



Functional response of *Adalia tetraspilota* (Hope) (Coleoptera: Coccinellidae) on cabbage aphid, *Brevicoryne brassicae* (L.) (Hemiptera: Aphididae)

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ABSTRACT: A study was conducted to assess the functional response of different life stages of the predacious coccinellid, *Adalia tetraspilota* (Hope) feeding on various densities of cabbage aphid, *Brevicoryne brassicae* (L.) under controlled conditions. It revealed that all stages of *A. tetraspilota* exhibit Type II functional response curve (a curvilinear rise to plateau) as *B. brassicae* densities increase and the curve predicted by Holling's disk equation did not differ significantly from the observed functional response curve. The fourth instar larva consumed more aphids (28.40 aphids / day) followed by adult female (25.06 aphids / day), third instar larva (24.06 aphids / day), second instar larva (21.73 aphids / day), adult male (20.06 aphids / day) and first instar (13.06 aphids / day). The maximum search rate with shortest handling time was recorded for fourth instar larva (0.6383) followed by adult female (0.6264). The results suggest that the fourth instar larva are best suited for field releases for the management of *B. brassicae*. However, further field experiments are needed for confirming its potential.

KEY WORDS: *Adalia tetraspilota*, Aphididae, *Brevicoryne brassicae*, Coccinellidae, functional response, handling time, predation, search rates

INTRODUCTION

The cabbage aphid, *Brevicoryne brassicae* (L.) (Hemiptera: Aphididae) is an important worldwide pest of cruciferous vegetables in temperate region. *Adalia tetraspilota* (Hope) (Coleoptera: Coccinellidae) is the dominant predator against *B. brassicae* on cruciferous crops in Jammu & Kashmir. Information based on the biology and feeding potential of *A. tetraspilota* suggests that it may act as an important biocontrol agent (Khan and Mir, 2008; Khan *et al.*, 2009). Little information is available on the response of this ladybird beetle with respect to change in density of *B. brassicae* and therefore it is unknown whether they may be expected to prevent or suppress population outbreaks of *B. brassicae*.

Coccinellid predators exhibit functional response, which is the change in the number of prey consumed per predator in response to changing prey density and numerical response, the change in predator density resulting from a change in prey density (Holling, 1959, 1965, Hemptinne *et al.*, 1996). The functional response may be constant

(Type I), decreasing (Type II), increasing (Type III). This could further be simplified in terms of density dependence as constant (I), decreasing (II) and increasing (III) rates of prey consumption and yield density dependent prey consumption, respectively (Pervez and Omkar, 2005).

Coccinellids generally exhibit Type II functional response as reported for *Coccinella septempunctata* (Ninkovic and Pettersson, 2003), *C. transversalis* (Pervez and Omkar, 2005), *Cycloneda sanguinea* (Isikber, 2005) and *Eriopis connexa* (Sarmiento *et al.*, 2007). The functional response of a predator feeding on a particular prey species are described by two widely used parameters, these are the predator's "attack rate" or search rate (a) and its "handling time" (Th) (Hassell *et al.*, 1976). When the predator passes through a series of instars, different values of a and Th will characterize for each predator stage-prey combination. Despite the undoubted effectiveness of such age structure effect on the dynamics of predator-prey interaction, only few workers have actually evaluated 'a' and 'Th' values for different stages of coccinellids preying on particular prey species. The present paper reports the functional response,

search rates and handling times for different life stages of the predatory ladybird beetle, *A. tetraspilota* on cabbage aphid, *B. brassicae* under controlled conditions in the laboratory.

MATERIALS AND METHODS

Insect rearing

Both *A. tetraspilota* and *B. brassicae* were collected from cruciferous crops in Vegetable Research Centre, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus, Srinagar, during 2007. The coccinellid and aphid cultures were maintained at 25 ± 5°C temperature, 60 ± 10% relative humidity and a photoperiod of 14 hour light: 10 hour dark. Ten pairs of coccinellids were released in separate plastic jars (height 20cm and diameter 15cm containing moist filter paper) for mating and oviposition. The jars were covered with muslin cloth and sufficient prey with host was provided daily for egg laying. Newly hatched larvae were collected from the jar and reared individually in separate jars and sufficient prey with host was provided daily for further studies.

Consumption rate

Different life stages of *A. tetraspilota* were taken from the culture for the experiments. The larvae and the adults were kept starved for 24 hrs in separate vials (height 5.0cm and diameter 3.0cm) individually before the experiments. This was to minimize differences in individual hunger levels (Nakamura, 1977). Thereafter, they were introduced individually into separate jars with 2, 4, 8, 16, 32, 64, 128, 256 aphids (medium size) on excised cabbage leaves stuck to agar medium. Test predators were randomly assigned to the various aphid density treatments and one treatment (control) was also designed for natural mortality of aphids. The experiment was replicated thrice and the whole experiment was repeated 5 times. The observations were taken after 24 hrs to record the number of aphids consumed by the different life stages of predator.

Statistical analysis

The numbers of aphids preyed by different life stages of *A. tetraspilota* at different densities of *B. brassicae* were analyzed separately using a non-linear least square programme (R Development Core Team, 2008). Usually, it is difficult to discriminate between Type II and III functional responses as mentioned by many workers (Mills, 1982; Trexler *et al.*, 1988). Hence, prior to fitting the data to a particular Holling’s Disc equation (1959), some correction needs to be done. Holling’s equation normal II curves is as follows:

$$N_a = \frac{a(N/V)T_t}{1 + aT_h(N/V)} \dots\dots\dots(1)$$

where, N_a is the number of prey consumed by one predator during a time period T_t , N is the initial prey density; V is the volume of the experimental cage and a and T_h are as above. This equation is done in an instant one and does not allow for the predation of prey during the experiment (Royama, 1971; Rogers, 1972). In contrast, the “random predator equation (2)” of Rogers (1972) takes prey exploitation into consideration. It is derived from

$$\frac{dN}{dt} = - \frac{a(N/V)}{1 + aT_h(N/V)} \dots\dots\dots(2)$$

This integrates to:

$$N_a = \left(\frac{N}{V} \right) (1 - \exp(- a(T_t - T_h N_a))) \dots\dots\dots(3)$$

Equation 3 now allows ‘ a ’ and ‘ T_h ’ to be calculated by iteration from experiments in which the consumed prey individuals are not replaced. In order to avoid the errors incurred by applying the linear regression method to estimate ‘ a ’ and ‘ T_h ’ as suggested by Rogers (1972), we used the non-linear function `nls()` provided by the R-software (R Development Core Team, 2008).

RESULTS AND DISCUSSION

The functional responses are usually measured to check the suitability of a predator as a biocontrol agent. The type of functional response, *i.e.*, the shape of relationship of the number of prey eaten versus prey available is a major factor which regulates predator-prey population and may contribute to stability of predator-prey systems. It shows the rate at which a predator kills its prey at different prey densities and can thus determine the effectiveness of a predator in regulating the prey population (Pervez and Omkar, 2005; Khan and Mir, 2008). Different life stages of *A. tetraspilota* play a vital job in controlling different densities of *B. brassicae*. Different life stages of this predator showed curvilinear shape depicting Holling type II functional response as steep initial rise in predation rates was recorded as the prey densities increased (Table 1 and Fig. 1).

The aphid consumption of fourth instar larva increased up to 28.40 aphids / day with increased densities of test prey (Fig. 1d) followed by adult female (25.06 aphids / day), third instar larva (24.06 aphids / day), second instar (21.73 aphids / day), adult male (20.06 aphids / day) and first instar larva (13.06 aphids / day) (Fig. 1). The resulting functional response showed clearly that the proportional consumption rate increased initially and declined later against the various densities of *B. brassicae* offered to *A. tetraspilota*, which

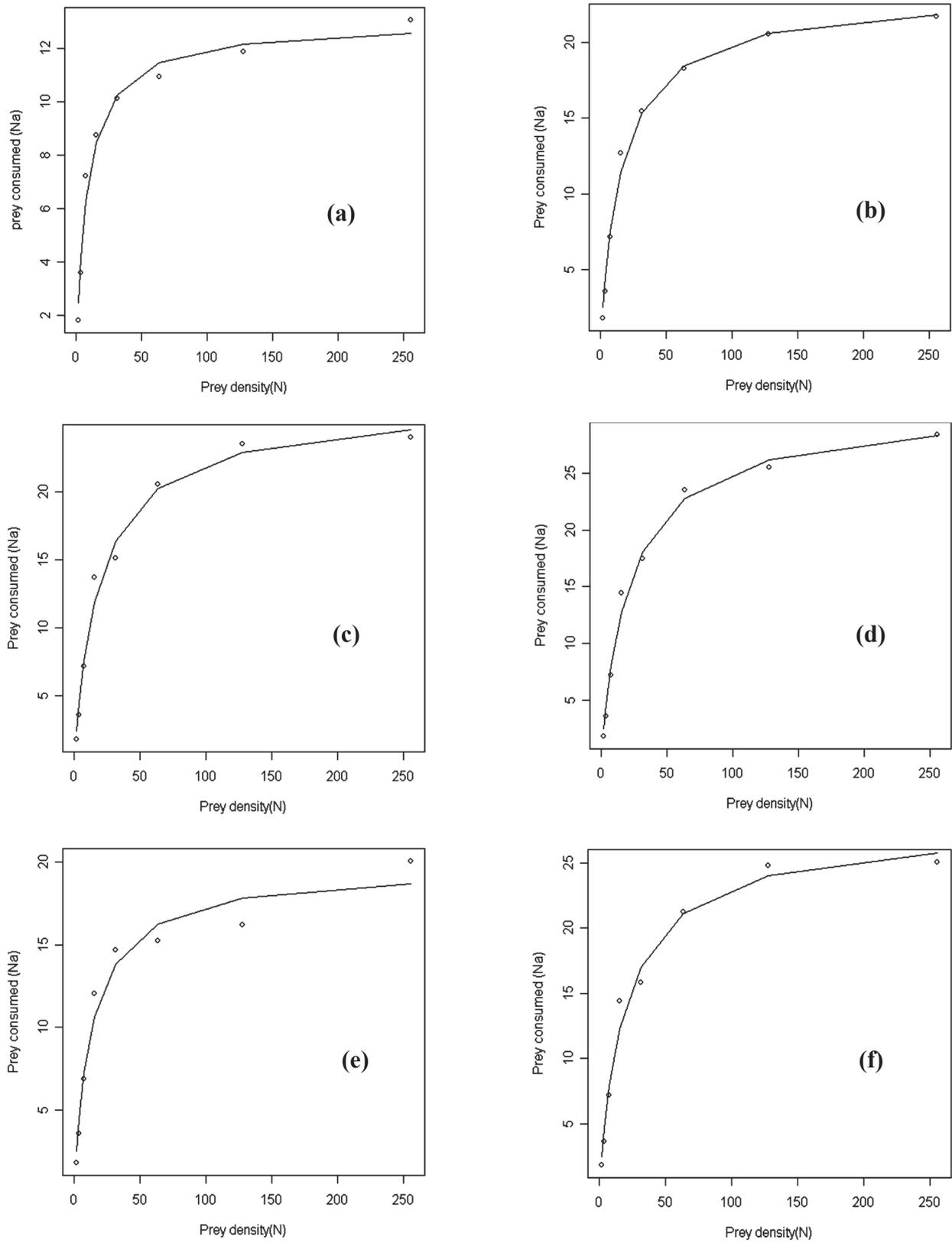


Fig. 1. Mean consumption of *B. brassicae* by different life stages of *A. tetraspilota* (a) first instar larva (b) second instar larva (c) third instar larva (d) fourth instar larva (e) adult male and (f) adult female

Table1. Functional response of *A. tetraspilota* on cabbage aphid, *B. brassicae*

Life stages of <i>A. tetraspilota</i>	Parameter	Estimate	SD	<i>t</i> value	r^2 at $p < 0.001$	Residual SD
I st instar larva	<i>a</i>	2.98609	0.35705	8.363	0.552	0.6167
	<i>Th</i>	1.85060	0.06207	29.817		
II nd instar larva	<i>a</i>	2.76717	0.22782	12.151	0.6061	0.7382
	<i>Th</i>	1.03252	0.02876	35.913		
III rd instar larva	<i>a</i>	2.63298	0.28597	9.207	0.6238	1.093
	<i>Th</i>	0.90557	0.03521	25.718		
IV th instar larva	<i>a</i>	2.65968	0.23646	11.252	0.6383	1.026
	<i>Th</i>	0.77764	0.02594	29.989		
Adult male	<i>a</i>	2.83011	0.46452	6.093	0.5889	1.264
	<i>Th</i>	1.21850	0.06398	19.046		
Adult female	<i>a</i>	2.69010	0.31490	8.543	0.6264	1.231
	<i>Th</i>	0.86380	0.03650	23.664		

is characteristic of Type II functional response as reported for *Adalia punctata* (Roche, 1998), *Harmonia axyridis* and *Cheilomenes sexmaculata* (Pervez and Omkar, 2005), *A. tetraspilota*, *Coccinella septempunctata*, *Calvia punctata* and *Hippodamia variegata* (Khan and Mir, 2008).

An assessment of functional response curves revealed that fourth instar larva of *A. tetraspilota* responded more vigorously to low densities of *B. brassicae* than other instars and adults. However, the prey consumption declined with prey density as in Type II functional response (Holling, 1959). Cardoso and Lazzari (2003) reported an earlier and steeper increase of functional response in fourth instar larvae of *Hippodamia convergens* Guerin-Meneville and *Cycloneda sanguinea* (L.) with an increase in aphid density while the former species showed a higher level of predation than the latter. If compared with male and female prey consumption the result showed the female consumed significantly more prey. Roche (1998) reported higher energy demands of adult coccinellid females may be due to egg production which is an energetically expensive process. As a result, females require and consume more aphids per day than males.

The search rate and handling time studied for the different stages of *A. tetraspilota* at various densities of *B. brassicae* are presented in Table 1, Fig. 2 and Fig. 3. The first instar larva had a high search rate but not significantly higher than that of other stages while the handling time of the fourth instar larva was significantly lower than that of other stages. Actually, the maximum searching with shortest

handling was determined by value of r^2 at $P < 0.001$ that was highest for the fourth instar larva (0.6383), followed by adult female (0.6264). Obviously, the search rate is determined by the speed, reactive distance at which a predator responds to the presence of prey and proportion of successful searches (Holling, 1959). The handling time and search rate are the parameters that reflect the significance of these responses. These parameters differed significantly and the stages of *A. tetraspilota* possess different capacities to pursue prey at increasing densities. Different stages of the predator manifested similar quantitative response curve effect on the *B. brassicae*. The values of different parameters varied due to the different size, satiation time, hunger levels, digestive power and searching speeds (Omkar and Pervez, 2004, Khan, 2009).

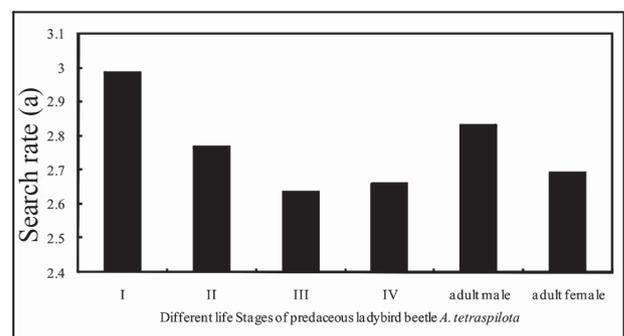


Fig. 2. Search rate(a) for different life stages of *A. tetraspilota* feeding on cabbage aphid, *B. brassicae*

Among all the life stages, the fourth instar larva responded more to increasing densities of *B. brassicae* than other stages. This result was vindicated by experimental evidence on the growth and development of fourth instar larva which acquires greater values in adaptation, growth and development using *B. brassicae* than other stages. Observed handling time is the accumulative impact of time taken during searching and capturing, overpowering and digesting the prey (Omkar and Pervez, 2003). The significant differences in the estimates of handling time of different class of predator on a single prey species indicates that any of these integral components of handling time might have contributed to the short handling time when fourth instar larva was used as predator rather than other life stages. This leads to the presumption that it digests its prey more quickly than the other life stages of *A. tetraspilota*.

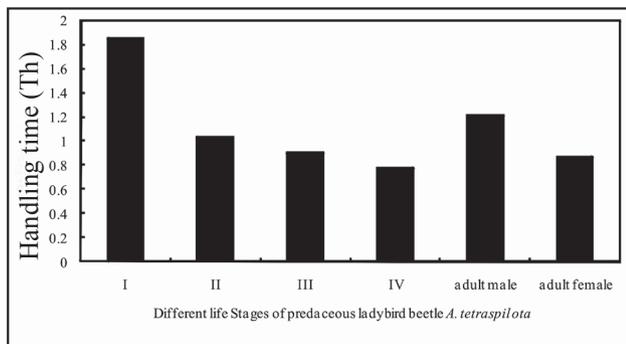


Fig. 3. Handling time (Th) of different life stages of *A. tetraspilota* feeding on *B. brassicae*

Functional response, though a momentous tool, cannot only be accredited to reported successes and failures in biocontrol programmes. For example, other factors such as adaptation, inherent growth rates, host patchiness, predation, inter- and extra-specific competition, host traits and complexities of the environment also have a major influence on the effectiveness of predator stages in managing the pest population.

It can be summarized that all the life stages of *A. tetraspilota* exhibited Type II functional response to *B. brassicae*, which differed quantitatively. The fourth instar larva appears to be the best stage for field releases for the management of *B. brassicae*. However, further field experiments are needed for confirming its potential.

ACKNOWLEDGEMENTS

The author is grateful to Dr. Athar Ali Khan, Associate Professor, Division of Agricultural Statistics, SKUAST (K), Shalimar, Srinagar, for statistical analysis and the Horticulture Technology Mission for financial assistance.

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(Received: 22.09.2008; Revised: 03.04.2009; Accepted: 27.04.2009)