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Recognition of Aphid Prey by the Lady Beetle, *Coccinella septempunctata bruckii* MULSANT (Coleoptera: Coccinellidae)

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The lady beetle, *Coccinella septempunctata bruckii*, is suggested to capture an aphid prey after it makes contact either by its maxilla or maxillary palps. Amputation of the maxillary palps decreased the number of prey consumed and the efficiency of capture supporting the above suggestion. The lady beetle continuously fed on a prey while its maxilla were in contact with the aphid body fluid.

INTRODUCTION

The role of chemicals in predatory behavior is not as well established as that in parasitoid behavior (VINSON, 1977). NAKAMUTA (1984 b) found that body fluids of the green peach aphid, *Myzus persicae*, stimulate the feeding of a predatory coccinellid, *Coccinella septempunctata bruckii* MULSANT, this being the first report on the role of food chemicals in the predatory behavior of coccinellids. It is unknown, however, how the lady beetle recognizes the aphid body fluid.

The lady beetle visually sighted the prey from a close range (NAKAMUTA, 1984 a). Even in artificial complete darkness, however, the lady beetle found the prey (NAKAMUTA, 1984 a), suggesting the involvement of stimuli of other modalities, since visual information would be of no use. VON KESTEN (1969) suggested that in a predatory coccinellid, *Anatis ocellata*, the maxillary palps played a role in prey recognition. NAKAMUTA (1983) also observed that *C. septempunctata bruckii* vibrated its maxillary palps while searching for prey, suggesting some role of these organs in prey finding.

The objective of this paper is to delineate how the aphid body fluid is recognized by the lady beetle. This was done by observing the response of the beetle after applying the aphid body fluid to the maxilla, the maxillary palp and the antennae. The role of the maxillary palps in predatory behavior is also delineated by observing the effect of their amputation on the number of prey consumed and capture efficiency under dark conditions.

MATERIALS AND METHODS

The lady beetle, *Coccinella septempunctata bruckii* MULSANT (incorrectly identified earlier as *Coccinella septempunctata* L. by one of us: NAKAMUTA, 1983, 1984 a, b) and the green peach aphid, *Myzus persicae* (SULZER), were reared in the laboratory using the method described by NAKAMUTA (1983). Apterous adults of the cabbage aphid, *Brevicoryne brassicae* (L.), were collected from an experimental field of Nagoya University. Before each experiment the lady beetles were deprived of food for 24 h after having fed to satiation. All experiments were conducted at $25 \pm 1°C$ from 10:00 to 17:00, the time that the lady beetle is usually active.

A lady beetle, ventral side up, was mounted on a wax plate with vinyl adhesive tape. It was then contacted with a 2nd or 3rd instar aphid fixed at the tip of a glass rod, or a glass rod coated with or without a droplet of aphid (*M. persicae*) body fluid. A droplet of aphid body fluid was pressed out of an adult *M. persicae* with forceps. The diameter of the glass rod was about 1 mm. The site contacted with each of stimuli was the distal segment of the maxillary palp, the maxilla (except for palp) or the distal end of the antenna. It was difficult to identify the exact site of maxilla where the stimulus was applied, since the size of the glass rod was larger than that of any part of maxilla. Therefore, in this paper the maxilla means all parts of maxilla other than the maxillary palp. Contact stimuli applied to the maxilla might be also a stimulus to the mandible, labrum and labium, since the size of the glass rod is large comparing with that of the maxilla.

Before stimulation the lady beetles were stationary and folded their maxillary palps showing no mandibular movement. Two responses were observed after the maxilla of the lady beetle were contacted by the glass rod coated with the aphid body fluid: i) they extended and protruded their maxillary palps and raised their head capsule; this is hereafter defined as a capture attempt. In a normal feeding position this response corresponds to lowering the head so that the maxilla, mandible or labrum touches the prey surface; ii) they moved their mandibles frequently as if biting the aphid, defined as biting movements.

Whether a lady beetle demonstrated the capture attempt or not was determined after it was stimulated by each stimulus mentioned above. Each lady beetle was observed ten successive times after ceasing the capture attempt, if any, using ten different stimuli.

The frequency of biting movements was counted for 30 s after a stimulation. Ten replicated observations were conducted on each lady beetle after it ceased the biting movements.

The role of the maxillary palps was elucidated by observing the effect of their amputation (maxillary palpectomy) on the capture efficiency and the number of prey consumed. A lady beetle starved for 24 h after satiation was confined in a plastic cup (9 cm dia and 5 cm depth) with a sufficient number of adult apterous *B. brassicae* (60–90 adults/cup) under dark conditions, thus avoiding any possible visual locating of prey. Twenty-four hours after this procedure the number of prey consumed were counted. The same lady beetle was fed to satiation and both maxillary palps were amputated at the proximal segment by microscissors after the insect was anesthetized with carbon dioxide. After 24 h food deprivation, the number of prey consumed for 24 h by maxillary palpectomized lady beetles were counted as described.

Capture efficiency was determined as follows. An intact, maxillary palpectomized or sham (see below) lady beetle was confined in a petri dish (9 cm dia and 1.5 cm depth) with 30 apterous adult *M. persicae*. For 30 min the number of prey contacted and captured were counted, and simultaneously the site of initial contact with prey was recorded under illumination by a 6 W red light ca. 30 cm away from the beetle. The efficiency of prey capture was given by the following formula; number of prey captured/number of prey contacted × 100(%). A sham lady beetle had the surface of its maxillary palps scraped by a razor in comparison with a maxillary palpectomized lady beetle. The spines on the surface of the maxillary palps were thus partly removed from the sham lady beetle.

RESULTS AND DISCUSSION

Capture attempts were observed when maxilla or maxillary palps were contacted by the aphid or a glass rod coated with aphid body fluid (Table 1). The maxilla invoked significantly higher capture attempts than the maxillary palps when contacting the aphid body fluid (Table 1). Contact with a glass rod did not elicit capture attempts, nor did any stimuli given to the antenna.

The frequency of biting movements is shown in Table 2. Biting movements were elicited by contacting the maxilla with the aphid body fluid and were weakly elicited by contacting a maxillary palp with the fluid. Neither an intact aphid or the glass rod elicited biting movements, nor did stimuli given to the antenna.

Although both the maxilla and the maxillary palps responded to either an intact aphid or the aphid body fluid and resulted in capture attempts (Table 1), the maxillary palps did not elicit biting movements as frequently as did the maxilla when contacting the fluid (Table 2). Therefore, the maxillary palps are thought to be concerned in

Table 1. Differences in percentage of capture attempts between stimuli and sites of stimulation

Types of stimuli	Sites of stimulation			No. of individuals
	Maxilla	Maxillary palp	Antennae	
Glass rod coated with aphid body fluid	90.0±11.4 a,d[a]	78.2±22.3 a,e	5.5±5.2 a,f	11
Aphid fixed to a glass rod	60.9±21.2 b,d	61.8±25.6 b,d	1.8±4.0 a,e	11
Control (glass rod)	4.5±6.9 c,d	0 c,d	0 a,d	11

[a] Values are mean±S.D. Different first and second letters following values indicate significant differences between types of stimuli and sites of stimulation, respectively ($P<0.05$, randomization test).

Table 2. Differences in biting movements between stimuli and sites of stimulation

Types of stimuli	Sites of stimulation			No. of individuals
	Maxilla	Maxillary palp	Antennae	
Glass rod coated with aphid body fluid	12.3±3.9 a,c[a]	2.3±1.2 a,d	0.3±0.6 a,e	11
Aphid fixed to a glass rod	0.3±0.4 b,c	0.1±0.2 b,c	0 a,d	11
Control (glass rod)	0.04±0.1 b,c	0 b,c	0 a,c	11

[a] Values are mean±S.D. of biting movements for 30 s. Different first and second letters following values indicate significant difference between types of stimuli and sites of stimulation, respectively ($P<0.05$, MANN-WHITNEY's U-test).

Table 3. Effect of maxillary palpectomy on the efficiency of prey capture

Treatment	Site of initial contact with prey			No. of individuals
	Head	Forelegs	Other	
Intact	88.4±11.4 a[a]	41.5±33.1 a	0.1±2.1 a	15
Maxillary palpectomy	28.9±14.8 b	25.0±40.8 a	0 a	8
Sham	83.5± 5.4 a	73.4±29.6 a	0 a	5

[a] Means±S.D. followed by different letters are significantly different between treatments ($P<0.05$, MANN-WHITNEY's U-test).

prey capture, and the maxilla in both prey capture and biting of a prey. The lady beetle captured a desiccated aphid but no longer consumed or ate it (NAKAMUTA, 1984 b). This might be due to the fact that the maxilla was not able to contact the body fluid of the aphid.

The lady beetle showed capture attempts when contacting the aphid body fluid with its maxilla or maxillary palps (Table 1). In normal feeding it is not likely that the aphid body fluid is contacted before the prey is captured. However, the lady beetle is able to recognize aphid body fluid while feeding on it. The beetle might have shown capture attempts because it was fixed to the wax plate ventral side up and was brought in contact with aphid body fluid; this is unusual in the normal feeding position. Therefore, we suggest that capture attempts elicited by the contact with aphid body fluid might correspond to the capture of later prey, whereas these elicited by contact with an intact aphid might correspond to the capture of an initial prey in normal feeding.

Maxillary palpectomized lady beetles consumed on an average of 31.2±30.0 ($n=10$) prey, whereas intact ones consumed 54.2±12.7 ($n=10$) prey; prey numbers consumed are thus significantly different ($P<0.05$, MANN-WHITNEY's U-test). Maxillary palpectomized lady beetles captured aphid prey less efficiently than intact lady beetles when the aphid was brought in contact with the head of the beetle (Table 3). Therefore, the decrease in the number of prey consumed by a maxillary palpectomized lady beetle might be due to a lack of prey recognition rather than to the suppression of activity because of damage by the maxillary palpectomy.

In silkworm larvae mixed gustatory and olfactory chemoreceptors on the maxillary palps suppressed feeding, unless the amount of feeding stimulants in the diet reached a certain level (ISHIKAWA et al., 1969). Maxillary palps played a role in food discrimination and food selection (BLANEY and CHAPMAN, 1970; BLANEY and DUCKETT, 1975) and in maintenance of feeding (MORDUE-LUNTZ, 1979) in acridid insects. In predatory insects, however, the role played by the maxillary palps is not yet known. The present results with *C. septempunctata bruckii* showed that the maxillary palps play a role in recognizing contact with a prey, supporting the suggestion by VON KESTEN (1969). The tactile sense, however, is not confined to these maxillary palps. This is corroborated by the fact that a maxillary palpectomized beetle did not completely lose the ability to capture aphid prey but that it operated at ca. 40% capture efficiency when prey contact was made with its forelegs (Table 3).

In conclusion, contact by the maxillary palps or maxilla with an aphid might be sufficient to elicit prey capture by a lady beetle. Moreover, the contact of the maxilla with the aphid body fluid might stimulate the beetle's continuous feeding on the prey.

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