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Feeding efficiency of wolf spider, *Pardosa pseudoannulata* (Boesenberg and Strand) against Brown Planthopper, *Nilaparvata lugens* (Stal)

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Abstract
Study on functional response of wolf spider, *Pardosa pseudoannulata* in relation to different prey densities of 3rd and 4th instar brown planthopper (BPH) nymphs was undertaken in glass jar and in microcosm arena. The number of attacked prey (H_a) and prey density per unit area over a period of time (HT) were determined and regression of $1/H_a$ on 1/HT in microcosm and jar arena revealed functional type II response of wolf spider on BPH nymphs. The attack rate, maximum attack rate and efficiency of attack were high in jar as compared to microcosm experiment but handling time was converse of this. This could be attributed to limited arena of the jar, which reduced searching time of predator and ultimately increased killing rate in jar arena compared to microcosm. The observed feeding tactic of *P. pesudoannulata* suggested that spiders can have beneficiary role in controlling rice pest such as brown plant hopper in density sensitive way. This functional response of spider provided the good information for understanding the effects of bio control agents in the field.

Keywords: Wolf spider, Brown planthopper, Microcosm and Jar

Introduction
Rice (*Oryza sativa* L.) is one of the key cereals of the world particularly in India. In India, rice was grown over an area of 44 million hectares with a production of 103 million tonnes and productivity of 2372 kg per ha (Directorate of Economics and Statistics, 2015). Rice production is hindered by abiotic factors and biotic factors. Among biotic stresses, damage due to insect pests is substantial as 20 - 33 species are economically important in different parts of the country, inflicting significant yield reductions in rice. Among the sap sucking pests of rice, brown planthopper have become economically important all over the world [1]. The BPH not only directly damages the rice crop by sap sucking but also transmits viral diseases of rice such as grassy stunt and rugged stunt [2].
Nowadays IPM practices are mainly considered to keep the pest under check, among which biological control is mostly recommended due to its environment friendly tactic. Under rice ecosystem, spiders are the most efficient predator to control the pest population. Lycosids were the most abundant spiders in rice agro ecosystems and could effectively regulate the pest population of leaf hoppers and plant hoppers [3]. The spiders were found active throughout the rice cropping period and their population was maximum from mid-October to mid- November [4].
Density dependent response between the prey and predator makes the prey-predator system to stabilize and result in population regulation. Predator population easily controls the prey population when it is low [5]. At different prey population densities, the rate of killing of prey by its predator was the functional response and it thus decided the effectiveness of a predator in the regulation of prey populations [6]. There are three different types of functional responses based on the pattern of the curve with respect to the number of prey killed against available prey population [7-8]. These curve patterns represent different relationships *i.e.,* increasing with linear rise to a plateau (type I), decreasing with negative rise to a plateau (type II) and sigmoid with S-shaped rise to a plateau (type type III). Type II functional response was common in spiders that were dependent on most abundant insect population [9].

Materials and methods

Collection of Brown planthopper population

3rd and 4th instar nymphs of BPH required to study the efficiency of spider were collected from rearing cage in glass house. Feeding potential experiment in glass jar arena was conducted under laboratory condition at 25±2 °C temperature and 70±5 % RH and in microcosm that consisted of rice plant in glass chamber, was conducted under glass house condition at 28 ±1^{0}C temperature and 65±5% RH.

Collection of wolf spider population

Sexually matured wolf spiders were collected from unsprayed rice field of Division of Entomology, Indian Agriculture Research Institute, New Delhi. Instantly without delay, collected spiders were kept individually and starved (as the spiders are sexually cannibalistic) in glass jar arena (19×15 cm^2) under laboratory condition and in glass chamber (37×37 cm^2) at room temperature (25±2 °C and 70±5 %) for three days [10]. The experiment on functional response of spider was carried out in glass jar. The number of individuals consumed by each spider was also recorded daily for three days. Dead BPH that were not preyed by spiders and also deformed BPH were also recorded.

Feeding potential of spider in jar under laboratory condition

Experiment on feeding potential of spider was conducted in jar measuring 19×15 cm^2 as arena under laboratory condition (25±2 °C temperature and 70±5 % RH) at different prey densities of 10, 20, 30, 40 and 50 BPH nymphs. Observations on spider feeding were noted at 24 hours intervals. Each experiment was replicated thrice.

Feeding potential of spider in microcosm under glasshouse condition

Experiment on feeding potential of spider was conducted in glass cage of 37×37 cm^3 dimensions containing rice plant with one tiller and five leaves at room temperature of 25±2 °C and 70±5 % RH. Observations were recorded at 24 hour intervals and each experiment was replicated thrice.

Analysis of feeding potential of wolf spider

The functional response of spider with respect to BPH was analyzed separately for jar and microcosm at different prey densities. The handling time (T^h), attack rate (a), maximum attack rate, efficiency of predator were determined using modified Holling disc equation *i.e*., reciprocal linear transformation at different prey densities.

Results

The results of the present study on functional response of wolf spider in relation to different prey densities of BPH nymphs showed that in microcosm arena, mean number of prey killed increased from 4.7 to 10 hoppers and predator consumption rate decreased from 47 - 20% with increase of prey density from 10 to 50 hoppers (Table 1). Similarly, in jar study, mean number of prey killed increased from 8 to 21.3 hoppers and predator consumption rate decreased from 80 - 43% with increase of prey density (Table 2). This showed that in jar, prey killing rate increased with increase of prey density, due to reduction of searching time under limited arena of jar compared to microcosm.

Regression of number of attacked prey $1/H_a$ on product of over prey density per unit area (H) and time duration (T) of experiment, expressed as 1/HT in the microcosm and jar arenas revealed functional type II response of wolf spider on BPH nymph (Fig. 1; Fig. 2). The attack rate, maximum attack rate and efficiency parameters of predator respectively, were higher but handling time was lower in jar compared to attack rate, maximum attack rate, efficiency parameters and handling time in microcosm (Table 3). This could be attributed to limited arena of the jar, which reduced searching time of predator and ultimately increased killing rate.

Table 1: Functional response parameters of the wolf spider *Lycosa pseudoannulata* on different BPH nymph densities in microcosm (37cm× 37cm)

Prey Density(H)	Spider density	Total prey offered	Total prey killed	Mean no. of prey killed(Ha)	$1/H_a$	1/HT	Proportion killed
10	1	30	14	4.67±0.33	0.21	0.034	0.47
20	1	60	20	6.67±0.88	0.15	0.017	0.34
30	1	90	25	8.34±0.67	0.12	0.011	0.28
40	1	120	29	9.67±0.34	0.10	0.008	0.24
50	1	150	30	10±1.0	0.1	0.0067	0.2

Table 2: Functional response parameters of the wolf spider *Lycosa pseudoannulata* on different BPH nymph densities in jar (19cm× 15cm)

Prey Density(H)	Spider density	Total prey offered	Total prey killed	Mean no. of prey killed(Ha)	$1/H_a$	1/HT	Proportion killed
10	1	30	24	8±0.58	0.13	0.034	0.8
20	1	60	42	14±0.58	0.07	0.017	0.7
30	1	90	58	19.34±0.88	0.052	0.01	0.6
40	1	120	62	20.67±0.34	0.048	0.008	0.52
50	1	150	64	21.34±0.67	0.047	0.0067	0.43

Table 3: Estimation of functional response parameters of wolf spider in microcosm and jar from linearization of Holling type II model

Condition	Handling time	Attack rate	Maximum attack	Efficiency parameter	Search rate (Area in mts.)
Microcosm	5.112	0.221	0.587	0.043	0.030
Jar	1.584	0.329	1.894	0.208	0.010

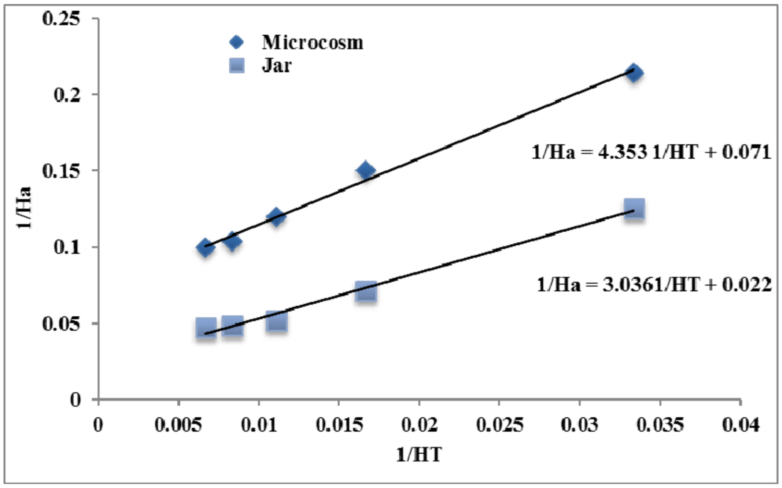

Fig 1: Relationship between 1/Ha and 1/HT of wolf spider in microcosm and jar

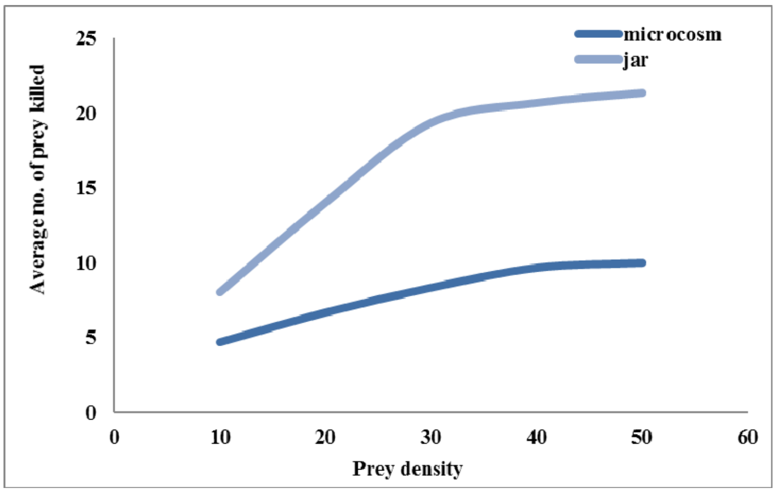

Fig 2: Comparison of predatory efficiency of wolf spider in microcosm and jar

Discussion

In this study, with increase of prey density consumption rate decreased, showing that the predator response fitted to the functional type-II response. This was consistent with the earlier reports of type-II insects-predator response incase of *Neoscona theisi* [10], *Adalia fasciatopunctata revelierei* [11]. Earlier, functional type-II response of predator has been found to be most commonly fitted response to the insect predator behaviour [12]. With increase of prey density, predator needed less time for searching of prey and spent more time for attacking and consuming the prey that increased its predation potential [13]. This type of response of predator was termed as “invertebrate response” and it seems to be common in spiders [14]. The functional response of predators provided good information for understanding the effects of bio control agents in the field [15].

Present study revealed that in jar predator killing rate was increased with increase of prey density, due to reduction of searching time under limited arena size of jar compared to microcosm. The arena size in jar was 15 × 19 cm^2 compared to 37 × 37 cm^2 in microcosm. The results thus indicated that size of arena was an important factor that regulated the killing rate of predator at each density. This has also been observed earlier, whitebacked planthopper killing rate of *Neoscona thesi* was higher under laboratory study compared to microcosm [10]. The efficiency of predator *Epilachna varivestis* against *Podisus nigrispinus* in petri plates and concluded that predator attacked its prey faster by spending less time in searching under limited arena [16]. Large arena thus allows spiders to search for BPH for a longer period of time thereby reducing their attack rate.

Feeding potential of spider under microcosm was therefore less compared to jar. However, increase of handling time of predator under larger arena ensured better intake of nutrients from its prey for longer time and enhanced its longevity [17]. Predator attack rate increased and handling time decreased at high prey densities due to more availability of prey and the predator required less searching area [18]. Predators might develop different strategy to attack their prey at low densities and at in larger arena and predators adapted in the complex environment by changing their behaviour and searching rate [19]. This information may be helpful in designing more elaborate studies on planthopper management by manipulating predator number for increased predator efficiency.

Conclusion

Present study on feeding efficiency of wolf spider on brown planthopper concluded that with increase of prey density consumption rate decreased, showing that the predator response fitted to the functional type-II response. In jar, predator killing rate was increased with increase of prey density compared to microcosm, due to reduction of searching time under limited arena size of jar. The results thus indicated that size of arena was an important factor that regulated the killing rate of predator at each density. This information may be helpful in designing more elaborate studies on planthopper management by manipulating predator number for increased predator efficiency.

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