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Research Article

Predatory efficiency and developmental attributes of *Harmonia dimidiata* (Fabricius) (Coleoptera: Coccinellidae) in relation to prey density

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ABSTRACT: The predatory efficiency and survival of immature stages of an aphidophagous ladybeetle, *Harmonia dimidiata* (Fabricius) were investigated at five different prey densities, *viz*., 25, 50, 75, 100 and 125 using *Cervaphis quercus* Takahashi as prey. A substantial influence of prey density on the rate of larval growth and development was observed. Increased prey density reduced the developmental period. The study also revealed that larval development could be completed at the lowest prey density of 25 prey aphids. The analysis revealed a positive correlation between survival of developmental stages and density of prey provided. A relative increase in weight was observed with increasing density of aphid prey, but only up to a prey density of 100. The functional response exhibited by fourth instar larva exemplified type II predatory response with optimum response at a prey density of 100.

KEY WORDS: *Harmonia dimidiata, Cervaphis quercus*, predatory efficiency, prey density, immature survival

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INTRODUCTION

The oak plant (*Quercus serrata* Thunberg) grows abundantly in the sericultural farms and foot hills of Manipur, Meghalaya, and some other parts of North-eastern India (Tikoo, 1988). It is the primary food plant of the oak tasar silkworm, *Antheraea proylei* Jolly. Several species of insects have been reported to attack *Q. serrata* in India (Feeny, 1970), of which aphids form a significant group. *Cervaphis quercus* Takahashi (Hemiptera: Aphididae) is a monoecious aphid species infesting particularly the young shoots, leaves as well as mature foliage of the oak plant throughout the year (Shantibala, 1993). Heavy colonization of aphids results in leaf curling, yellowing, stunted growth, etc., thereby lowering the nutritive value of host plants. Among the biocontrol agents, ladybird beetles have proved their efficacy and approximately 90% of the known coccinellids are predatory and beneficial (Iperti and Paoletti, 1999). *Harmonia dimidiata* (Fabricius) is a voracious aphidophagous ladybird beetle commonly found feeding on *C. quercus* in oak fields. Studies on various life attributes, developmental stages, prey consumption, prey suitability, etc. of a predator are essential in assessing its viability as a biocontrol agent. Similar to other predators, coccinellids react to changing density of prey in several ways which were first described and defined by Solomon (1949) and analyzed by Holling (1965). However, a perusal of literature reveals that the above aspects of *H. dimidiata* have not been studied and well documented. The present investigation was designed to provide information on density-dependent development, immature survival and prey consumption of *H. dimidiata* on *C. quercus,* a key pest of oak.

MATERIALS AND METHODS

Adults of *H. dimidiata* were collected from sericultural fields and brought to the laboratory to establish stock cultures. A group of 20 beetles (sex ratio 1:1) was kept in plastic containers (12 x 11.5 cm) at 252°C, 65 ± 2% R.H. and 16:8 hrs L: D in an incubator. The beetles were fed daily with supply of aphids *ad libitum* (*Cervaphis quercus*). The containers were lined with damp tissue paper and a piece of corrugated filter paper for oviposition.

Eggs were collected from the culture and on hatching the larvae were kept singly in Petri dishes (11.0 x 1.5 cm) and reared till pupation at different prey densities (25, 50 75, 100 and 125). Ten replications were maintained for each prey density. The fresh weight from first instar onwards till pupation of the coccinellid beetles for all replicates was also recorded. Consumption at different prey densities per day was estimated only in the case of fourth instar larva since it is regarded as the most voracious stage. The per cent immature survival (*i.e.*, number of pupae x 100/number of first instar hatched) was calculated. The data obtained from the above experiments were subjected to one-way ANOVA using the statistical Software SPSS–10.

RESULTS AND DISCUSSION

The relative duration and weight of different life stages of *H. dimidiata* when provided with six different densities of the aphid prey *C. quercus* are depicted in Table 1. A substantial influence of varying prey density on the rate of larval growth and development was observed in the present study. Duration of the first (F = 14.2; $P < 0.05$), second (F = 6.06; $P < 0.05$) and third instars (F = 2.22; $P < 0.05$) decreased with increase in prey density. A significant decrease in the duration of fourth instar (F = 133.77; $P < 0.05$) and total larval period (F = 136.11 P < 0.05) of *H. dimidiata* was also recorded with increase in density from 25 to 100 prey aphids. Several studies have shown that higher density of prey reduces the developmental period and larval growth of immature stages. Wratten (1973) observed that *Adalia bipunctata* when provided with excess food accomplished development of first instar within 8.7 days, second in 5.6 days, third in 5.8 days and fourth in 10.3 days, which on a low supply of food increased to 17.7, 23.9, 14.7 and 35.6 days, respectively. Similarly in the present study the total larval duration was limited to a period of 5.90 days at the highest prey density (125) and extended to a period of 48.12 days at the lowest prey density (25). The significant effect of varying prey density was also observed on pre-pupal (F = 2.1; $P < 0.05$) and pupal (F = 9.64; $P < 0.05$) durations. The present findings are also in conformity with those of Kawauchi (1979) on *Propylea japonica* and Hukusima and Ohwaki (1972) on *H. axyridis*.

The study also revealed that larval development could be completed at the least prey density of 25 prey aphids. It may be ascribed to the fact that predaceous coccinellids show a pronounced ability to adjust to food scarcity as an adaptation to intermittent absence of prey. According to Hodek and Honek (1996), the larvae of *Coccinella septempunctata* could complete its development when food supply was artificially reduced to 55 or 40 per cent. Though the larvae pupated, emergence of adult was observed to be comparatively lower. The present investigations also yielded more or less similar results.

The percentage of immature survival increased from 40% to cent per cent with increase in prey density from 25 to 100 (Fig. 1). The correlation analysis revealed a positive correlation between survival of developmental stages and density of prey provided showing a regression equation of $Y = 19.0 + 0.68\ X$; $r = 0.95$; $P < 0.05$. The first instar, *i.e.,* neonate stage, suffered the highest mortality irrespective of prey density. The relatively high mortality of first instar has also been reported in *Chilocorus nigrita* (Ponsonby and Copland, 1996) and *Propylea dissecta* (Omkar andPervez, 2004), the reason being their smaller sizes with thin cuticles making them more vulnerable to physical stresses.

The weight of different life stages of *H. dimidiata* when provided with different densities of prey aphid widely varied (Table 1). The average weight of first (F = 2.10; $P < 0.05$), second (F = 10.90; $P < 0.05$) and third (F = 9.66; $P < 0.05$) instars at different densities varied significantly. A relative increase in weight was observed with increasing density of aphid prey but only up to a density of 100. Thereafter additional food consumption revealed insignificant contribution to weight of adults. The weight of fourth instars (F = 3.43; $P < 0.05$), prepupa (F = 1.90; $P < 0.05$) and pupa (F = 1.90; $P < 0.05$) varied more significantly than weight of neonates and early instar. The net weight of fourth instar larvae fed on higher prey density (100) was about four times as much as that on the least prey density (25). Thus it can be inferred that the quantity of aphid consumed had a substantial effect on development and final weight of the immature stages.

Table 1. Duration (days) and weight (mg) of different life stages of *H. dimidiata* in relation to prey density

Developmental stage	Prey density				
	25	50	75	100	125
First instar	2.7 ± 0.09	2.64 ± 0.22	2.25 ± 0.03	2.01 ± 0.02	1.6 ± 0.24
Second instar	2.47 ± 0.21	2.36 ± 0.22	2.04 ± 0.06	1.64 ± 0.22	1.50 ± 0.22
Third instar	2.60 ± 0.14	2.38 ± 0.08	2.16 ± 0.09	1.90 ± 0.20	1.38 ± 0.11
Fourth instar	40.35 ± 2.37	17.18 ± 0.95	13.61 ± 1.05	2.54 ± 0.14	1.42 ± 0.24
Total larval period	48.12 ± 2.56	24.56 ± 1.18	19.84 ± 1.08	8.09 ± 0.37	5.90 ± 0.29
Pre-pupal period	1.53 ± 0.12	1.26 ± 0.10	1.23 ± 0.11	1.15 ± 0.10	1.25 ± 0.19
Pupal period	6.55 ± 0.42	6.04 ± 0.43	5.35 ± 0.26	4.18 ± 0.40	4.92 ± 0.29

Values are mean ± SE

Table 2. Weight (mg) of different life stages of *H. dimidiata* in relation to prey density

Developmental stage	Prey density				
	25	50	75	100	125
First instar	0.34 ± 0.2	0.36 ± 0.2	0.41 ± 0.004	0.44 ± 0.02	0.46 ± 0.01
Second instar	5.42 ± 0.12	6.96 ± 0.27	7.66 ± 0.23	8.88 ± 0.20	9.24 ± 0.13
Third instar	5.64 ± 0.20	8.52 ± 0.15	8.74 ± 0.21	9.34 ± 0.18	9.42 ± 0.30
Fourth instar	14.29 ± 3.12	23.70 ± 1.75	30.42 ± 0.83	39.54 ± 0.44	31.40 ± 0.73
Pre-pupal period	18.90 ± 0.87	22.03 ± 1.96	29.04 ± 0.75	38.08 ± 0.57	29.88 ± 0.72
Pupal period	17.62 ± 0.84	20.90 ± 1.98	27.75 ± 0.72	36.88 ± 0.66	28.54 ± 0.78

Values are mean ± SE

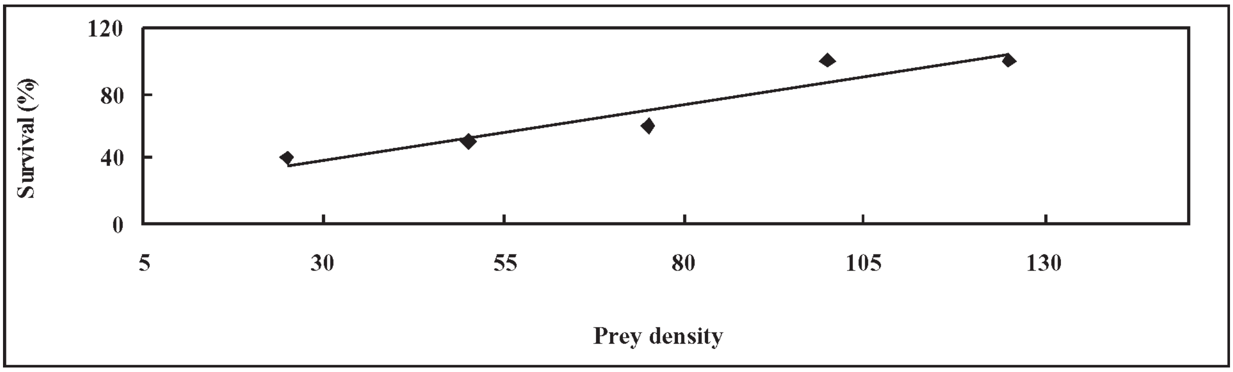

Fig. 1. Immature survival (%) of *H. dimidiata* at different densities of *C. quercus*

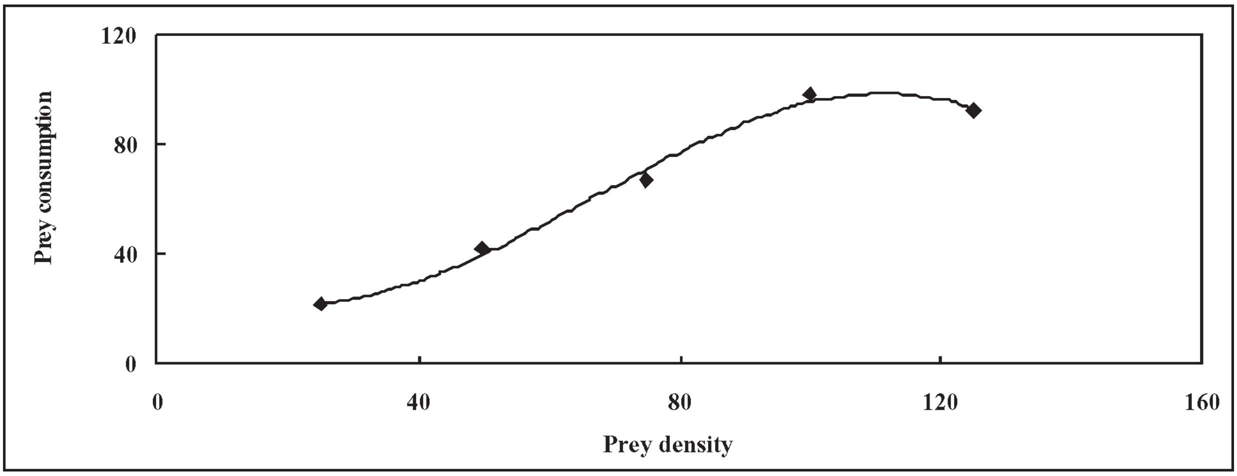

Fig. 2. Prey consumed by fourth instar of *H. dimidiata* at different densities of *C. quercus*

During the present investigation, the fourth instar was recorded to be the most voracious stage owing to increased requirement of food energy for growth (Sharma *et al*., 1997) to attain critical weight for pupation (Omkar and Srivastava, 2003) and as a function of reproduction and searching efficiency in adults (Agarwala and Yasuda, 2000). Studies on the functional response of fourth instar *H. dimidiata* larvae in relation to prey density revealed an initial rapid increase in prey consumption with a gradual decrease at higher prey density (Fig. 2). An optimum response was obtained at 100 prey aphids. The functional response exhibited by the fourth instar larvae exemplified type II predatory response as described by Holling (1959). The present findings are in conformity with those of Agarwala and Bardhanroy (1997) on *Cheilomenes sexmaculata* and Omkar and Pervez (2004) on *P. dissecta*.

It may be inferred that prey density significantly affects the immature survival of *H. dimidiata* with the first instar larvae suffering the highest mortality. Larval development could be completed at the least prey density of 25 prey aphids. *H. dimidiata* larvae exhibited an optimum response at a prey density of 100 aphids. Thus the present study provides a better understanding of the predator-prey interaction and would be helpful in efficient utilization of *H. dimidiata* for the management of *C. quercus* infestation in oak fields.

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