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Searching and feeding efficiency of a ladybeetle, *Coccinella transversalis* Fabricius on aphid, *Aphis gossypii* Glover

OMKAR and BARISH E. JAMES
Department of Zoology, University of Lucknow
Lucknow 226 007, Uttar Pradesh, India
E-mail: omkaar55@hotmail.com

ABSTRACT: **Searching and feeding efficiency of a predaceous ladybird beetle, *Coccinella transversalis* Fabricius was investigated for brinjal aphid, *Aphis gossypii* Glover at varying predator and prey densities. Rate of prey consumption per predator decreased with increase in the number of predators, due to mutual interference (0.90) amongst the larvae. Searching efficiency (area of discovery) of fourth instar larvae decreased from 0.1846 to 0.0779 when one, two, four and eight predators were exposed to a constant prey density (200). Prey consumption by a single larva increased with increase in prey densities but the percent prey consumption decreased. Maximum percent prey consumption was noticed at the lowest prey density (50) and minimum at highest prey density (800). Searching efficiency of a fourth instar larva decreased from 1.7263 to 0.4727 with increase of prey density from 50 to 800 individuals of *A. gossypii*. The predator-prey ratio of 1:50 may be considered optimal for the augmentative release of *C. transversalis* for the biocontrol of *A. gossypii*.**

KEY WORDS: *Aphis gossypii*, *Coccinella transversalis*, Coccinellidae, Coleoptera, predation, searching

INTRODUCTION

To be an effective biocontrol agent, the success of a predator depends upon its foraging ability. The searching and predation response of a predator can be traditionally and analytically studied under headings: (i) Functional response, which involves the prey consumption by a predator at different prey densities, and (ii) Numerical response, which is the response to changes in predator density at a constant prey density (Solomon, 1949). Functional response of the predator was earlier promulgated in three disc equations (Holling, 1959). Most of the previous studies on functional response, using predaceous coccinellids as models revealed Holling's Type II response with a curvilinear relationship between prey consumption and prey density (Kumar *et al.*, 1999; Yasuda and Ishikawa, 1999; Xia *et al.*, 1999; Omkar and James, 2001; Omkar and Srivastava, 2001). However, a few exhibited Type III response, which is sigmoidal in shape (Haji-Zadeh *et al.*, 1994).

Though, searching efficiency is an important component of prey-predator interactions, not much attention has been paid using predaceous coccinellids. Nicholson and Bailey (1935) proposed a model to explain such interactions for parasitoids. However, it can also be applicable for predators, as it introduced the term "area of discovery", a measure for searching efficiency, which is initially proposed to be independent of prey and predator-densities.

The later inductive model explains that area of discovery decreases exponentially with predator population and is not a constant (Hassell and Varley, 1969). This model was widely accepted due to its simplicity and hence used in the present investigation to calculate mutual interference.

Coccinella transversalis Fabricius, an important predator of brinjal aphid, *Aphis gossypii* Glover was used (George, 1999; Omkar *et al.*, 1999; James, 2001; Omkar and James, 2003) for the present investigation. Though, an economically important coccinellid, meagre information is available on its predatory potential, which prompted to select it as an experimental model for the present study.

Besides, the evaluation of its functional response and searching efficiency, the optimal predator-prey ratio needed for the augmentative release of the predator was also estimated.

MATERIALS AND METHODS

The first set of experiments was designed to evaluate the searching efficiency and second set for the functional response of the fourth instar of *C. transversalis.*

Searching Efficiency

For the first set of experiments, twelve hour starved 1, 2, 4 and 8 fourth instars of *C. transversalis* were introduced into four glass beakers (diameter 11.0cm x height 8.5 cm) containing two hundred individuals of *A. gossypii* infested on a twig of brinjal, *Solanum melongena*. Open ends of glass beakers were covered with muslin cloths fastened with rubber bands and placed in an Environmental Test Chamber (ETC) at 27±2°C and 65±5 per cent R.H. After three hours of exposure, larvae were taken out and unconsumed aphids were counted to find out the number of aphids consumed. The prey consumption per predator was calculated by taking the ratio of number of prey consumed and predator density. The data were subjected to One-way ANOVA using statistical software MINITAB on PC. Differences between means of activity were calculated using Tukey's honest significance test at 5 per cent level.

Functional Response

Second set of experiments was designed to study the effect of varying prey densities on searching efficiency of predator. For the purpose, 50, 100, 200, 400, 600 and 800 individuals of *A. gossypii* were kept in separate glass beakers (as above) along with host plant twigs. One twelve hour starved fourth instar larva of *C. transversalis* was introduced in each beaker and open end was covered with a muslin cloth fastened with a rubber band. After twenty-four hours exposure at 27±2°C, 65±5 per cent R.H., the larvae were taken out from the beakers to record the number of unconsumed aphids to find out the number of aphids consumed. The percent prey consumption was calculated by taking the ratio of prey consumed and initial prey density. The data were subjected to One-way ANOVA using statistical software MINITAB on PC. Differences between means of activity were calculated using Tukey's honest significance test at 5 per cent level.

Both the experiments were replicated ten times. Area of discovery was calculated following Nicholson and Bailey (1935).

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

Where, a= area of discovery, N= prey density exposed for predation, P = predator density released for predation, and S= number of prey surviving predation.

As per the new inductive model of searching efficiency proposed by Hassell and Varley (1969), which incorporate mutual interference constant (m), derived as:

$$a = Q / P^m$$

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).
P = predator density released for predation.

The log values of initial number of prey and predators were evaluated and data obtained were analyzed by linear regression to determine the relationship between, (1) area of discovery and log

initial number of predators, and (2) area of discovery and log initial number of prey. The log values, *i.e.* log prey consumption and log prey density obtained from the data of second experiment were subjected to regression analysis following a statistical package "Statistix 4.1" on PC. The disc equation proposed by Holling (1959) was transformed to nullify the assumption of constant prey density and to obtain a linear equation. This transformation was made following Livdahl and Stiven (1983) and Veeravel and Baskaran (1997).

RESULTS AND DISCUSSION

Searching Efficiency

Prey consumption by fourth instar larvae of *C. transversalis* increased significantly ($F=594.54$; $P<0.001$; d. f. = 3, 36) from 33.70±1.61 to 92.70±1.34 individuals of *A. gossypii* at constant density of 200 when predator density increased from one to eight (Table 1). But, prey consumption per predator decreased with increase in predator density. The prey consumed by the larvae did not double when prey density doubled, but remained less than the double. Prey consumption increased curvilinearly with predator density (Figure 1). There was an inverse linear relationship (Figure 2 and 3) between the log numbers of predator and prey densities with the area of discovery.

Study on searching efficiency revealed that when more number of larvae of *C. transversalis* was introduced at a constant prey density, the prey consumption increased but rate of consumption by individual larva decreased. This was in agreement with earlier finding on *C. transversalis* (Veeravel and Baskaran, 1997). Fourth instar larvae exhibited a strong mutual interference constant, which signifies that they frequently encountered each other, which adversely affected the prey consumption rate, hence the overall prey consumption decreased at high predator density. This suggests that the presence of more larvae reduces the foraging and feeding success of conspecifics by consuming the prey sighted and interfering with them. The findings are in conformity with those of Roger and Hassell (1974), Evans (1991) and Phoofolo and Obrycki (1998).

The area of discovery decreased from 0.1846 to 0.0779 and mutual interference constant was 0.90 when one, two, four and eight predators were searching. This decrease in area of discovery was possibly due to intra- and interspecific interferences. Predator density may influence the area of discovery in two ways. Firstly, due to relative high activity of predator, when it searches singly as compared to that at high predator density, which results in increased area of discovery (Hassell and Varley, 1969). Secondly, relatively lesser handling time of predator per prey at low predator density also effects in increased area of discovery (Hassell and Varley, 1969).

Table 1. Prey consumption and area of discovery of *C. transversalis* at different predator densities

Predator density	Total prey consumed*	Prey consumption per predator	Area of discovery
1	33.70±1.52a	33.70	0.1846
2	44.20±1.10b	22.10	0.1249
4	64.80±0.06c	16.20	0.0979
8	92.70±1.34d	11.60	0.0779

Mutual interference = 0.90

* Values are Mean ± SEM

Different letters denote that data are statistically significant (Tukey's Test; range = 3.81; d. f. = 3, 36)

Functional Response

Prey consumption by a fourth instar larva of *C. transversalis* increased significantly (F=2370.87; P<0.001; d. f. = 5, 54) from 41.1±1.52 to 301.8±2.27 individuals of *A. gossypii*, whilst per cent prey consumption decreased from 82.2 to 37.73 with increase in prey density from 50 to 800 (Table 2). Area of discovery of a fourth instar larva decreased from 1.7263 to 0.4727 when the prey density increased from 50 to 800. Log prey consumption increased linearly with log prey density (Figure 4) and the regression equation for the same was log y = 0.47 + 0.70logX (r = 0.98; P<0.001).

Functional response reveals that prey consumption by *C. transversalis* increased with increase in prey density, whereas percent prey consumption decreased, which exemplifies Holling Type II predatory response (Holling, 1959). The present finding is in close agreement to those recorded on other ladybeetles (Yasuda and Ishikawa, 1999; Kumar *et al.*, 1999). When one larva was searching, the prey consumption rapidly increased and thereafter gradually decelerated, resulting in a plateau, at which consumption rate remained almost constant irrespective of further increase in prey density. Area of discovery decreased at high prey density, possibly as an outcome of more area restricted (*i.e.*, intensive) search, enabling more exposure of predator to prey individuals. Clumping of prey at high prey density results in increased prey capture as also opined by Munyaneza and Obrycki (1998) for *Coleomegilla maculata* de Geer larvae.

Higher prey density also results in reduction of unsuccessful attacks of predator on a prey, as there are less chances of escape irrespective to those in scarce prey density, where there are more chances for the prey to escape from predator (O'Neil, 1988). At high prey density, less time was spent in searching, therefore more time was spent in handling, whereas at low prey density the searching time always dominated the handling time (O'Neil, 1988). Disturbance by another prey at high prey density also aggravated a hungry predator during feeding, which resulted in killing of more prey individuals than normal. Thus, the greater interferences at higher prey density may partly result in increased prey mortality.

Assemblage of prey also affected the searching. Since aphids were widely spaced out at lower prey density, more time and energy were expended in searching because of the dispersed

Table 2. Functional response in terms of number of prey consumed and are of discovery of *C. transversalis* at different prey densities

Predator density	Prey density	No. of prey consumed	Prey consumption (%)	Area of discovery
1	50	41.10±1.52a	82.2	1.7263
1	100	76.50±1.05b	76.5	1.4484
1	200	129.90±2.25c	64.95	1.0486
1	400	210.00±2.12d	52.50	0.7446
1	600	249.90±1.08e	41.65	0.5362
1	800	301.80±2.27f	37.73	0.4727

Values are Mean± SEM
Different letters denote that data are statistically significant.
Tukey's Test; (range = 4.02, d.f. = 5, 54)

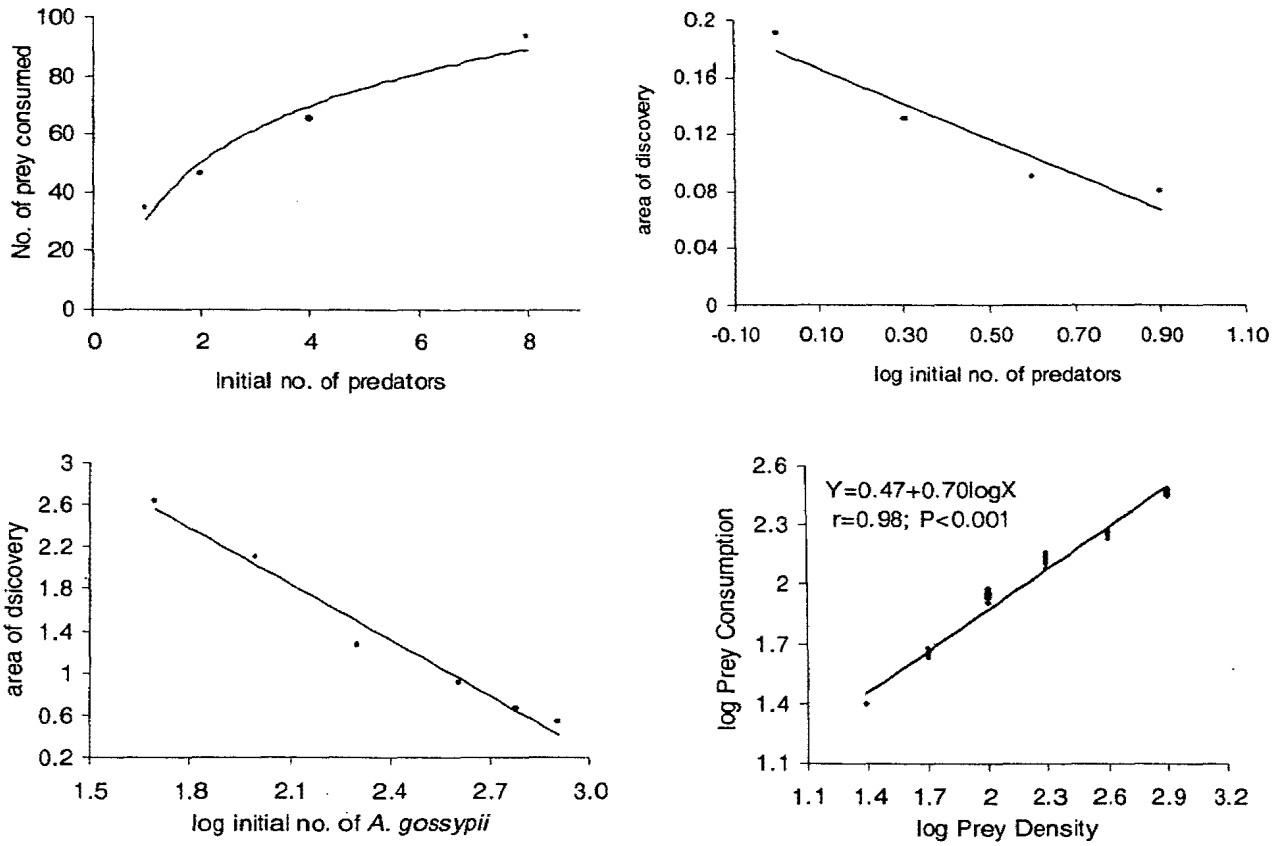


Figure 1. Relationship between number of prey (*A. gossypii*) consumed and different densities of *C. transversalis.*
Figure 2. Relationship between log area of discovery of *C. transversalis* and log initial numbers of predator.
Figure 3. Relationship between log area of discovery of *C. transversalis* and its log initial numbers of *A. gossypii.*
Figure 4. Relationship between the log density of *A. gossypii* and log consumption by fourth instar of *C. transversalis*

prey pattern, whereas, at higher prey density, there was a ready supply of prey. In field conditions the ladybeetle might spend more time to find the patch where the prey was present (Tamaki and Long, 1978).

Satiation is a possible reason for decreased percent prey consumption at high prey density, since satiated beetles spent more time in prey handling due to which rate of prey capture decreased (Mora *et al.*, 1995; Drayer *et al.*, 1997; Veeravel and Baskaran, 1997). Mutilated remnants of prey were more at higher prey densities, which suggested that after attaining satiation, the predator did not completely devour the prey and ate only the soft portion leaving aside the hard body surfaces, such as the appendages. Whereas, hungry larva fiercely attacked and completely devoured the prey at lower prey density, leaving no mutilated remnant.

The searching efficiency and rate of consumption was maximum when one predator was searching and at prey density of 50 aphids. Thus, the predator-prey ratio of 1:50 may be considered suitable for the release of the predator at the infested prey site and it might be used for predicting the dynamics of prey populations under field conditions.

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