Original article

Functional response of *Neoscona theisi* (Araneae: Aranidae) against *Sogatella furcifera* (brown plant hopper)

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Abstract

Present study was designed to assess the predatory interaction of orb-web spider *Neoscona theisi* (Araneae: Aranidae) against its prey brown plant hoppers *(Sogatella furcifera)*. *N. theisi* is the highly abundant on folliage in all agro-ecosystems of Punjab, Pakistan. Its feeding efficiency was studied in laboratory and in microcosm under different prey densities. The amount of prey consumed at different densities of prey represents type II functional response. Handling time and attack rate was calculated by linear regression. The attack rate and efficiency of attack per hour were high in lab as compared to microcosm experiment but handling time was opposite of this. The observed feeding strategy of *N. theisi* suggested that spiders can have positive role in controlling agricultural pest such as brown plant hopper in a density sensitive way.

Key words: Punjab, spider, agricultural pest, brown plant hoppers,

INTRODUCTION

Rice is most widely consumed and cereal crop which causes the uplifting of economy. Pakistan produces 6.22 million tons of rice annually but this rate of production is low as compared to other Asian countries. One reason of low production is attacks of different insect's pests (Schoently *et al.,* 1998; Hashmi, 1994). Brown plant hopper, Leafhopper, Stem borers and Grasshopper causes economic damage to the rice crop (Saleem*et al.,* 2004). White backed brown hopper, *Sogatella furcifera* is major pest of rice in Pakistan (Ashfaq *et al.,* 2005). They can cause hopper burn and destroys 7-10 % yield annually (Ramzan *et al.,* 2007). Biological agents like parasitoids, wasps and spiders, which are dominant in rice field, can be used to overcome insect pest populations (Johnson, 2000; Thacker, 2002).

Spiders are dominant and diverse predators of insects in rice field and play important role in regulation of pest population (Marc*et al.,* 1999; Symondson *et al.,* 2002; Nyfeller and Sunderland, 2003; Tahir and Butt, 2008). Stabilization in the predator-prey system lies on density-dependent response of prey and predator. If prey population increase, predation pressure also increases, and this pressure helps to minimizes prey population. If the population size of the prey is low, predator can easily control them (Riechert and Lockley, 1984; Morin, 1999). Functional response is ecological process which manipulates the rate of killing prey by its predators at different densities of that prey. Ecologists draw three types of functional response, according to curve patterns when the number of prey killed is plotted against number of prey available. The curves represent an increasing relationship (type I), decreasing relationship (type II) or sigmoid relationship (type III) (Murdoch and Oaten, 1975).

Type I is based on filter feeding and not been found in spiders because food is not present in equal ratio for longer life span. In type II, consumption of prey decreased due to reduction in capture rate and handling time of prey. Prey population either goes to extinction at low density and escape predation at high densities (Marc *et al.,* 1999). This type is so much common in spiders when insects are so much abundant (Marc *et al.,* 1999; Rypstra, 1995). Type III refers to switching of prey selection and thus, is strong stabilization mechanism. According to research only vertebrates follow type III functional responses (Riechert and Lockely, 1984; Morin, 1999).

Studies showed that spiders exhibit significant levels of density-dependent switching (Nyfeller *et al.,* 1994; Riechert and Lawrence, 1997). They kill more prey than (Riechert and Lockley, 1984). Killing of prey is much greater than the amount needed for spider to fulfill their metabolic needs (Nyfeller *et al.,* 1994; Persons, 1999). However, functional responses can be modified by intra-specific interactions between general predators like spiders. Spiders cannibalize and interfere with each other for better habitats. While interference reduce functional response effect (Nilsson, 2001). This factor might decrease effectiveness of spider community in controlling pest populations (Hodge, 1999).In present study, feeding behaviour of *Neoscona theisi* (Araneae: Aranidae) against different densities of brown plant hopper (*Sogatella furcifera*) was studied in laboratory and in the microcosm. These spiders are very common in agricultural fields of Pakistan. This study will help us to assess the predatory potential of *N. theisi* at different densities of pest population.

MATERIALS AND METHODS

Collection of Prey

Brown plant hoppers were collected by the help of sweep net from unsprayed fields of rice located at University of the Punjab, Lahore from July to October, 2012. The specimens were kept in glass jars (5 cm height and 1.5 cm diameter) at laboratory. They were fed with 10% sucrose solution by making small packet of parafilm and placed at top of jar. The specimens were used within twenty four hours.

Collection of Predators

Neoscona theisi were collected by hand picking and sweep net from unsprayed field of rice. They were kept singly in glass jars (5 cm height and 1.5 cm diameter). In each jar, the layer of wet sand was present and jar was covered with muslin cloth at room temperature 35±2 °C and 50±20 %. Each spider was starved for three days then used in experiments.

Lab Bioassay

Functional response experiment was conducted in laboratory at four different densities (5, 10, 15, 20) of prey. Single adult spider was used as predator in experiment. Experiment was performed at 35±2 °C and 50±20 % RH, and 14 L; 10 D photoperiod. Glass jars of (15 cm height and 5 cm diameter) were used as arena. Every arena contains a packet of 10 % sucrose solution attach at the top of the arena. Arena also contains some twigs for movement of spider. For experiments one spider was exposed to one of the prey density. The number of prey killed by predator is recorded after every 12 h. Prey was not replaced during experiment. Each experiment was replicated ten times.

Microcosm Bioassay

The experiment of microcosm was conducted on rice plant potted inside plastic cage (50 cm height × 20 cm diameter). The rice plant had one tiller of 6 leaves. The plants were exposed to any one of the pest densities i.e. (5, 10, 15, 20) prey per microcosm. One predator was released on the soil of pot. Experiment was performed at 35±2 °C and 50±20 % RH, and 14 L; 10 D photoperiod. The number of prey killed by predator was recorded after every 12 h. Each experiment was replicated ten times.

Data analyses

The type of functional response was determined using logistic regression analysis of proportion of prey killed in relation to initial density. The data were fitted to polynomial function that describes relationship between N_e/N_0.

$$\frac{N_e}{N_0} = \frac{\exp(P_0 + P_1 N_0 + P_2 N^2_0 + P_3 N^3_0)}{[1 + \exp(P_0 + P_1 N_0 + P_2 N^2_0 + P_3 N^3_0)]}$$

Where N_e is the number of prey consumed, N_0 is initial prey number available and P_0, P_1, P_2, P_3 were intercept, linear, quadratic and cubic coefficients, respectively. If $P_1 > 0$ and $P_2 < 0$, the proportion of prey consumed is positively density dependent, thus explaining type III functional response. If $P_1 < 0$ and $P_2 > 0$, the prey consumed is negatively density dependent, explains type II functional response. Although the logistic model easily illuminates the subtle differences in the Type II and III responses, it fails to discriminate them from Type I (Juliano, 2001). The value of handling time (H_t) and attack rate (a) were calculated using Holling disc equation modified by reciprocal linear transformation (Livdah and Stiven, 1983).The modified equation is

$$\frac{1}{H_a} = \frac{1}{a} \cdot \frac{1}{H_t} + \frac{T_h}{T}$$

Where $1/H_a$ represents y, $1/a$ represents a and $1/H_t$ represents x and T_h/T represents b. The linear regression was y= ax+ b. Maximum number of consumed prey per predator, H_a = T/T_h was also calculated.

Significant differences between parameter of the species were tested with the superposition of 95 % confidence intervals critertion. Mean values of T_h, estimated by non linear least square regression, were used to calculate maximum predation rate T/T_h (Hassell, 2000). They represent the maximal number of prey that can be attacked by the predator during the time interval considered. ANOVA was used to checkthe difference between treatments of different prey densities by using Minitab 16.

RESULTS

Logistic regression showed that *N. theisi* exhibits type II functional response for brown plant hopper in laboratory as well in microcosm (Table I). Fig. 1 showed that mortality rate of prey increased with the density both in laboratory and microcosm. However the number of prey killed at each density was high in lab as compared to microcosm.

Table I: The difference in feeding behavior of *Neoscona theisi* in laboratory and microcosm with help of regression analysis.

Parameters	Laboratory	Microcosm
Intercept (P_0)	0.3450	0.1800
Linear (P_1)	0.1898	0.0033
Quadratic (P_2)	-0.01700	0.00080
Cubic (P_3)	0.000407	0.000027
R^2	0.626	0.027
F	20.12	0.34
D.F.	3, 36	3, 36

Parameters of functional response i.e. handling time (T_h) and attack rate (a) were calculated by linear at different prey densities both laboratory and microcosm separately (Table II-III; Figs. 2-3). The equations form in result of regression which is presented in Fig. 2-3 was then modified into reciprocal linear transformation (Equation 2).

Attack rate and efficiency of attack per hour was high in laboratory as compared to microcosm experiments. However, spiders take more time to handle prey in microcosm as compared to lab arena (Table IV).

Table II: Functional response parameters of the predator *Neoscona theisi* (n=10) feeding on different densities of *Sogatella furcifera* in laboratory.

Prey density (H)	Total prey killed (Ha/H)	No of prey killed (Ha)	1/Ha	1/Ht	Proportion killed
5	46	4.6	0.22	0.4	0.92
10	95	9.5	0.10	0.2	0.95
15	111	11.1	0.09	0.13	0.74
20	119	11.9	0.08	0.1	0.60

Table III. Functional response parameters of the predator *Neoscona theisi* (n=10) feeding on different densities of *Sogatella furcifera* in microcosm.

Prey density (H)	Total prey killed (Ha/H)	No of prey killed (Ha)	1/Ha	1/Ht	Proportion killed
5	9	0.9	1.11	0.4	0.18
10	16	1.6	0.63	0.2	0.16
15	21	2.1	0.47	0.13	0.14
20	28	2.8	0.36	0.1	0.14

Table IV: Estimation of functional response parameters from linearization of Hollings Type II model.

Condition	Handling time (T_h)	Attack rate (a)	Maximum attack (T/T_h)	Efficiency parameter (a/T_h)
Laboratory	1.40	0.53	1.42	0.37
Microcosm	7.59	0.10	0.26	0.013
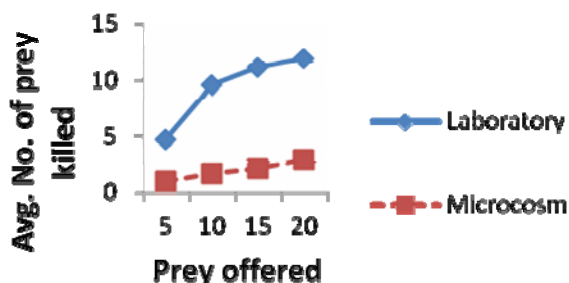
Figure 1: **Comparison between predatory efficiency of *N. theisi* in laboratory and microcosm.**
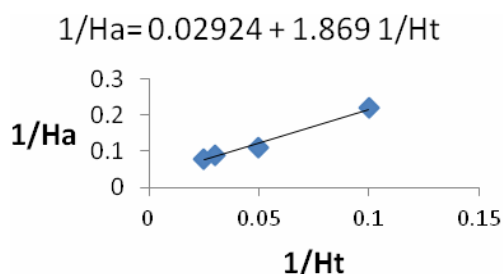
$$1/Ha = 0.02924 + 1.869\ 1/Ht$$

Figure 2: Relationship between 1/Ha and 1/Ht of *Neoscona theisi* in laboratory after 2 days.

$$1/Ha = 0.1582 + 9.499\ 1/Ht$$

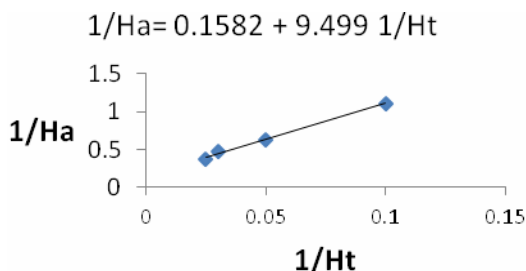**Figure 3:** **Relationship between 1/Ha and 1/Ht of *Neoscona theisi* in microcosm after 2 days.**

DISCUSSION

In this study, the predator behavior *N. theisi* was examined in laboratory and microcosm experiments at four different densities of prey, *Sogatella furcifera* for 48 h. In this study, consumption rate decrease with the increase of prey density. This show that data describe well by type II functional response. Many studies have reported type II functional

response in insects and spiders such as *Cheillomenes sexmaculata Fabricusand Coccinellatransversalis* (Pervez and Omkar, 2005), *Adalia fasciatopunctata revelierei* (Atlihan and Bora Kaydan, 2010), *C. undecimpunctata* (Moura *et al.,* 2006) and *Grammonota trivitatta* (Denno *et al.*, 2004).

The functional response of a natural enemy offers a good conceptual framework for understanding the action of biological control agents in the fields (Waage and Greathead, 1988). Many studies have been devoted to the foraging behavior of insect predators (Nakamuta, 1982; Ettiffouri and Ferran, 1993). Type II functional responses are evidented by an initial decrease in the proportion of prey eaten with increasing prey offered (Trexler *et al.*, 1988; Juliano, 1993). The type II functional response is the most common functional response in insects.

Many feeding theories includes application of optimum foraging theory (Cook and Cockrell, 1978; Stephens and Krebs, 1986) predict changes in feeding characteristics, such as handling time and consumption rates, as the density of prey changes. A higher prey density enables the predators to spend less search time on its prey and to utilize more of it in attacking and consuming of prey (Claver *et al.,* 2003). Denno *et al.* (2004) reported that with increase in plant hopper prey density, sheet web spider *Grammonota trivitatta* capture more prey but the proportion of prey didnot increase with the prey offered. This type of response is known as "invertebrate curve" and indeed seems to be common in spiders (Smith and Wellington, 1983; Hardman and Turnbull, 1974; Riechert and Harp, 1987).

Morris (1992) and Hacker and Bertness (1995) also reported that natural enemies appear to contribute more than host-plant factors to the suppression and population dynamics of many plant-feeding insects. When brown plant hopper only present in permanent cages spider species viz., *A. inustus* and *P. pseudoannulata* killed more brown plant hopper than in temporary cages with a mixture of prey. Both hunting *(A. inustus)* and wolf spiders *(P. pseudoannulata)* are polyphagous predators. BesideBPR, they feed on more than one species includingother species of predators (Heong and Rubia, 1990). Theirability to catch their prey depends on the environment.In mixed prey environments they chose the easiestprey to catch and eat (Hassell, 1978).With a predator/prey ratio 1:3 to 1:11 these two

spiderspecies caused 78 to 91 percent of BPH mortalitywhen BPH populations are in normal situation. *P. pseudoannulata* and *A. inustus* spiders are very common in Cambodian rice fields (Preap, 2001). Spider genera of *Pardosa* and *Araneus* formed a large part, of total natural enemies and are key factors in keeping rice crops free from BPH attacks. As the population of predator increases along with prey populations, a spider/BPH ratio at not much over 1: 11 is sufficient to save a crop from pest attack. They need to take care of spiders and others natural enemy in their fields. If a spider/BPH ratio is higher than 1:11 and continues to increase up to or higher than 1:20, then the crop is in danger of damage and a chemical control method would be chosen, especially for a susceptible variety, and a selective chemical compound would highly recommend.

In this study, killing rate of prey was higher in the lab as compared to microcosm. The result of this study indicated that change in size of arena is an important factor. The size of arena in lab was (274.75 cm^2) 14 times smaller than microcosm (3768 cm^2). Wiedenmann and O' Neil (1991) studied the predatory efficiency of *Epilachna varivestis* against *Podisus nigrispinus* in Petri dishes. Their results showed that limited arena can allow predators to find their prey faster and re-attack those that escaped. In contrast, the predators have more difficulty searching for prey in more complex environments, which increase the time spent searching and thus decreases the encounter and the attack rate. However, a longer handling time may allow a better intake of nutrients from the prey and increase the longevity of predators (Montserrat *et al.,* 2000). In our experiments the handling time, attack rate, maximum attack and efficiency parameters in *N. theisi* in laboratory were almost similar.

Hassell *et al.* (1976) reported that predator attack more in high densities, as the prey availability increases or searching area decreases, predators can increase their attack rate and decrease the handling time. Predators have a different strategy to attack prey at low densities. This need to be considered for their establishment in the environment and it suggested that they can change their behavior and searching rate due to complexity of environment (O'Neil *et al.*, 1996). They reduce the searching behavior at low prey density in order to reduce the use of energy and nutrients (Opit, 1997).

The attack rate, efficiency parameters and maximum attack rate is more in laboratory than microcosm. In microcosm, Presence of growing plant makes the environment more complex. Due to complexity, the preys have hiding places and have more chances to escape from the predator. As the plant was potted, it has large excess amount of food available and no disturbance to the prey. That's why prey feed on leaves in quite condition and the movement in mean was reduced. *N. theisi* make web and follow sit and wait strategy. The pray traps in web if it fly in the arena. That's why less numbers of preys is captured by *N. theisi* in microcosm as compared to laboratory.

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