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Switch in Searching Behavior and Stimulus Causing Host Examination by *Trichogramma chilonis* Ishii, an Egg Parasitoid of *Plutella xylostella* L.

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Abstract

The locomotory response of walking *Trichogramma* chilonis female to the contact of scales and secretions of host moth, *Plutella xylostella*, and elicitation of oviposition behavior were observed. In response to a contaminated Sealon film with host moth scales and secretions, a *T. chilonis* female exhibited a response involving walking at a reduced speed. *T. chilonis* female remained during a much longer period of time on a contaminated Sealon film than on a clean one. Also moth scales and/or secretions elicited the oviposition behavior of *T. chilonis* females.

Discipline: Insect pest
Additional key words: biological control, moth scales and secretions

Introduction

The diamondback moth (DBM), *Plutella xylostella* (L.), is a noted defoliator of numerous cruciferous plants in many areas of the world. Since the resistance to many of the commonly used insecticides makes it one of the most difficult pests to manage[1,16], it was necessary to develop alternative methods of control that did not depend on toxic agents, including biological control. *Trichogramma chilonis* Ishii is an important solitary egg parasitoid of DBM[9,25]. Since much of the work in biological control may be characterized as "trial-error" methods[14], it is important to predict how released parasitoids might behave. Although a large number of studies has been carried out on various aspects of the biology of *T. chilonis*[17-20], relatively little is known about how released *T. chilonis* females search for DBM eggs and which cues elicit the oviposition behavior on DBM eggs. The present study was carried out to analyze the searching behavior and elicitation of the oviposition behavior of *T. chilonis* females on DBM eggs in the laboratory.

Materials and methods

T. chilonis used was a part of the stock culture stored at the Chugoku National Agricultural Experiment Station, which was derived from the original colony introduced from Taiwan[8] and reared with *Ephestia kuehniella* Zellar eggs under 24°C and 16L-8D conditions. Larvae and pupae of DBM were collected from cabbage fields in Fukuyama, Hiroshima Prefecture, in 1991. The stock culture of the DBM was continuously maintained in a cabinet controlled at 24°C and cabbage leaves were supplied as a food for the larvae. The moths emerging were released into a rearing cage (34 × 34 × 26 cm) containing a piece of Sealon film® (Fuji Photo Film Co., LTD) as a substratum for oviposition and honey solution (20%) as food.

Experiments were conducted by observing the behavior of a single female in a petri dish arena (9 cm diameter, 2 cm height). The top of the petri dish was covered with an acrylic plate. A piece of new Sealon film (1 × 1 cm) or contaminated Sealon film used as a substratum for laying DBM eggs which contained moth scales and secretions was centered on the petri dish. A DBM egg was also placed in a part of the Sealon film described above. A mated *T. chilonis* female within 24 h after emergence which had never been exposed to host eggs was introduced into the petri dish. Then the searching path of the female was traced upon the acryl plates with a felt pen for 15 min and the oviposition behavior was

observed. At every 15 s the tracks were marked, so that the average walking length could be computed. After 10 min of tracing, 10–33 replications were conducted for each treatment pattern. Initiation of the oviposition behavior of the female was identified by the drumming stage on a DBM egg. Experiments were carried out at 24 ± 1°C. An opisometer was used to measure the length of the trace.

Results

The mean distance covered by walking in 15 s on the Sealon film with moth scales and secretions was significantly shorter than that on a clean Sealon film ($p<0.01$, Kruskal-Wallis test) (Table 1). The contaminated Sealon film with or without a DBM egg was equally effective. Female wasps showed an antennal-searching behavior on the contaminated Sealon film without DBM eggs. Three typical examples of walking paths of *T. chilonis* female are shown in Fig. 1. Clearly, the behavior of the female wasp changed when she came into contact with the Sealon film contaminated with most scales and secretions. Also *T. chilonis* females remained for a relatively longer period of time on the contaminated Sealon film than on the clean one (Table 2).

The elicitation rate of oviposition behavior after the female came into contact with a DBM egg was significantly higher on a contaminated Sealon film than on a clean one ($p<0.01$, Fisher's exact probability test) (Table 3).

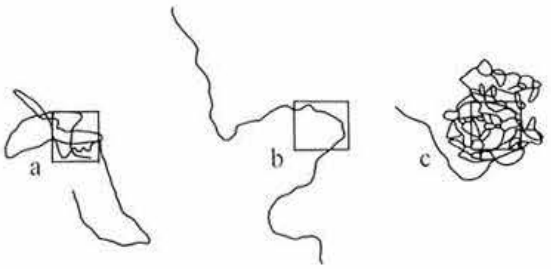

Fig. 1. Walking pattern of *T. chilonis* female in a petri dish with a central square of Sealon film
a: Film covered with moth scales and secretions without a DBM egg, b: Clean film, c: Film covered with moth scales and secretions with a DBM egg.

Table 1. Mean walking distance covered in 15 s on the Sealon film

Presence of moth scales and secretions	Presence of DBM eggs	No. of path	Mean walking distance in 15 s Mean ± SD (cm)
Yes	Yes	52	0.648 ± 0.112a*
	No	48	0.638 ± 0.116a
No	Yes	10	1.631 ± 0.369b

* Values not followed by the same letter in a column are significantly different at 1% level by the Kruskal-Wallis test.

Table 2. Period of stay of *T. chilonis* female on the Sealon film

Presence of moth scales and secretions	Presence of DBM eggs	No. of individuals			
		Period of stay			
		<30 s	<60 s	<5 min	over 5 min
Yes	Yes	3	1	1	9
	No	2	2	6	0
No	Yes	13	2	3	1

Table 3. Elicitation rate of oviposition behavior of *T. chilonis* female after coming into contact with a DBM egg

Presence of moth scales and secretions	No. of tested females	Elicitation rate of oviposition behavior (%)
Yes	17	90.9*
No	11	29.4

* Significantly different from the elicitation rate for the absence of moth scales and secretions at 1% level (Fisher's exact probability test).

Discussion

The present results indicated that *T. chilonis* female changes its walking behavior on a Sealon film with remnants of scales and secretions of adult DBM female. It moves more slowly and changes its direction more frequently, regardless of the presence of DBM eggs (Fig. 1, Table 1), suggesting that the female wasps were searching "carefully" so that a decrease in speed may result in increased antennation per unit of space. This change is referred to as area-concentrated search or local search. Local search is characterized by a high turning rate, strong turn bias, and low locomotory activity[5]. Such behavioral changes were observed in several insects including *Trichogramma* when resource or patch cues were perceived[5]. *Trichogramma* has been a traditional subject in investigations on parasitoid searching behavior[2-7,11-13,15,17,21-24,26-30]. For example, some *Trichogramma* tended to stay in and search for other host eggs in this restricted area[3,21,22,29]. However, the change in the searching behavior of *T. chilonis* had not yet been studied in detail. Although it is obvious that such a behavioral switchover is caused by the contact with moth scales and/or secretions, it remains to be determined whether contact with either moth scales or with secretions or both is actively involved.

Many studies on kairomones have been carried out in *Trichogramma*[17,25-28]. Although these studies showed that kairomones increased the parasitism rate of host egg, host-searching and oviposition behavior of *Trichogramma* females was not observed in detail. It remained to be determined whether the elicitation of the host-searching or oviposition behavior may account for the increased parasitism rate of the eggs. In the present study, it was shown by direct observation that moth scales and/or secretions elicited the ovipositional behavior of *T. chilonis* females on DBM eggs.

Salt[27] considered that in *Trichogramma* a visual stimulus from the host egg was a cue to find it. However, it is assumed that the ovipositional behavior of *T. chilonis* does not occur mainly on the basis of visual stimuli, because *T. chilonis* females could not exhibit the oviposition behavior on DBM eggs present on a clean Sealon film.

Since DBM eggs are usually deposited as an egg mass, it is possible that another egg can be found near the site where the first egg was parasitized. Thus, the local search of *T. chilonis* females after egg parasitization is considered to increase the probability for the parasitoid to encounter the next egg. Consequently switchover from faster searching to slow one induced by moth scales or secretions would be advantageous for *T. chilonis*. One problem in behavioral ecology is to determine how foraging animals exploit food distributed in patches in the environment. Iwasa et al.[10] showed that an optimal foraging strategy depends critically on the spatial distribution of prey. They suggested that the fixed-GUT strategy is the best strategy only when the distribution of food is highly contagious. Thus it is assumed that *T. chilonis* female shows suitable characteristics for the biological control of DBM.

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