

Switchover in Searching Behavior of *Coccinella septempunctata* L. (Coleoptera : Coccinellidae) Caused by Prey Consumption

Kiyoshi NAKAMUTA

*Laboratory of Applied Entomology and Nematology, Faculty of Agriculture,
Nagoya University, Nagoya 464, Japan*

(Received April 9, 1982)

Searching behavior of the adult of a ladybeetle, *Coccinella septempunctata* L., was observed in an experimental arena. After having eaten a prey, the searching path of the beetle became more convoluted, and the beetle tended to stay in the vicinity of the site of the first prey consumption. Slower speed and increased number of turns were responsible for this change of searching path. As a rule, these changes in searching behavior were not maintained more than 70 sec when the beetle could not find any prey. Such switch-over in the searching behavior of the ladybeetle observed in this experiment would be advantageous for the beetle because its preys are mostly living in clusters.

INTRODUCTION

After having captured a prey or host while searching, most of insect predators and parasitoids change their searching paths, and this change is considered to enhance the efficiency of searching (CURIO, 1976). For example, some predatory coccinellids such as the larva of *Stethorus picipes* CASEY (FLESCHNER, 1950), the larva of *Adalia bipunctata* (L.) (BANKS, 1957), the larva of *A. decempunctata* (L.) (DIXON, 1959) and the adult of *Hippodamia convergens* GUÉRIN-MÉNEVILLE (ROWLANDS and CHAPIN, 1978) tended to stay in the vicinity of the antecedent prey capture and to search for another prey in this restricted area. This behavior is called area-concentrated search by SMITH (1971, in Curio, 1976, p. 48). However, this change in searching behavior of the ladybeetle, *Coccinella septempunctata* L. is not yet studied in detail. In this paper, changes in searching behavior of the beetle after prey consumption were described and stimulus causing the change of searching behavior is discussed.

MATERIALS AND METHODS

The ladybeetle, *C. septempunctata* were reared on an excess of food, the green peach aphid, *Myzus persicae* (SULZER) under $25 \pm 3^\circ\text{C}$ and 16 hr photophase. Aphids were reared on potted cabbage plants under the same condition of temperature and light as the beetle.

To record the searching path of the beetle, an observation apparatus, consisted of a gray vinyl chloride cylinder (30 cm diameter and 5 cm height) resting on a white paper which overlaid a transparent acryl plate, was used. The top of the cylinder

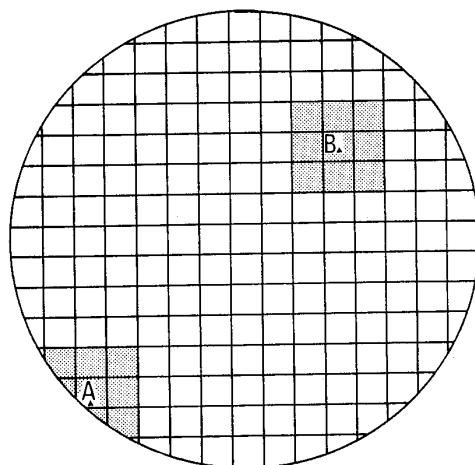


Fig. 1. Schematic representation of experimental arena. Blocked triangles indicate the site of prey consumption in a marginal section (A) and in a 2×2 cm closed square (B). Dotted area represents the vicinity of prey consumption. See text for details.

was covered with another transparent acryl plate, on which a cellophane paper was laid. A beetle was not fed for 24 hr before the experiment. This period was sufficient for every beetle to elicit searching behavior. The beetle was released into the observation arena and was habituated to the surroundings for two min. After that, searching path of the beetle was traced upon a cellophane paper with a felt pen for three min. At every 15 sec the traced tracks were marked, so that the average walking speed can be computed. After the three min tracing, a prey (an apterous adult of *M. persicae*) was placed in front of the beetle with forceps and the tracing of its searching path was continued after the beetle had consumed the prey.

To observe the effect of the number of aphids consumed on the searching behavior, another experiment was made. A beetle was released into the arena and habituated as described above and was fed two, or four preys in this case. After this treatment tracing was conducted by the same method as mentioned above. Each experiment was repeated ten times with different individuals. The temperature in the arena was $25 \pm 3^\circ\text{C}$ and observations were conducted during the light phase when the predator is active. An opisometer (Curvimeter®, KENT, TOKYO) was used to measure the length of the trace. The numbers of obtuse-angle turns (relative to the original path) were counted from the traces of searching paths.

The experimental arena was divided into 145 2×2 cm squares and 56 marginal sections (Fig. 1). The word "vicinity" was defined here as a square (or a marginal section) in which a prey was captured and adjacent squares (or marginal sections) in contact with it (Fig. 1).

RESULTS AND DISCUSSION

Two examples of searching paths of the beetle were shown in Fig. 2. Figure 2 a and b represent the searching paths of the same individual before prey capture and after prey consumption, respectively. Before prey capture the beetle tended to move along the perimeter of the arena (Fig. 2a), and its average searching

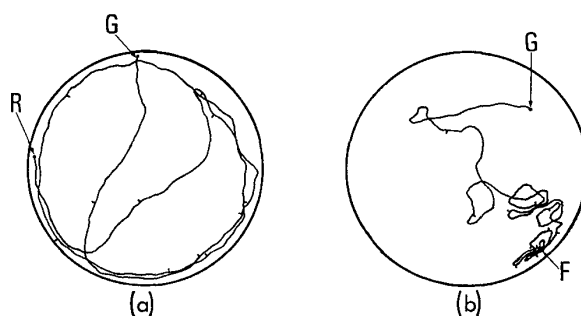


Fig. 2. A set of searching paths of a 24 hr-starved ladybeetle (a) before capture and (b) after consumption of a prey. 'R', 'F' and 'G' indicate the point of two min after the introduction of the beetle, the point where an aphid was consumed, and the point where the beetle is at the end of tracing, respectively.

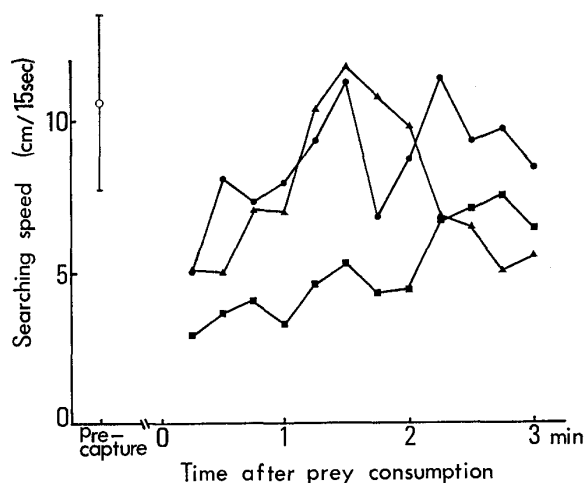


Fig. 3. Mean searching speeds (cm/15 sec) before prey capture (○, vertical bar indicates a S.D.) and after consumption of a prey (●—●), two preys (■—■) and four preys (▲—▲).

speed was 10.6 ± 2.9 cm/15 sec ($n=10$) (Fig. 3). But after consumption of a prey the beetle tended to search within a restricted area (Fig. 2b) and its speed decreased to significantly lower level than that before prey capture ($p < 0.05$, Student's *t*-test, Fig. 3). No significant difference of searching speed from before prey capture was detected at later than 30, 135 and 45 sec after consuming one, two and four preys, respectively. This meant that searching speed gradually recovered and it took 30, 135 and 45 sec to recover the searching speed when one, two and four preys were fed, respectively (Fig. 3).

The ratios of the length of an actual searching path of the beetle to the beeline distance during 15 sec-intervals are shown in Fig. 4. The larger the ratio, the more tortuous the searching path of the beetle was. As shown in Fig. 4, the ratio of the starved beetle before prey capture was 1.3 ± 0.3 ($n=10$), suggesting that the searching path of a starved beetle was almost linear. But after consumption of a prey, the ratio increased to 3.4 ± 2.8 in the first 15 sec period, 4.1 ± 3.3 in the second 15 sec period and 2.3 ± 1.3 in the third 15 sec period. These values were significantly different from that before prey capture ($p < 0.05$, Cochran-Cox's *t*-test). After that,

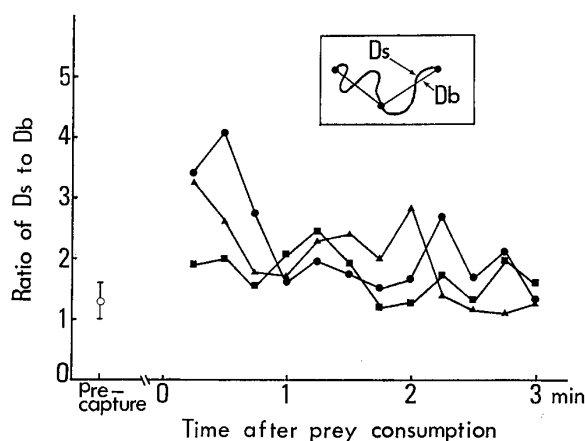


Fig. 4. Mean ratios of the length of an actual search path (D_s) to the beeline distance (D_b) during 15 sec intervals before prey capture (\circ , vertical bar indicates a S.D.) after consumption of a prey (\bullet — \bullet), two preys (\blacksquare — \blacksquare) and four preys (\blacktriangle — \blacktriangle).

the ratio was not significantly different from that before prey capture. When the beetle was fed two preys, there was no significant difference of ratios between before and after prey consumption. The reason for this result is not clear but two possibilities can be considered. Firstly, moving distance after consuming two preys was short as indicated by the slower searching speed than after consuming one or four preys and this made the difference of actual search path from the beeline distance small. Secondly, the variance of ratio from beetle to beetle after consuming two preys was so large that the ratio did not differ significantly from pre-capture of prey. The ratio in first and second 15 sec period after consumption of four preys were significantly different from that before prey capture ($p < 0.05$, Cochran-Cox's t-test). After that, the ratio was not significantly different from that before prey capture.

The numbers of obtuse-angle turns (relative to the original direction) described above were shown in Table 1. Before prey capture, beetles showed only a few turns but after prey consumption beetles turned more frequently. The number of turns was not affected by the number of preys consumed (Table 1).

The searching times (not including handling time) of the beetle in the vicinity of the site of prey consumption were also shown in Table 1. The time was greatly increased by the prey consumption, though it was not affected by the number of preys

Table 1. Number of obtuse-angle turns (relative to the original direction) and time of searching made in a vicinity of first prey consumption (for the term "vicinity", see text.)

	No. of turns	Mean searching time in sec within the vicinity (range)
Before prey capture	0.1 ± 0.1^a	4.6 ± 4.0^a (2—12)
After having eaten a prey	2.5 ± 2.4^b	34.5 ± 23.5^b (15—75)
two preys	3.3 ± 2.9^b	49.5 ± 23.5^b (15—120)
four preys	3.2 ± 2.1^b	64.5 ± 59.6^b (15—180)

^{a, b} Values were represented as mean \pm S.D. of ten beetles. Values not followed by the same letter in a column of no. of turns are significantly different at 0.05 level by the t-test and in a column of searching time, at 0.01 level by the Mann-Whitney's U-test.

consumed.

These results indicate that the beetle changes its prey searching behavior after prey consumption; it moves slower and turns its direction more frequently. In consequence of these changes in searching behavior, the beetle tends to search for a next prey in the vicinity of the place of the first prey consumption. When there is no more prey in the arena, the beetle resumes the searching path as before within 35–65 sec.

Such behavioral changes were observed in several predatory coccinellids (FLESCHNER, 1950; BANKS, 1957; DIXON, 1959; ROWLANDS and CHAPIN, 1978), however, the duration of the concentrated searching after prey consumption was not reported. Seventy-two sec was given by MARKS (1977) as the duration of the intensive searching of *C. septempunctata* larvae following prey consumption in the experimental condition. As shown in this experiment, *C. septempunctata* usually left the vicinity of the site of prey consumption 35–65 sec after the prey consumption. In any case, time spent for the concentrated searching was not longer than 180 sec.

Most of aphid species, which are the staple prey of *C. septempunctata*, usually live in clusters (DIXON and WRATTEN, 1971). Therefore, it would be quite possible that another aphid can be found near the site where the first prey was captured. Thus the area-concentrated searching of the beetle after prey consumption is considered to raise the beetle's probability of encounter with the next prey. Consequently a switchover from linear searching to concentrated one induced by prey consumption would be advantageous for the beetle. In case of not being able to find the next prey in the vicinity of the site of prey consumption, it might be better for the beetle to give up searching and to go to another area as soon as possible. Thus, a switchover from concentrated searching to linear one elicited by not finding prey in a short period (35–65 sec) would be also advantageous.

In this experiment, behavioral switchover after prey consumption could be observed without any more prey in the experimental arena. Therefore, such behavioral changes after prey consumption may be the consequences of some changes in internal factor of the beetle. ROWLANDS and CHAPIN (1978) observed similar behavioral changes of a ladybeetle, *H. convergens*, and suggested that these behavioral changes were caused by the stimulus of a successful attack upon an aphid. Many aphids were distributed in the experimental arena of their experiment, they could not make clear whether behavioral changes are due to the stimulus of attacking on a prey or due to the environmental stimuli of distributed aphids.

It is not yet clear whether such behavioral switchover is caused by contact with a prey, capture of a prey, consumption of a prey, or other stimuli. This would be an interesting area for future research.

ACKNOWLEDGEMENTS

The author thanks Drs. T. SAITO and Y. ITÔ of this laboratory for their invaluable advice and criticism on the manuscript. Thanks are also made to Dr. Y. TSUBAKI of this laboratory and Dr. T. ONO of Kinjo Gakuin University for their critical reading of the manuscript.

REFERENCES

- BANKS, C. J. (1957) The behaviour of individual coccinellid larvae on plants. *Brit. J. Anim. Behav.* **5** : 12-24.
- CURIO, E. (1976) *The Ethology of Predation*. Springer-Verlag, Berlin. 250pp.
- DIXON, A. F. G. (1959) An experimental study of the searching behaviour of the predatory coccinellid beetle *Adalia decempunctata* L. *J. Anim. Ecol.* **28** : 259-281.
- DIXON, A. F. G. and WRATTEN, S. D. (1971) Laboratory studies on aggregation, size and fecundity in the black bean aphid, *Aphis fabae* Scop. *Bull. ent. Res.* **61** : 97-111.
- FLESCNER, C. A. (1950) Studies on searching capacity of the larvae of three predators of the citrus red mite. *Hilgardia* **20** : 233-265.
- MARKS, R. J. (1977) Laboratory studies of plant searching behaviour by *Coccinella septempunctata* L. larvae. *Bull. ent. Res.* **67** : 235-241.
- ROWLANDS, M. L. J. and CHAPIN, J. W. (1978) Prey searching behavior in adults of *Hippodamia convergens* (Coleoptera : Coccinellidae). *J. Georgia Entomol. Soc.* **13** : 309-315.
- SMITH, J. N. M. (1971) Studies of the searching behaviour and prey recognition of certain vertebrate predators. Ph. D. thesis, Univ. Oxford.