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Predation and searching efficiency of a ladybird beetle, *Coccinella septempunctata* Linnaeus in laboratory environment

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The predation and searching efficiency of fourth instar of predatory *C. septempunctata* at various densities of mustard aphid, *Lipaphis erysimi* (Kaltenbach) and predator was investigated under laboratory conditions. The feeding rate of predatory stage decreased at increased prey- and predator densities. Highest percent (92.80%) prey consumption was observed at initial prey density and lowest percent (40.86%) prey consumption at highest prey density by the fourth instar, though the total prey consumption increased with increase in either prey- or predator densities. Similarly, the individual prey consumption was also highest at initial predator density and lowest at highest predator density owing to the mutual interference between the predators at higher densities. The area of discovery (searching efficiency) also decreased with increase in prey- and predator densities. Handling time of predator was highest at lower prey densities, which decreased with increased prey densities. The highest percentage of prey consumption at the prey density of 50 revealed that 1:50 predator-prey ratio was the best to reduce the pest population.

Lipaphis erysimi (Kaltenbach) is an economically important aphid pest of mustard crops. *Coccinella septempunctata* Linnaeus (Coccinellidae: Coleoptera) is a cosmopolitan predator of aphids, mealybugs, scale insects and other small soft-bodied insects[1], prevalent in agricultural and horticultural fields. The population dynamics of aphids is determined by biotic and abiotic factors in the agroecosystems. Predation is one of the major biotic factors in suppressing pest populations. The degree of suppression is dependent on searching efficiency, handling time and feeding response of a predator in an adequate time and space. The present investigation thus deals with predation and searching efficiency of fourth instar of *C. septempunctata* on *L. erysimi*. The study has been carried out in laboratory conditions to provide an academic support for evaluation of predatory efficiency in open environment under field conditions.

Two sets of experiments were designed for the study of predation and searching efficiency of 12 hr starved fourth instar of *C. septempunctata* in relation to the aphid prey, *L. erysimi*. The first set of experiments was designed to study the effect of prey densities on the rate of consumption and searching efficiency of the predator (functional response) and the second set to study the effect of different predator densities on the rate of consumption of prey (aggregative numerical response).

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Functional response—For the first set of experiment, fourth instars of *C. septempunctata* were kept singly in separate glass beakers (11.0 cm height and 8.5 cm diameter) for 12 hr starvation. A single 12 hr starved predatory stage was introduced in each of the glass beakers containing 6 different densities, *viz.* 50, 100, 200, 400, 600 and 800 of third instar nymphs of *L. erysimi* for 24 hr and open ends of the beakers were covered with muslin cloth, fastened with rubber bands. The beakers were kept in an Environmental Test Chamber (ETC) maintained at 25°±2°C and 65±5 R.H. To provide the accurate number of prey, third instar nymphs and not gravid females were selected because the gravid females may reproduce and cause error in the counting of prey. After 24 hr exposure the predators were taken out from the glass beakers and unconsumed aphids counted to find out the predation. The experiment was replicated 10 times.

Aggregative numerical response—Due to highest prey consumption by fourth instar of *C. septempunctata*, the second set of experiments was designed to evaluate its aggregative numerical response. Fifteen fourth instars were kept separately in different glass beakers (height 11.0 cm and diameter 8.5 cm) for 12 hr starvation to standardize their level of hunger and to avoid cannibalism. One, two, four and eight fourth instars of *C. septempunctata* were introduced in separate glass beakers having 200 third instar nymphs of

L. erysimi on mustard twigs and the open ends of the beakers were covered by muslin cloths with the help of rubber bands. This exposure of predator(s) to prey was given for 3 hrs. After 3 hr, unconsumed aphids were counted to evaluate the predation. The experiment was replicated 10 times. Handling time of prey (*i.e.* time taken by the predator for pursuing, subduing, consuming and digesting the prey) was calculated by taking the ratio of time duration and number of prey consumed by the predatory stages. The area of discovery (*i.e.* searching efficiency) was calculated as per formula given below:

$$A = 1/P \log_e N/S$$

where, A: area of discovery; N: prey density exposed for predation; P: predator density released for predation; and S: number of prey surviving predation

A model of searching efficiency of predators was proposed[2], which incorporated a mutual interference constant (m) and quest constant was calculated.

$$A = Q/P^m$$

where, Q: quest constant, (a = area of discovery, when only one predator is searching); m: mutual interference constant (the slope of regression of log a on log p); and P: predator density released for predation.

Data so obtained from both the experiments were subjected to One-way ANOVA and linear regression analysis. Linear regression analysis was applied to the (i) log prey consumption and log prey density, (ii) prey consumption and predator density, (iii) area of discovery and log initial number of prey, and (iv) area of discovery and log initial number of predator(s), using PC with Statistix 4.1 (1994) software.

Functional response—The prey consumption of fourth instar increased from 46.40±0.70 to 327.80±1.75 ($F=89.84$; $P<0.001$) when the prey density increased from 50 to 800 (Table1). Regression analysis between the log prey consumption and log prey density of fourth instar exhibited a linear relationship. The regression equation of fourth instar was $Y=0.44+0.72 \log X$, $r=0.99$. Percent prey consumption of fourth instar of a ladybird beetle decreased from 92.80 to 40.86 with the increase in prey density. The prey handling time of fourth instar decreased from 31.03 to 4.97min as the prey density increased from 50 to 800.

The number of prey consumed by the predatory stages initially increased rapidly with the increase in prey density but slowed down with further increase in prey density, thus, exhibiting type II functional response[3]. The increase in prey consumption by the predatory stage with increase in prey densities may be due to factors like greater interaction of prey and predators, handling time, limited area of searching and the level of starvation. Increased prey density resulted in reduction in the searching arena for predators, increasing the chance of prey-predator interaction. At low prey densities, aphids were spaced out due to which the predators spent most of their energy and time in foraging. The prey handling time was relatively lower at higher densities (200-800) for the fourth instar (ranging from 10.03 to 4.97 min). Relatively lesser handling time at higher prey densities (200 to 800) shows that it was easier to obtain and catch prey at these densities.

Aggregative numerical response—The data (Table 2) revealed that prey consumption by fourth instar(s) increased from 34.50±1.08 to 93.40±1.06 individuals of *L. erysimi* (($F=593.25$; $P<0.001$) when predator density increased from one to eight. Thus, there was a curvilinear increase in the prey consumption with the increase in predator density. The regression equation for predator density and prey consumption was $Y=28.89+8.26\log X$, $r=0.99$. A linear declination in the rate of prey consumption per predator with the increase in predator density was observed. This resulted in reduction in individual prey consumption of fourth instar from 34.50 ± 1.08 to 11.65 ± 0.16 individuals of *L. erysimi* with increase in predator

Table 1—Number of prey consumed, percent prey consumption and handling time of fourth instar of *C. septempunctata* at various prey densities of *L. erysimi*

[Values are mean±S.E]

Prey density	No. of prey consumed	% of prey consumption	Handling time of prey
50	46.40±0.70	92.80	31.03
100	87.60±0.98	87.60	16.44
200	143.60±1.21	71.80	10.03
400	239.30±1.00	59.83	6.02
800	327.80±1.75	40.86	4.97

Table 2—Prey consumption (numerical response) of fourth instar of *C. septempunctata* at various predator densities and constant density of *L. erysimi*

[Values are mean±S.E]

Predator density	Total number of prey consumed	Prey consumed per predator
1	34.50±1.08	34.50±1.08
2	46.30±1.00	23.15±0.50
4	65.20±0.85	16.25±0.22
8	93.40±1.06	11.65±0.16

Table 3 — Area of discovery (searching efficiency) of searching grubs of *C. septempunctata* at different *L. erysimi* densities (exposure period 24 hour) and at its different densities (exposure period 3 hour)

Prey density	Area of discovery	Predator densities	Area of discovery
50	2.6310	1	0.1893
100	2.0874	2	0.1317
200	1.2658	4	0.0986
400	0.9119	8	0.0787
600	0.6600		
800	0.5272	Mutual interference	0.55
		Quest constant 0.2469	

density from one to eight. The values of mutual interference constant and quest constant were 0.55 and 0.2469, respectively when the predator density rose from one to eight.

In the limited time and space of predation, the predators had to face the hindrance caused by the increased prey and predator densities and thus the prey consumption decreased. At higher prey-predator densities competition amongst predators also increased due to which decrease in prey consumption took place.

The area of discovery of a single fourth instar decreased from 2.6310 to 0.5272 when the prey density increased from 50 to 800. Similarly the area of discovery decreased from 0.1893 to 0.0787 when predator density increased from one to eight, at the constant prey density of 200 (Table 3).

The decrease in the area of discovery of fourth instar with increased prey and predator densities may be ascribed to the fact that with increase in prey and predator densities, the predator switches over from extensive to intensive search, which leads to the decrease in the area of discovery. Highest area of discovery at lowest prey density suggests that prey scarcity stimulates the foraging behaviour of the ladybird beetle. The availability of aphid is easy therefore searching efficiency was increased at higher prey densities. The higher densities of prey and predator have an inverse effect on the searching efficiency of the predator[2,4,5] and to overcome the prey population more predators are required. The aphid population determines the predator population[6]. The highest percentage of prey consumption at the lowest prey density (50), the highest individual consumption at the lowest predator density and the highest area of discovery (searching efficiency) in both the conditions indicate that the predator and prey ratio of 1:50 may prove to be the best prey-predator ratio.

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References

1 Omkar & Bind R B, Records of aphids-natural enemies complex of Uttar Pradesh II The coccinellids, *J Adv Zool*, 14 (1993) 96.

2 Hassell M P & Varley G C, New inductive population model for insects parasites and its bearing on biological control, *Nature*, 223 (1969) 1133.

3 Holling C S, Functional response of predators to prey density and its role in mimicry and population regulation, *Mem Entomol Soc Can*, 45 (1959) 3.

4 Tripathi C P M, Siddiqui A, Dubey R J, Sinha G, Kumar N & Rai S, *Effect of food plant on the searching efficiency, mutual interference and killing power of the ladybird beetle, Coccinella septempunctata* Linn, a predator of *Lipaphis erysimi* (Kalt), Seventh National Symposium on Aphidology, 11-13 March, 2000 at DDU Gorakhpur University, Gorakhpur, (2000) 55.

5 Ofuya T I & Akingbohungbe A E, Functional and numerical responses of *Cheilomenes lunata* (Fabricius) (Coleoptera: Coccinellidae) feeding on cowpea aphid, *Aphis craccivora* Koch *(Homoptera: Aphididae)*, *Insect Sci Appl*, 9 (1988) 543.

6 Wagiman F X, Numerical response and density dependent relationship of *Menochilus sexmaculatus* against *Aphis gossypii*, *Insect Sci Appl*, 2 (1996) 44.