention movements on the punched region of pigeon pea leaf (table 7). With saliva treated along with leaf edges, all parasitoids have performed searching movements (mean search: 28.6  $\pm$  7.5") and 75% of them have shown stabbing intention movements. When females came across with leaf piece whose surface was treated with host larval saliva, 85% of them have shown searching movements (mean search: 25.5  $\pm$  4.04") and 60% have performed stabbing intention movements. The filter paper which was treated in the above method was relatively less effective to saliva treated on leaves of pigeon pea (table 7). The factors that brought the exhibition of searching and stabbing intention movements were again olfactory.

**3.3d Responses to larval faeces (Expt. 9):** With the fresh wet faeces all females have performed intensive searching movements (mean search: 52  $\pm$  10.39") and 95% of them have shown stabbing intention movements. The dry faeces were

**Table 7.** Responses of female, *E. argenteopilosus* to objects treated with saliva of host larvae.

Treatment/saliva applied	n	Females searched (%)	Females shown stabbing intention movements (%)	Mean search $\pm$ SE
<b>Pigeon pea leaf</b>				
Edge	20	100	75	28.6 $\pm$ 7.5"
Around hole	20	100	85	33.85 $\pm$ 8.45"
Surface	20	100	60	25.5 $\pm$ 4.04"
Leaf without saliva	20	100	—	35.74 $\pm$ 6.77"
<b>Filter paper</b>				
Edge	20	70	45	23.2 $\pm$ 4.06"
Around hole	20	90	55	23.3 $\pm$ 7.18"
Surface	20	25	25	21.5 $\pm$ 5.59"
Filter paper without saliva	20	—	—	—

**Table 8.** Responses of female, *E. argenteopilosus* to faeces.

	n	Females searched (%)	Females performed stabbing intention movements (%)	Mean search $\pm$ SE
Fresh, wet faeces	20	100	95	52.0 $\pm$ 10.39"
Dry faeces	20	80	55	18.7 $\pm$ 4.06"

relatively less effective, because 80% of females have performed searching movements (mean search: 18.7  $\pm$  4.06") and 55% of them have performed stabbing intention movements. The olfactory stimuli that emanated from faeces of host larva were responsible for intensive searching and stabbing intention movements of female parasitoids (table 8).

3.3e *Responses to filter paper treated with pigeon pea leaf juice and saliva (Expt. 10):* With pigeon pea leaf juice and saliva, 100% females have performed intensive searching movements (mean search: 40.35  $\pm$  5.84") and 75% of them have shown stabbing intention movements. Similarly, with the control filter paper, all female parasitoids have performed intensive searching movements (mean 23.35  $\pm$  3.22") but, only 15% of them have shown stabbing intention movements (table 9).

#### 3.4 *Host larval factors eliciting attacking behaviour*

3.4a *Responses to host larvae (Expt. 11):* The close vicinity of a host larva brought about intensive searching movements and excitement in female parasitoids. By contacting the host larva female thrusts ovipositor in host's body by bending

**Table 9.** Responses of female, *E. argenteopilosus* to filter paper treated with pigeon pea, leaf juice and saliva of host larva.

	n	Females performed searching movements (%)	Females performed stabbing intention movements (%)	Mean search $\pm$ SE
Leaf juice	20	100	15	23.35 $\pm$ 3.22"
Leaf juice + saliva	20	100	75	40.35 $\pm$ 5.84"

the abdomen. The mean searching period among female was of 45". Their mean delay to a first oriented stabbing was  $10.4 \pm 2.4$ ".

Further, the host larvae were exposed to female parasitoids directly without any food plant leaves. The female was able to recognise the larvae only when they were in 2–4 mm distance. Female performed orientation of antennae and up-and-down movements of abdomen. Further, she moved closer to the host larva, grasped it and inserted her ovipositor into the abdominal segments of host's body. The average time required for first stabbing was  $18.2 \pm 3.8$ ". The factors responsible were both visual and olfactory in nature.

**3.4b Responses to host larva wrapped in cellophane (Expt. 12):** The female parasitoids have not performed any searching or exciting movements with host larva wrapped in cellophane. The results indicate that visual stimuli alone were not sufficient to bring about parasitization behaviour in the parasitoids.

**3.4c Responses to host larvae in the dark (Expt. 13):** The females have identified and oviposited in the host larva as they did in the presence of light. The stabbing occurred in  $22.8 \pm 2.2$ ". The factors responsible here were olfactory.

**3.4d Responses to leaves contaminated with host's odour (Expt. 14):** All females have performed vigorous searching and stabbing intention movements on the leaf surface. The mean searching period was  $52 \pm 3.4$ ". The females have performed vigorous antennal movements, leg movements and up-and-down abdominal movement, while doing so they brought their ovipositor in contact with leaf surface. The factors responsible were olfactory.

**3.4e Responses to filter paper treated with extracts of host larvae (Expt. 15):** The filter paper treated with ether extract of host larva was more effective than the ether washed larva. With ether extract, all females have performed searching and 75% of them have shown stabbing intention movements (mean search:  $24.1 \pm 2.38$ "). Whereas, only 60% of female have performed stabbing intention movements (mean search:  $13.55 \pm 2.81$ ") on larva washed with ether (table 10). The above results indicate that odours were mainly responsible for eliciting searching and stabbing intention movements in female parasitoids.

#### 4. Discussion

The main objective of a female parasitoid should be to locate and oviposit in or on

**Table 10.** Responses of female, *E. argenteopilosus* to filter paper treated with extracts of host larvae.

	n	Females performed searching movements (%)	Females performed stabbing intention movements (%)	Time to first stab	Mean search $\pm$ SE
Intact larva	20	100	100	10.4 $\pm$ 2.4	13.55 $\pm$ 2.81"
Larva washed with ether	20	100	60	18.24 $\pm$ 1.4	16.83 $\pm$ 1.72"
Filter paper + ether extract	20	100	75	16.46 $\pm$ 2.1	24.1 $\pm$ 2.38"
Filter paper ether	20	—	—	—	—

to its host. Unless emergence occurs alongside a suitable host, the parasitoids respond to a series of environmental cues which lead the parasitoid towards appropriate habitat, host locality (food plant) and host and stimulate to oviposit (Vinson 1977).

The experimental proof of habitat selection was provided by Laing (1937) in the braconid, *Alysia manducator* Panzer. Attraction of ovipositing females to the food plant of phytophagous hosts has been shown for the ichneumonid, *Pimpla ruficollis* (a parasitoid of Lepidoptera larvae) (Thorpe and Caudle 1938) and among the Diptera for the tachinid, *Drino bohémica* Mesn parasitoid of sawfly larvae (Monteith 1955, 1964), and *Eucarcelia rutilla* Vill, a parasitoid of Lepidopteran larvae (Herrebut and Van den Veer 1969). Stray (1964) described the role of aphid's host plant for those parasitoids in the family Aphidiidae. Mackauer (1965) suggested that aphid parasitoids may respond to signs of aphid damage and presumably find the hosts habitat by visual means.

The present observations demonstrate that *E. argenteopilosus* females were attracted by the food plant leaf of their hosts and were stimulated to start searching, further stimulation from new damage by host larvae released excitement behaviour and continued intensive searching. In the close vicinity of a host, orientation of antennae occurs and finally stabbing. In such a sequence of behaviours, the step-by-step release of the different responses might contribute greatly to the efficiency with which hosts were found.

The experimental analysis revealed that the initial attraction to the food plant leaf was made by olfactory stimuli emitted from it. Once on a leaf, the odour of the plant then elicits searching. Intensive searching, however, was not elicited without the nearby presence of leaf damage by host larvae. The factors responsible were olfactory rather than visual. The odour was due to the combination of leaf juices and host saliva, perhaps chemical breakdown product of the two. That odour elicited excitement and stimulated stabbing intention movements even without the presence of host larvae. A host larva itself always attracted a nearby female wasp but only over a few mm. The factor was again not visual but olfactory.

The females of parasitoid discussed were also stimulated by host larval saliva and faeces. The variety of effective stimuli have not confused females, but actually improved their chances of finding a host by eliciting intensive searching, the most essential for which was odour from damaged leaves. Such damage was continually

renewed as long as host larvae were feeding, so the response to the fresh damage had a specific locating function.

The odour of a food plant leaf elicited searching, but the searching lasted for about 10" only unless other stimuli elicited later components in the sequence. Thus, in the presence of a host larva, females came across a damaged part of a leaf and switched to intensive searching, which would then lead to an encounter with the host larva. When host larvae were not present, a female will therefore, soon takes off without wasting time on further unprofitable searching. The above observations indicate that in *E. argenteopilosus* olfactory stimuli were responsible in attracting female parasitoids towards host food plant/host larvae.

The chick pea plants secrete oxalic acid over their surface—probably the odour of this acid might be responsible for attracting *C. chlorideae* towards this plant. It was also noted that per cent parasitism of *H. armigera* was nil on chick pea by *E. argenteopilosus* while *C. chlorideae* showed high per cent parasitism on the same. The odours emitting from the food plants might be responsible in attracting/repelling female parasitoids and further to increase/decrease the per cent parasitism in the field conditions.

There is a need to identify and synthesize the chemicals involved in the process of parasitization behaviour. These chemicals would be useful in pest management programmes for attracting parasitoids into crops and for stimulating and prolonging searching behaviour.

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