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A Life Table of the Ladybird Beetle *Harmonia axyridis* PALLAS (Coleoptera, Coccinellidae) in Relation to the Aphid Abundance

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Abstract A field study was performed to construct a life table of the ladybird beetle, *Harmonia axyridis* PALLAS, in relation to seasonal change in the number of the artichoke aphid, *Capitophorus elaeagni* (del GUERCIO). Sibling and non-sibling cannibalism killed 31.16% of all eggs. Mortality of fourth instar larvae (93.33%) was higher than those of the other stages (<50.51%), probably due to food shortage caused by the adult oviposition timing synchronized with seasonal change in the aphid. Egg cannibalism may be advantageous for cannibals to escape food limitation and thus important in the life history strategy of *H. axyridis*.

Key words: Life table; ladybird beetle; *Harmonia axyridis*; predator; cannibalism; *Capitophorus elaeagni*.

Introduction

Predatory ladybird beetles have been studied from the viewpoint of biological control of insect pests (HAGEN, 1962; HODEK, 1973) and foraging behaviour (CURIO, 1976). However, population field studies on predatory ladybird beetles and their prey have been few mainly due to the difficulty of population estimation. An exception is a study on the monophagous predatory coccinellid, *Aiolocaria hexaspilota*, and its prey, the walnut leaf beetle, *Gastrolina depressa*, which revealed that temporal and spatial distributions of the coccinellid and its prey overlapped (MATSURA, 1976). However, the population characteristics of aphidophagous ladybird beetles are still unclear in many points. In aphidophagous ladybird beetles, the oviposition is synchronized with aphid abundance (BANKS, 1955; DIXON, 1970, 1971; WRATTEN, 1973; OSAWA, 1989), but the prey abundance is not always maintained throughout the larval stages. Additionally, previous studies have not considered, through life table analysis, the adaptive significance of sibling and non-sibling cannibalism, which occur frequently (OSAWA, 1989). To elucidate the life history strategies of the ladybird beetle, a field population should be studied in relation to seasonal change in prey abundance.

In this study, a life table of the aphidophagous ladybird beetle, *Harmonia axyridis* PALLAS, is analyzed in relation to the seasonal change in the number of the artichoke aphid, *Capitophorus elaeagni* (del GUERCIO), and the role of egg cannibalism in the life history strategy of *H. axyridis* is discussed.

Materials and Methods

The study site was the Botanical Garden, Kyoto University (35°02'N, 135°47'W). An artichoke, *Cynara scolymus* (1.5 m in height), was examined every day from 5 May to 6 June in 1987, and numbers of eggs, larvae of each stages, pupae, and newly emerged adults of *H. axyridis* were directly counted. When egg batches and pupae were newly discovered, their locations were individually marked with vinyl tape. The number of prey aphid, *C. elaeagni*, on the plant was counted at 18 times during the study period without distinguishing adults and larvae.

It is known that egg cannibalism often occurs in coccinellids (HODEK, 1973). Egg cannibalism can be divided into two types through the kin relatedness between a cannibal and a victim: sibling and non-sibling cannibalism (OSAWA, 1989). Sibling cannibalism is that of newly-hatched larvae feeding on fertile and infertile eggs in the same egg batch (BROWN, 1972). While, non-sibling cannibalism is that of younger larvae derived from an egg batch feeding on eggs in another egg batch before the eggs hatch (OSAWA, 1989). Also in *H. axyridis*, sibling and non-sibling cannibalism were major mortality factors in egg stage (OSAWA, 1989). Because newly-hatched larvae stayed near the original egg batch for about 24 hours, cannibalism occurring within 24 hours after hatching was regarded as sibling cannibalism. When an unhatched egg batch was cannibalized by larvae of another batch (non-sibling cannibalism), the number of eggs consumed by the cannibal larvae were recorded.

To construct a life table of *H. axyridis*, the method of KIRITANI and NAKASUJI (1967) was used to estimate the numbers of individuals at the beginning of second instar, third instar, and fourth instar. Total numbers were determined for the stages; egg, first instar larva, pupa, and newly emerged adult were directly counted in the field census.

Results

Figure 1 shows the seasonal change in the number of *H. axyridis* in each developmental stage. The number of first instar larvae peaked on 14 May, second instar larvae on 18 May, third instar larvae on 21 May, and fourth instar larvae on 22 May. The number of eggs may have peaked before 9 May.

Table 1 shows a life table of *H. axyridis*. In the egg stage, 13.91% were killed by non-sibling cannibalism and 17.25% by sibling cannibalism. In larval stages, mortality was the highest for fourth instar larvae. Among 13 pupae, 12 pupae emerged successfully and one was cannibalized.

The number of the prey aphids decreased from 8 May to 24 May, and thereafter no aphids were present (Fig. 1). This suggests that scarcity of prey caused the high mortality of fourth instar larvae.

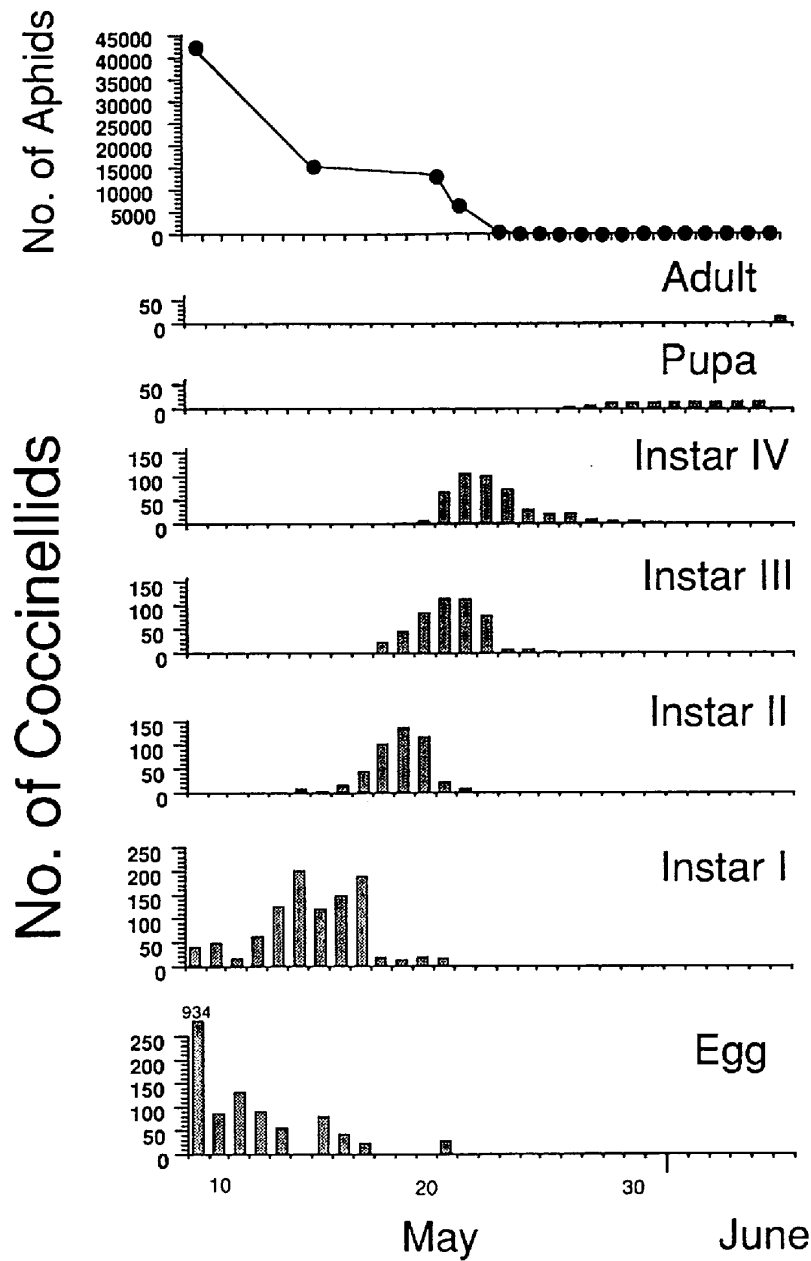


Fig. 1. Seasonal changes in number of the ladybird beetle, *H. axyridis*, and the artichoke aphid, *C. elaeagni*, on the artichoke.

Discussion

Both sibling and non-sibling cannibalism occurred frequently in *Harmonia axyridis* (OSAWA, 1989). Sibling cannibalism occurred in most egg batches throughout the entire oviposition period, whereas non-sibling cannibalism occurred mainly in the middle and late oviposition periods and when the egg batches were laid close

Table 1. A life table of *H. axyridis*.

Age interval (x)	No. of alive at beginning of x (l_x)	Factors of dx (dx/F)	No. dying during x (dx)	dx % ($100 qx$)
Egg	1467	Cannibalism	457	31.16
		by non-sibling	204	13.91
		by sibling	253	17.25
1st instar	1010	Unknown	426	42.18
2nd instar	584	Unknown	190	32.53
3rd instar	394	Unknown	199	50.51
4th instar	195	Unknown	182	93.33
Pupa	13	Cannibalism	1	7.69
Adult	12	—	—	—

to an aphid colony (OSAWA, 1989). Thus, the occurrence of non-sibling cannibalism may depend on ecological conditions, but this appears not to be the case in sibling cannibalism. Frequency of non-sibling cannibalism in this study was significantly lower than that (36.10%) in OSAWA (1989) ($\chi^2=220.61$, d. f.=1, $P<0.001$), probably because in this study most eggs were laid in early oviposition period, when aphid density was high.

Food limitation for larval *H. axyridis* became severe in proportion as the larvae developed, and this may have caused the low survival rate of the last instar. Because the oviposition of coccinellids were concentrated at the time of peak aphid density (see also BANKS, 1955; DIXON, 1970, 1971; WRATTEN, 1973; OSAWA, 1989), severe food shortage for older instars may be an inevitable consequence of prey exploitation by the coccinellid populations. Decrease in aphid density was probably accelerated by the great food requirement of older instar larvae (MOGI, 1969; OKAMOTO, 1978) and dispersal of the winged aphids.

First instar larvae of *H. axyridis* can safely moult to second instar in one day after eating three conspecific eggs (KAWAI, 1978; OSAWA, 1991). Therefore sibling and non-sibling cannibalism enable rapid development of newly-hatched larvae, which appears important for escaping severe food shortage in fourth instar. Thus, the cannibalism by first instar larvae of *H. axyridis* may increase cannibal's survival rate in older stages.

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