

Functional response of *Pardosa altitudis* Tikader and Malhotra, *Teragnatha maxillosa* Thorell, *Neoscona mukherjei* Tikader and *Theridion* sp. to rice green leafhopper

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ABSTRACT

Laboratory experiments were performed to determine the functional response of visual hunting spider, *Pardosa altitudis* Tikader and Malhotra and web-building spiders, *Teragnatha maxillosa* Thorell, *Neoscona mukherjei* Tikader and *Theridion* sp. to 2nd and 3rd instar nymph of rice grasshopper. The functional response of *P. altitudis*, *T. maxillosa*, *N. mukherjei* and *Theridion* sp. to the different density of 2nd and 3rd instar nymph of rice grasshopper was typically of Holling Type II with a steep initial rise in prey capture rates as the density increased. *P. altitudis* consumption increased to 26.7 per day 2nd instar nymphs of rice grasshopper which was higher than that of *N. mukherjei* (23.1), *T. maxillosa* (22.4) and *Theridion* sp. (18.8). However, in case of 3rd instar nymph of rice grasshopper, the consumption of *N. mukherjei* was increased to 21.2 per day which was higher than that of *L. altitudis* (20.4), *T. maxillosa* (19.2) and *Theridion* sp. (16.2). The search rate of *N. mukherjei* was not significantly higher than *L. altitudis* against 2nd instar nymph of rice green hopper and handling time of *L. altitudis* was significantly lowest as compared to *N. mukherjei*. In case of 3rd instar nymph of rice green hopper, the search rate of *N. mukherjei* was significantly higher followed *P. altitudis*, *T. maxillosa* and *Theridion* sp. while the handling times of *N. mukherjei* was not significantly higher than *L. altitudis*. The lowest search rate and highest handling time taken by *Theridion* sp. for both 2nd and 3rd instar nymph of rice grass hopper. The result suggested that *P. altitudis* have potential for being effective biocontrol agents.

Key words: rice, spiders, planthopper, functional response, search rate

Spiders are generalist predators colonising all habitats and they constitute 80 % of total predatory fauna in rice ecosystem (Khan and Misra, 2006). They develop a great variety of life histories, behaviour and morphologic, physiological and ecological adaptations (Khan and Misra, 2003a, b). Because of their diversity relationships with the environment and their impact on prey populations (Khan, 2006), spiders have been proposed as very suitable for pest limitation in rice ecosystem (Khan and Misra, 2009).

The control of a pest by a predator depends strongly on its functional and numerical response (Holling, 1959). The functional response is the change in number of prey eaten per unit of time by a predator in relation to change in prey density (Soloman, 1949). Holling (1959) identified three fundamental types

functional response. The most common form of the response for invertebrate predators is the Holling type II, with a negatively accelerating rise in number of prey captured to an asymptote at higher prey densities. It is extensively used to describe the functional response of a predator feeding on a single species of prey, these are the predator's search rate (a) and its handling time (T_h) (Hassell *et al.*, 1976) means the number of prey captured by predator is dependent on the time available to the predator for search. In Kashmir rice ecosystem, visual hunting spider, *Pardosa altitudis* Tikader and Malhotra (family: Lycosidae) and web-building spiders, *Teragnatha maxillosa* Thorell (family: Tetragnathidae), *Neoscona mukherjei* Tikader (family: Araneidae) and *Theridion* sp. (family: Theridiidae) are dominant spider species and only rice greenhopper is a prominent insect

pest. The main objective of this work is to determine the functional response of dominant spider species to nymphs of rice leafhopper.

MATERIALS AND METHODS

The different species of spiders viz., *Pardosa altitudis* Tikader and Malhotra, *Teragnatha maxillosa* Thorell, *Neoscona mukherjei* Tikader and *Theridion* sp. and the 2nd and 3rd instar nymph of rice green leafhoppers were collected from rice fields during 2009 in the month of July-August and maintained in culture room in cages at 25 ± 2°C temperature, 60 ± 10% relative humidity and a photoperiod of 14 hour light: 10 hour dark.

The females of different species of spiders were taken from the culture for experiments and starved for 24 hrs in vials individually before the experiments. This was to minimize differences in individual hunger levels (Nakamura 1977). Thereafter, they were introduced individually into the experimental cages separately together with 4, 8, 16, 32, 64 and 128 rice green leafhoppers of 2nd and 3rd instar nymphs on potted rice plants in cages. Test predators were randomly assigned to 1 of 6 leafhopper density treatments, respectively. At each level of hopper density 3 replicates were used for different species of spiders. These experimentations were repeated 10 times. After 24 hrs, the numbers of leafhoppers consumed by the species of spiders were recorded by counting the remaining rice leafhoppers present in each cage.

The numbers of rice grasshoppers preyed by different spiders at different densities were analyzed separately using a non-linear least square programme (R Development Core Team 2008). Hence, prior to fitting the data to a particular Holling’s Disc equation (1959) that is type II functional response:

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

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 searching rate and handling time, respectively. 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:

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

Equation 3 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 (nlm) provided by the R-software (R Development Core Team 2008).

RESULTS AND DISCUSSION

The functional response of spiders offers an excellent framework for considering the potential action of bioagents in inundative release. The functional response of *P. altitudis*, *T. maxillosa*, *N. mukherjei* and *Theridion* sp. to the different density of 2nd and 3rd instar nymph of leafhopper were typically of type II with a steep initial rise in prey capture rates as the density increased (Fig. 1 & 2, Table 1). *P. altitudis* consumption increased to 26.7 per day 2nd instar nymph of rice grasshopper (figure 1a) which was higher than that of *N. mukherjei* (23.1), *T. maxillosa* (22.4) and *Theridion* sp.(18.8) (figure 1c,b,d). However, in case of 3rd instar nymph of rice grass hopper, the consumption of *N. mukherjei* was increased to 21.2 per day (figure 2c) which was higher than that of *P. altitudis* (20.4), *T. maxillosa* (19.2) and *Theridion* sp.(16.2) (figure 2a,b,d). Very little information is available to support the present paper, only Sigsgaard and Villareal (1999) studied functional response of spider *Atypena formosana* on 2nd and 3rd instar nymph of brown planthopper and green leafhopper and maximum predation was noted against 2nd instar nymphs.

The visual hunter (*L. altitudus*) has ability to run rapidly and capture more prey than web builders (*N. mukherjei*, *T. maxillosa* and *Theridion* sp.). The 2nd instar nymph of rice grasshoppers are smaller in size and also jumps slowly on rice hills as compared to 3rd instar nymph as a result it was easily captured more in number by *P. altitudis* than other spiders and later

Table 1. Parameter values of Holling’s disc equation estimated from functional response experiments with spiders feeding on rice green leafhopper

Spider species	Stage of rice grasshopper used	Parameter	Estimate	SD	<i>t</i> value	r ² at p<0.001	Residual SD at 4df
<i>P. altitudis</i>	2 nd instar nymph	<i>a</i>	69.773	12.355	5.647	0.484	1.833
		<i>T_h</i>	0.782	0.059	13.125		
	3 rd instar nymph	<i>a</i>	66.122	13.558	5.030	0.733	1.615
		<i>T_h</i>	1.016	0.078	12.940		
<i>T. maxillosa</i>	2 nd instar nymph	<i>a</i>	69.462	12.986	5.349	0.589	1.694
		<i>T_h</i>	0.904	0.068	13.211		
	3 rd instar nymph	<i>a</i>	65.387	9.784	4.758	0.250	1.091
		<i>T_h</i>	1.123	0.062	17.899		
<i>N. mukherjei</i>	2 nd instar nymph	<i>a</i>	70.934	13.486	5.260	0.625	1.689
		<i>T_h</i>	0.926	0.069	13.240		
	3 rd instar nymph	<i>a</i>	68.145	10.369	6.309	0.323	1.276
		<i>T_h</i>	1.023	0.064	12.993		
<i>Theridion</i> sp.	2 nd instar nymph	<i>a</i>	54.019	7.383	4.316	0.186	1.010
		<i>T_h</i>	1.105	0.063	17.681		
	3 rd instar nymph	<i>a</i>	50.749	6.649	3.632	0.158	0.818
		<i>T_h</i>	1.318	0.068	19.358		

a - Search rate, *T_h* - handling time

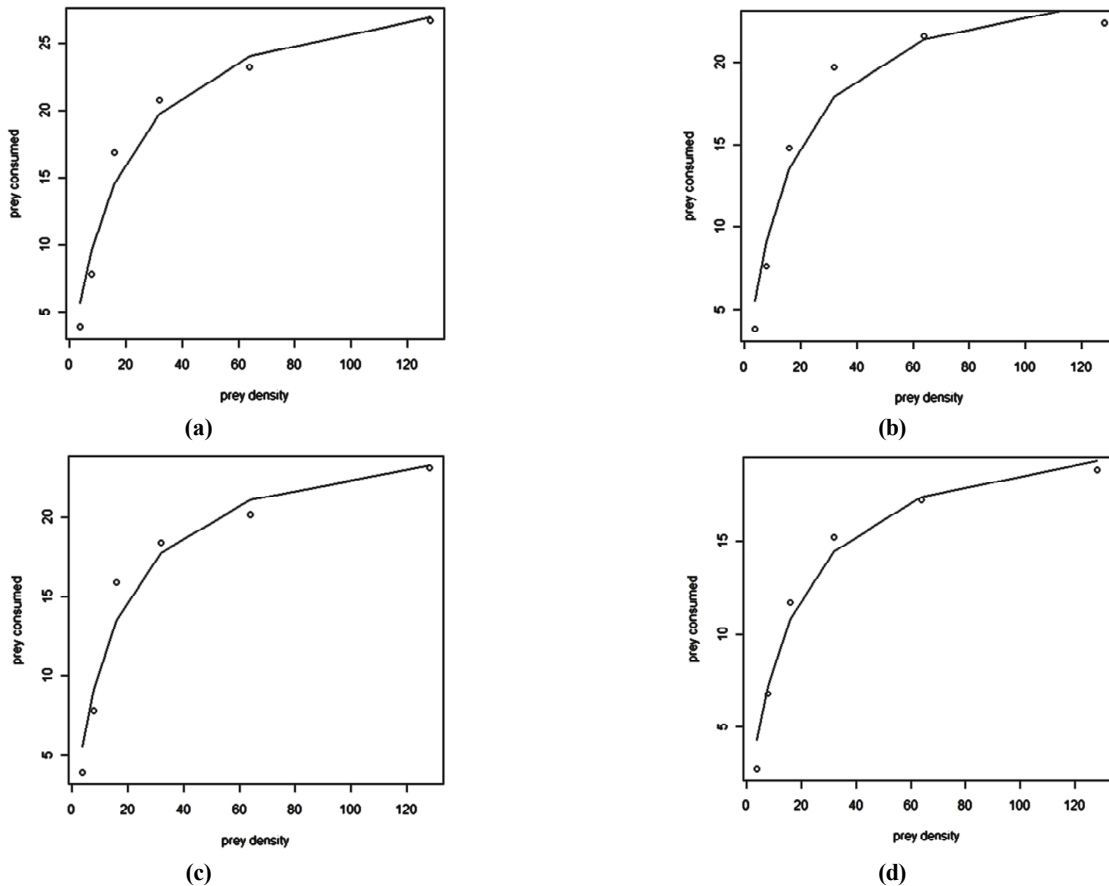


Fig. 1. Mean number of 2nd instar rice green leafhopper nymph eaten by individual spiders (a) *Pardosa altitudis* Tikader and Malhotra (b) *Teragnatha maxillosa* Thorell (c) *Neoscona mukherjei* Tikader (d) *Theridion* sp. All curves are Type II functional responses fitted by Holling’s disc equation model (Holling, 1959) using the parameter values given in Table 1.

instar was captured more by *N. mukherjei* followed by *P. altitudis*. Among web builders, *N. mukherjei* was bigger in size and also stronger and captured more 3rd instar nymph of rice leafhoppers as compared to 2nd instar while the size of *Theridion* sp. was small and their consumption was lowest (18.8 per day 2nd instar and 16.2 per day 3rd instar nymphs). In support of this, Khan and Misra (2009) results show that predation of *Lycosa pseudoannulata* on large size prey was lowest. According to Provencher and Coderre (1987), sit and wait predators (web builders and tactile hunters) as compared to hunting spiders have not received much attention in biological control.

The behaviour of web builders in the experimental arenas created a refuge for rice green hoppers, as these spiders occupied the upper part of the arenas while 2nd nymph generally remained in the middle parts as compared to 3rd instar nymph of rice green hoppers. Thus, the captured rice grass hoppers

would mainly be those that dispersed toward the upper zones of rice hills. The effect of hunger on behaviour (Hardman and Turnbull, 1980) would be change the movement of web builders to moved middle to lower side of arena and captured the preys (Nakamura, 1977). On the other hand, hunting spiders *P. altitudis* have ability to move in whole arena and as a result capturing the more preys.

The results show that a type II curvilinear curve provides an adequate depiction of the data. The higher asymptote of the relationship showed the maximum possible consumption rate of spiders. The search rates (a) and handling time (T_h) estimated for the four spiders show that *N. mukherjei* had the highest search rate followed by *P. altitudis*, *T. maxillosa* and *Theridion* sp. against 2nd instar. The search rate of *N. mukherjei* (t value= 5.260) was not significantly ($P < 0.001$) higher than *P. altitudis* (t value= 5.647) against 2nd instar nymphs of leaf hopper. The handing time of *P. altitudis*

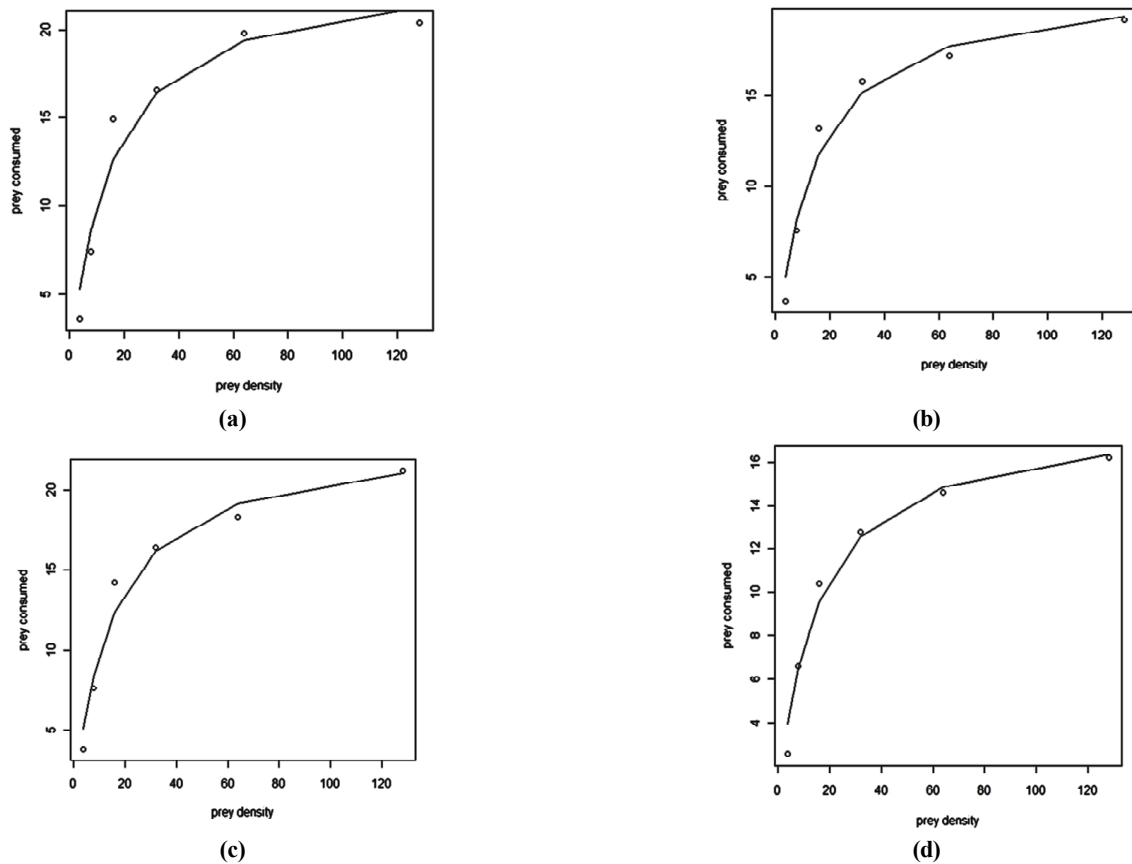


Fig. 2. Mean number of 3rd instar rice leafhopper nymph eaten by individual spiders (a) *Pardosa altitudis* Tikader and Malhotra (b) *Teragnatha maxillosa* Thorell (c) *Neoscona mukherjei* Tikader (d) *Theridion* sp. All curves are Type II functional responses fitted by Holling's disc equation model (Holling, 1959) using the parameter values given in Table 1.

(t value= 13.125) was significantly ($P < 0.001$) lowest as compared to *N. mukherjei* (t value= 13.211) and highest handling time taken by *Theridion* sp. (t value= 17.681). Generally, the handling times of the predators were just the opposite of the search rate, only exception was recorded against *P. altitudis*, the search rate was insignificantly lower than *N. mukherjei* and later species showed significantly higher handling time against 2nd instar nymph of rice green hopper.

In case of 3rd instar nymph of rice green leafhopper, the search rate of *N. mukherjei* was significantly ($P < 0.001$) higher followed *P. altitudis*, *T. maxillosa* and *Theridion* sp. while the handling times of *N. mukherjei* (t value= 12.993) was not significantly higher than *P. altitudis* (t value= 12.940). The lowest search rate (t value= 3.632) and highest handling time taken by *Theridion* sp. (t value= 19.358) (Table 1). Evidently, the search rate is determined by the movement speed, reactive distance at which a predator responds to the prey of presence and density of prey and the proportion of attacks that are successful (Holling, 1965, Khan and Zaki, 2006).

The attack rate and the handling times are the parameters that reflect the significance of these responses. The fact that these parameters differed significantly among the spider species when exposed to 2nd and 3rd instar nymph of rice green leafhopper indicates that four spider species possess different capacities to hunt prey at increasing rice green leaf hopper densities. It as well shows that spiders manifesting analogous qualitative response curves may not necessarily have the same quantitative impact on the prey (Khan and Misra, 2005). The values of different parameters varied due to the preying behaviour, size of prey and predator, greediness, satiation time, hunger levels, digestive power, searching speed, etc. (Khan and Misra, 2009, Khan, 2010). The significant differences in the estimates of handling times of different predator species on two instars of a single prey species indicate that any of these integral components of the handling time might have contributed to the short handling time when *P. altitudis* was used as predator rather than *N. mukherjei*, *T. Maxillosa* and *Theridion* sp. This leads to the presumption that the former species is the most efficient to search for 2nd and 3rd instar nymph of rice green leafhopper and to overpowering, and digest its prey than any other of the tested spiders.

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