

Functional Response of *Oxyopes javanus* (Araneidae: Oxyopidae) to *Sogatella furcifera* (Hemiptera: Delphacidae) in Laboratory and Mesocosm

Abida Butt* and Muhammad Xaaceph

Department of Zoology, University of the Punjab, Lahore, Pakistan

Abstract.- Most spiders species are generalist predator and used as a biological control agent of insect pests in agroecosystems including rice. Predatory potential of the spider depends upon their interaction pattern with the prey. In present study, functional response of adult hunting spider, *Oxyopes javanus* (Araneae: Oxyopidae) against different densities of adult white back planthoppers (*Sogatella furcifera*) was assessed in laboratory and mesocosm. The proportion of prey killed at different densities of prey represents type II functional response both in laboratory and mesocosm. Handling time was low and the attack rate and efficiency of attack was high in laboratory as compared to mesocosm. In both experimental arenas, increase of prey density resulted decrease in total search time and search efficiency while handling time increased. The attack rate did not change with the prey density in both experiments. The observed feeding strategy of *O. javanus* suggested that its relationship with the prey is affected by the density of the prey and complexity of the habitat.

Key words: White back planthopper, functional response, predation, spider

INTRODUCTION

Rice is second most widely consumed cereal crop in Pakistan and play a significant role in the uplifting of the economy of growers and country. Pakistan produces 3.44 tons of paddy per hectare and export about 3.75 million tons of rice annually, including basmati rice. The production of rice in Pakistan is less than many other countries (like China, India, Japan, Bangladesh) due to many factors such as climatic conditions, shortage of water, attack of many pathogens and pests. Hashmi (1994) reported 70 species of insect pest on the paddy of Pakistan. Among these pest, white backed planthopper, *Sogatella furcifera* (Horváth, 1899) is one of the major pests and causes 7-10% yield losses annually in both in coarse and basmati rice (Ashfaq *et al.*, 2005). Approximately 40 species of biological control agents have been recorded from rice fields of Pakistan including spiders (Salim, 2002; Tahir and Butt, 2008).

Previous studies showed that spiders are most abundant generalist predators in agroecosystem (Marc *et al.*, 1999; Nyffeler and Sunderlands, 2003;

Pearce and Zalucki, 2006; Tahir and Butt, 2008). Most of them are polyphagous and feed on various insect pests of agricultural crops (Schmidt *et al.*, 2004; Takashi *et al.*, 2006). They significantly reduce prey densities in agricultural fields due to their top-down effects, microhabitat use, prey selection, polyphagy, wasteful killing, functional response, numerical response, and obligatory feeding strategies (Greenstone and Sunderland, 1999; Riechert, 1999; Symondson *et al.*, 2002; Schmidt *et al.*, 2004; Pearce and Zalucki, 2006).

Oxyopes javanus (Thorell, 1887) is one of the most dominant spiders in the rice fields of Punjab, Pakistan and constitute more than 13% of the total spider fauna. Its high density was recorded in September through October due to high pest's densities in these months (Tahir and Butt, 2008). They feed on prey which range from 1-2.9 mm in size. On the basis of prey size, it can be predicted that rice pests such as planthopper may be the part of spider's diet (Nyffeler *et al.*, 1992).

Biocontrol potential of a predator depends upon its functional and numerical responses against different densities of prey. Being univoltine, spiders are unable to increase their abundance rapidly in response to high prey density (Foelix, 1996). So their predatory efficiency can be estimated by functional response *i.e.*, variation in the attack rate of predator in response to variation of prey density

* Corresponding author: abdajawed@yahoo.com

0030-9923/2015/0001-0089 \$ 8.00/0

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(Riechert and Lockley, 1984). Scientists designate four types of functional response *i.e.*, linear increase (type I), an increase decelerating at high density (type II), sigmoidal increase (type III), and a dome shape increase (type IV) (Holling, 1961; Pervez and Omkar, 2005; Sakaki and Sahragard, 2011). Studies reported functional responses of type II, III and IV in spiders. However, type II was much common than type III (Riechert and Lockley, 1984; Rypstra, 1995; Marc *et al.*, 1999; Liznarova and Pekar, 2013).

In this study, functional response of *Oxyopes javanus* (Araneae:Oxyopidae) was evaluated against different densities of adult planthopper (*Sogatella furcifera*) in laboratory as well as in the mesocosm.

MATERIALS AND METHODS

Maintenance of predator and prey

For experiments, adults of white backed planthoppers (*Sogatella furcifera*) were collected by sweep net from infested rice fields located at the University of the Punjab (Lahore, Pakistan). The captured specimens were brought to laboratory and released on the potted rice plants to develop the stock for the study. Adults of hunting spider, *O. javanus* (Family: Oxyopidae) were collected by hand picking and sweep net from rice fields and kept singly in transparent glass container (5cm in height x 1.5 cm in diameter). At the base of each container, 1 cm thick layer of wet sand was placed to maintain the humidity. The mouth of container was covered with muslin cloth and spiders were fed daily *ad libitum* with different types of prey available in rice fields. The stock of spider and brown planthoppers was maintained in laboratory at 35±5 °C and 50±20 % RH.

Laboratory experiments

To evaluate the predatory potential of *O. javanus*, six densities (*i.e.*, 5, 10, 15, 20, 30 and 40) of adult *S. furcifera* were used as prey. These densities were offered separately to an individual predator starved for 72 h in a transparent plastic container (15 cm height x 5 cm diameter) with one or two leaves of rice planted cut from the base and embedded in wet sponge surrounded by soil. Walls of the plastic container were rough so spider can

walk on the walls. Prey was offered with 10% sucrose solution in small packets of parafilm attached near the mouth of the container. Experiment was performed at 35±5°C and 50±20% RH, and photoperiod of 14:10 h. The number of prey killed by predator was recorded after 48 h. Dead prey was not replaced during the experiment. To estimate natural mortality in predator and prey, their densities used in experiment were also maintained separately in the laboratory as control. Each experimental treatment repeated thirty times in three groups.

Mesocosm experiments

For experiments, mesocosm was created using a potted rice plant encaged in a clear plastic cylinder. The top of the cylinder was covered with white cotton cloth for ventilation. Cylinder was 16 cm high and 6 cm in diameter and fixed in the soil of the pot. In each pot, one seedling of rice (15 days old) was transferred and allowed to grow for 35 days. For the experiment, only one tiller of rice plant with 6 leaves (approximately 15–20 cm long) was left and all other tillers cut down. Microcosm was placed in open field at a temperature of 35±7°C and 50±20% RH, and photoperiod of 14:10 h. To evaluate the functional response of *O. javanus* against adult planthoppers, the design of laboratory study was followed. We added planthopper in a mesocosm according to experimental plan and allowed them to settle on the leaves. After two hours, single predator was added to microcosm. To estimate natural mortality in the prey specimens, different densities of prey were also maintained in mesocosm without predator. Each experimental treatment was replicated thirty times in three groups. The mortality of prey was recorded after 2 days to avoid disturbance in the arena. Dead prey was not replaced during the experiment.

Data analyses

To determine the type of functional response, data was fitted to polynomial function that describes relationship between proportion of prey killed (N_a) in relation to prey density offered (N_o) (Holling, 1959a,b). For this purpose, cuboid model in logistic regression analysis was used (Juliano, 2001):

$$N_a / N_o = \frac{\exp (P_0 + P_1 N_o + P_2 N_o^2 + P_3 N_o^3)}{[1 + \exp (P_0 + P_1 N_o + P_2 N_o^2 + P_3 N_o^3)]}$$

P_0, P_1, P_2, P_3 were intercept, linear, quadratic and cubic coefficients, respectively. Negative value of P_1 describe type II functional response, while positive value a type III functional response. The values of handling time (T_h) and attack rate (a) were calculated using Holling disc equation modified by reciprocal linear transformation (Livdahl and Stiven, 1983). The linear regression was $y = ax + b$. The modified equation was

$$1 / N_a = 1/a \cdot 1/T N_o + T_h / T$$

In this equation, $1/N_a$ represents y , $1/a$ represents a , $1/T N_o$ represents x and T_h/T represents b . N_a represent number of consumed prey, N_o initial prey density, T total observation time (48 h) and T_h handling time. From estimated handling time, we calculated total handling time ($T_{h\ total} = T_h \times N_a$), search time ($T_s = T - T_{h\ total}$), attack rate ($a = N_a / (N_o \times T_s)$) and search efficiency ($E = N_a / N_o$) for each prey density (Hassell, 2000; Rocha and Redaelli, 2004).

General linear model was applied to assess the variations in killing rate of predator in different experimental plans and prey densities. ANOVA was used to assess the difference in the searching time, handling time, attack rate and efficiency of predator at different prey densities. Two sample t test was applied to compare the consumption rate in laboratory and mesocosm at a particular prey density. All these analysis were performed using statistical software MINITAB.

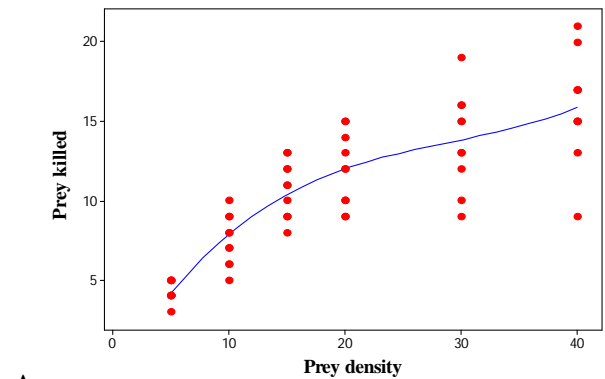
RESULTS

Logistic regression analysis revealed that *O. javanus* exhibited Type II functional response against *S. furcifer* both in laboratory and mesocosm. The linear parameter P_1 is negative and proportion of prey killed by *O. javanus* decreased as prey density increased in arena (Table I, Fig. 1). Average mortality in *S. furcifer* ranged from 40% to 86% in laboratory and 25% to 64% in mesocosm at maximum and minimum prey density, respectively. Due to 98% survival rate in control

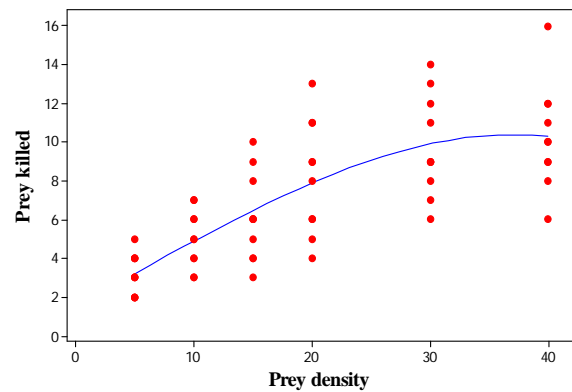
groups, mortality estimates were not adjusted. The mortality in prey was higher in laboratory as compared to mesocosm ($F_{1, 348} = 73.49$; $P = 0.00$), even at each prey density also ($F_{5, 348} = 46.21$; $P = 0.00$: $t = 2.82, 3.64, 5.17, 3.12, 3.17, 4.06$ at density of 5, 10, 15, 20, 30 and 40 respectively; $P < 0.005$).

Table I.- Regression Parameters of functional response of *O. javanus* against different prey densities.

	Laboratory	Mesocosm
Intercept	0.9146	0.8313
Linear	- 0.0105	-0.0469
Quadratic	-0.00043	0.00163
Cubic	0.00009	0.00002
R ²	0.360	0.267
F	36.74	14.93
d.f.	3,56	3,56
P	<0.010	<0.010



A



B

Fig. 1. Functional response of *O. javanus* against different densities of *S. furcifer* in (a) laboratory and (b) mesocosm.

Parameters of functional response *i.e.*, handling time (T_h), attack rate (a) and maximum predation rate per predator (calculated by linear regression using Holling disk equation) for *O. javanus* are represented in Table II. Handling time was shorter (1.72 h) in laboratory than mesocosm (3.26 h). While attack and predation rate by *O. javanus* was higher in laboratory than mesocosm. Density of the prey was directly proportional to the handling time in both types of arena. However the searching time and search efficiency decrease with the increase of prey density. No difference was recorded in attack rate of predator at different densities of the preys (Table III).

DISCUSSION

In this study, *O. javanus* showed type II functional response both in laboratory and mesocosm when exposed to six different densities of prey, *Sogatella furcifera*. Many studies have reported type II or III of functional response in different species of spiders such as *Grammonota trivitatta* (Denno *et al.*, 2004), *Cheiracanthium mildei* Koch (Clubionidae), *Philidromus rufus* Dondale (Marc *et al.*, 1999), and genus *Portia* of jumping spiders (Salticidae) (Jackson and Pollard, 1996). Type of the functional response showed by the predators play important role in the stability of prey population (Begon *et al.*, 1996).

Functional response of a predator is affected by many factors such as temperature (Gitonga *et al.*, 2002; Zamani *et al.*, 2006), predator, prey size and density (Kooijman, 1993; Aljetlawi *et al.*, 2004), presence of alternative pray (Abrams, 1990), environmental factors, complexity of the habitat and internal state of the predator (Hassel *et al.*, 1976). In this study laboratory arena was very simple as compared to mesocosm. Factors such as leaf size, foliage overlap and habitat spatial structure was decreasing the predatory efficiency of the spider in the mesocosm (Kaiser, 1983; Karevia and Perry, 1989; Messina and Hanks, 1998).

The application of optimum foraging theory (Cook and Cockrell, 1978; Stephens and Krebs, 1986) on predator prey relationship predicted changes in searching time, handling time and predation rates, with the change of prey density. At

Table II.- Estimations of functional response parameters by Hollings disc equation.

	Laboratory	Mesocosm
Handling time (T_h)	1.72	3.26
Attack rate (a)	0.52	0.4
Maximum predation rate (T/T_h)	27.91	14.72

Table III.- Functional response parameters of *O. javanus* at different densities of *S. furcifera* in (a) laboratory and (b) mesocosm.

No. of prey offered	Total handling time (Th)	Total search time (Ts)	Attack rate (a)	Search efficiency (E)
Laboratory				
5	7.4 (0.34)a	40.6 (0.34)a	0.021 (1.4×10^{-3})a	0.86 (0.042)a
10	12.9 (0.86)b	35.1 (0.86)b	0.042 (1.9×10^{-3})a	0.75 (0.050)ab
15	18.5 (0.95)c	29.5 (0.95)c	0.024 (2.0×10^{-3})a	0.72 (0.037)ab
20	20.4 (1.27)c	27.6 (1.27)c	0.021 (2.4×10^{-3})a	0.59 (0.037)bc
30	23.7 (1.64)cd	24.2 (1.64)cd	0.018 (2.9×10^{-3})a	0.46 (0.032)cd
40	27.3 (1.86)d	20.6 (1.86)d	0.019 (3.5×10^{-3})a	0.39 (0.027)d
Mesocosm				
5	10.43 (1.06)a	37.5 (1.06)a	0.017 (2.3×10^{-3})a	0.64 (0.065)a
10	16.3 (1.54)a	31.7 (1.54)a	0.015 (2.4×10^{-3})a	0.50 (0.065)ab
15	19.8 (2.35)ab	28.1 (2.35)ab	0.014 (3.9×10^{-3})a	0.40 (0.065)bc
20	26.7 (3.03)bc	21.3 (3.03)bc	0.019 (10.0×10^{-3})a	0.41 (0.065)bc
30	31.9 (2.70)c	16.1 (2.70)c	0.020 (18.5×10^{-3})a	0.32 (0.065)bc
40	33.5 (2.79)c	14.4 (2.79)c	0.017 (11.8×10^{-3})a	0.25 (0.065)c

higher prey density, predators spend less time on searching of prey and more time on attacking and consuming of the prey (Claver *et al.*, 2003). Denno *et al.* (2004) reported that sheet web spider *Grammonota trivitatta* capture more prey at high plant hopper density but the proportion of prey didn't increase with the prey offered. This type of response is often called the "invertebrate curve" and indeed seems to be common in spiders (Hardman and Turnbull, 1974; Riechert and Harp, 1987).

In the study, size of the arena determined the killing rate of the hoppers. The size of laboratory

arena was 275 cm² and of mesocosm 3768 cm². Small arena of laboratory allowed predators to find their prey faster and re-attack those that escaped (Wiedenmann and O' Neil, 1991). In contrast, the predators have more difficulty searching for prey in large mesocosm, which increase the time spent for 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). Laboratory arena was also less complex so prey did not have more hiding places as compared to mesocosm. Presence of plant makes the environment more complex. Due to complexity, the prey has hiding places and has more chances to escape the predator.

Handling time is good source of information about predation rate and effectiveness of predator because its shows cumulative effect of time taken during capturing, killing, subduing, and digesting the prey (Atlihan and Bora, 2010). Hassell *et al.* (1976) reported that at high densities, as the prey availability increases or searching area decreases, predators increased their attack rate and decrease the handling time. Predators have a different strategy at low prey densities. Predators usually reduce the searching activity at low prey density in order to reduce the use of energy and nutrients (Opit, 1997). In present study, attack rate remain constant in both laboratory and mesocosm arena even with the increase of prey density.

At short handling time, curve reduces to the asymptote very rapidly (Nordlund and Morrism, 1990). It also affects the search time and search efficiency of the predator. In our experiment also, spider spend less time in handling the prey in laboratory than in mesocosm. Holling (1959) reported that attack rate did not depend upon density of the prey. However, attack rate, efficiency parameters were more in laboratory than mesocosm.

The results of this study are helpful to estimate potential of *O. javanus* in suppression of *S. furcifera* in the rice field. However, elaborated field studies are necessary to incorporate *O. javanus* in the integrated pest management programs against *S. furcifera*.

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(Received 28 April 2014, revised 4 June 2014)