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Effect of Pupation Site on Pupal Cannibalism and Parasitism in the Ladybird Beetle *Harmonia axyridis* PALLAS (Coleoptera, Coccinellidae)

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Abstract Pupal cannibalism and parasitism of the ladybird beetle, *Harmonia axyridis* PALLAS, were studied in relation to the pupation sites and the direct distance from the pupation site to the nearest aphid colony. Cannibalism and parasitism occurred more intensely on host plants of prey aphids than in the other pupation sites. Cannibalism was more intense in a pupation site which was closer to an aphid colony, but it was not the case with the parasitism by *Phalacrotophora* sp. The higher rate of cannibalism near an aphid colony seemed to be due to the intensive searching of a cannibal near an aphid colony, whereas the frequent occurrence of parasitism on prey's host plants seemed to be due to the host searching of the parasitoid concentrating on host plants.

Key words: Cannibalism; parasitism; pupation site; pre-pupal dispersal; ladybird beetle; *Harmonia axyridis*.

Introduction

Cannibalism is common in many taxonomic groups of insect including several species of ladybird beetles (*e.g.* FOX, 1975; POLIS, 1981). In ladybird beetles, a larva cannibalizes conspecific individuals of all developmental stages (HODEK, 1973). Cannibalism is one of the most important mortality factors in the ladybird beetle, *Harmonia axyridis* PALLAS (OSAWA, 1991 a). Oviposition timing and the distance from an egg batch to the nearest aphid colony that may affect the intensity of non-sibling cannibalism on egg stage have been already reported (OSAWA, 1989), but few studies have clarified ecological conditions under which pupal cannibalism occurs.

Parasitism is another important mortality factor in pupal stage of ladybird beetles (HODEK, 1973). Three and 6 genera of Diptera and Hymenoptera have been recorded as parasitoids of coccinellids, respectively (HODEK, 1973). Only *Phalacrotophora* sp. (Phoridae) has been reported as a pupal parasitoid of *H. axyridis* in Japan (MAETA, 1969).

TAKAHASHI (1989) suggested that the occurrence of pupal cannibalism is affected by food conditions for cannibals, whereas VINSON (1976) suggested that it is affected by habitat preference of the parasitoid. In this paper I examine pupal cannibalism and parasitism in the ladybird beetle, *H. axyridis*, under different pupation sites, and show that the pre-pupal dispersal of the beetle is important both for cannibalism

and parasitism avoidance.

Materials and Methods

During the period from early April to early August, field observations were conducted in the Botanical Garden of Kyoto University (about 1 hectare in area), Kyoto, in central Japan. In the garden, 7 species of trees were inhabited by 8 species of aphids. The plants were 1 to 3.5 m in height. The pupae on these host trees were individually distinguished by attaching vinyl tapes to near pupation sites and checked daily whether or not the pupae survived successfully. Mature larvae often pupated apart from host plants of prey aphids and also from colonies of the aphids. In order to elucidate whether or not the pupation sites affect the intensity of cannibalism and parasitism, the location of pupation sites and the direct distance from the site of each pupa to the nearest aphid colony were recorded. Except when directly observed, cannibalism and parasitism were distinguished in the following manner: a pupa destroyed was regarded as being cannibalized and the one with an emergence hole as being parasitized. The pupation sites were divided into 2 categories (whether or not the pupae were located on host plants of prey aphids) and the distance (d) into 3 categories ($d \leq 10$ cm, $10 \text{ cm} < d \leq 50$ cm, $d > 50$ cm). In each category, the percentages of pupal parasitism and cannibalism were determined.

In 1990, 249 pupae were collected in the same study area and reared at 25°C, 16L-8D in a laboratory to identify parasitoid species. Of all these pupae, 17.7% ($n=44$) were parasitized by *Phalacrotophora* sp. and no other parasitoid species were observed. Because of this, I considered that the parasitism in *H. axyridis* in 1987 and 1988 would also be done by this species.

Results

Of all the *H. axyridis* pupae marked ($n=146$), 78.8% ($n=115$) were located on the host plants, and the rest 21.2% ($n=31$) in the other sites. The average direct distance from a pupation site to the nearest aphid colony was 39.4 ± 3.4 cm ($\bar{x} \pm$ S.E., $n=146$). Thus mature *H. axyridis* larvae often pupated apart from host plants of prey aphids and the aphid colonies.

About 75% ($n=110$) of the pupae survived, but 14.4% ($n=21$) were killed by cannibalism and 10.3% ($n=15$) by parasitism (Table 1). The percentage of

Table 1. Intensity of cannibalism and parasitism in the pupal stage of *H. axyridis*.

No. of pupae studied	146	
No. of pupae which survived	110	(75.3%)
No. of pupae killed	36	(24.7%)
by cannibalism	21	(14.4%)
by parasitism	15	(10.3%)

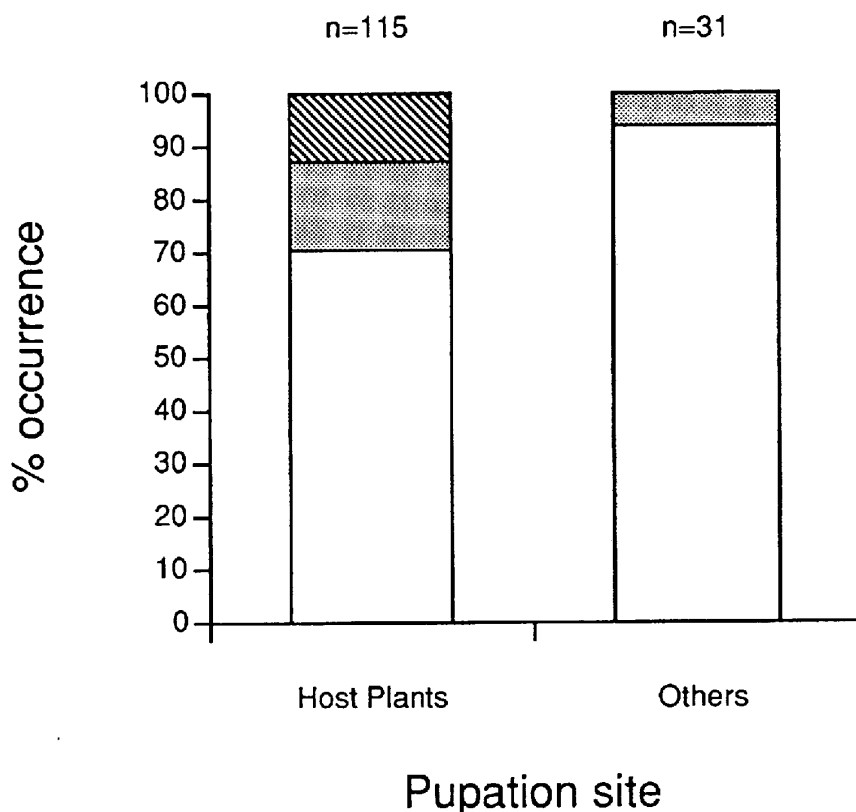


Fig. 1. Comparison of the percentages of parasitism and cannibalism between the pupae on the host plants of their prey aphids and those in the other sites. Open bars indicate % pupae survival, dotted bars % cannibalism, and dashed bars % parasitism.

pupae killed by cannibalism plus parasitism on host plants were significantly (χ^2 -test for no. of pupae, $\chi^2=5.8$, d.f.=1, $P<0.05$) higher than that located on the other sites (Fig. 1). About 70% of the pupae on host plants survived to adults, while more than 90% of those in the other sites survived. No pupa that was located on the sites other than host plants of preys was parasitized. Thus it was evident that both cannibalism and parasitism were more intense in the pupae on host plants. Figure 2 showed that the shorter the distance from an aphid colony the higher the percentage of pupae killed by cannibalism and parasitism (χ^2 -test for no. of pupae, $\chi^2=6.1$, d.f.=2, $P<0.05$). This was largely due to an increase in % cannibalism. These results showed that the pre-pupal dispersal of *H. axyridis* larvae from host plants of prey aphids is effective for avoiding both cannibalism and parasitism, while the dispersal from an aphid colony is effective only for avoiding cannibalism.

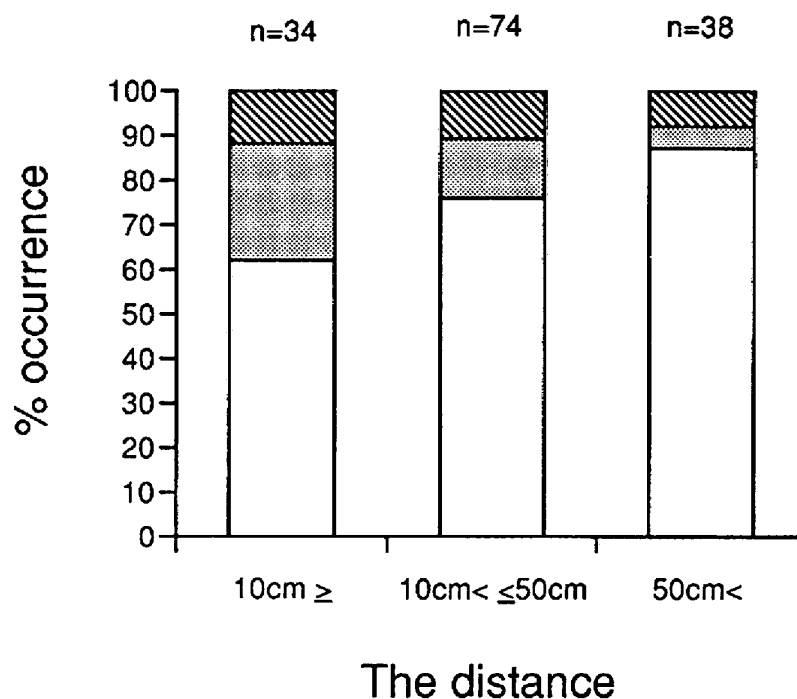


Fig. 2. Comparison of the percentages of parasitism and cannibalism among the pupae located at 3 different distances from an aphid colony. Open bars indicate % pupae survival, dotted bars % cannibalism, and dashed bars % parasitism.

Discussion

This study indicated that pupal cannibalism of *Harmonia axyridis* was more intense when the larvae pupated on host plants of prey species and the closer the pupation site to an aphid colony the higher the % cannibalism. The higher rate of successful emergence in sites which were apart from host plants and aphid colonies was due to a decreased intensity in cannibalism because a *H. axyridis* larva tended to continue intensive searching near an aphid colony after feeding an aphid (KAWAI, 1976). This study showed that only 10.3% of pupae were killed by cannibalism, suggesting that the pre-pupal dispersal effectively diminished the possibility of being cannibalized by conspecific larvae, although food condition for cannibals was rather severe during the latter half of fourth instar period (OSAWA, 1991 b).

In general, the process that may result in successful parasitism can be divided into four steps: (a) host habitat location, (b) host location, (c) host acceptance, and (d) host suitability (DOUTT, 1964). Among the four processes, little information is available on how parasitoids locate macrohabitats (VAN ALPHEN & VET, 1986). This study indicated that pupal parasitism was more intense on pupae located on host plants than that on other pupation sites, but the distance from an aphid colony did not affect parasitism intensity. This may be because habitat location of the par-

asitoid, *Phalacrotophora* sp., is restricted only to host plants and the parasitoid searches pupae only within host plants.

This study showed that *H. axyridis* larvae could escape from cannibalism and parasitism by the pre-pupal dispersal from host plants. Nevertheless, 78.8% of pupae were observed on host plants. This suggests that the pre-pupal dispersal from host plants may be costly or risky for *H. axyridis* larvae because habitats of the larvae are patchily distributed.

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