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RESEARCH ARTICLE :

Effect of climate change on functional response of the predator wolf spider, *Pardosa pseudoannulata* (Boesenberg and Strand) feeding on the brown planthopper, *Nilaparvata lugens* (Stal.)

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SUMMARY : Study on effect functional response of wolf spider, *Pardosa pseudoannulata* (Boesenberg and Strand) in relation to different prey densities of 3rd and 4th instar Brown planthopper, *Nilaparvata lugens* (Stal.) nymphs was undertaken in glass jar arena with '3' spiders under both ambient CO_2 and elevated CO_2 conditions. Under elevated CO_2 condition, predator feeding rate increased from 10.0±3.24 to 31.0±4.36 hoppers/ predator with increase of prey density from 10 to 50 hoppers /predator compared to feeding rate (10.0±3.24 to 33.0±4.39) under ambient CO_2 condition. The feeding rate of the spider under elevated CO_2 was slightly higher than ambient CO_2 condition because elevated CO_2 probably lowered the quality of rice plant and ultimately reduced the quality of prey. In order to compensate for poor nutrient quality of prey, predators might have consumed more number of prey under elevated CO_2 compared to ambient CO_2. Based on predation study, number of attacked prey (H_a) and prey density per unit area over a period of time (HT) were determined. Regression of $1/H_a$ on 1/HT under ambient CO_2 as well as elevated CO_2 revealed functional type II response of wolf spider on BPH nymph. The attack rate (0.43), maximum attack rate (4.27) and efficiency parameters (0.53) of the predator were higher but handling time was lower (0.71) under elevated CO_2 compared to ambient CO_2 condition.

KEY WORDS :
Ambient CO_2, Brown plant hopper, Elevated CO_2, Wolf spider, Rice plant

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BACKGROUND AND OBJECTIVES

Rice (*Oryza sativa* L.) is one of the important cereals of the world particularly in Asian countries and forms staple diet for more than 50 per cent of the population. Rice production is hindered by abiotic factors such as soil fertility, soil moisture, droughts and floods etc. and biotic factors responsible for yield loss as in rice are pests and diseases. It is thus, apparent that in future, rice production is likely to face many constraints thereby leading to inconsistency in production and enormous economic losses (Khush, 2004). Among the various 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. Among the sap sucking pests of rice, the planthoppers have become economically important all over the world (Magunmder *et al.*, 2013). Of the two important planthoppers, brown plant hopper (BPH), *Nilaparvata lugens* Stal. (Homoptera: Delphacidae), is the most serious and destructive pest causing huge losses. 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 (Reissig *et al.*, 1986).

For many years, rice pest control was mainly dependent on insecticides but the continuous and indiscriminate use of wide range of pesticides led to problems of resistance, resurgence, secondary pest outbreaks, loss of biodiversity and environmental pollution. Among different IPM tactics, biological control is considered to be very important one. Vanden Bosch *et al*.(1982) reported many benefits of control of agricultural pests by means of parasitic and predatory natural enemies. Spiders are most abundant and ubiquitous obligate carnivorous arthropods, which feed on different type of prey in all cropping systems. The wolf spider, *Pardosa pseudoannulata* is a polyphagous predator in rice ecosystem in most parts of Asia. Spiders frequently feed on plant hoppers, leaf hoppers and other insects (Bardwell and Averill, 1997).

Climate change also affects the natural enemy populations, which play an important part in the suppression of pest population and is a one of the most important component of integrated pest management (Walker and Jones, 2001). Stiling *et al*. (1999) observed that natural enemies feeding on insects under elevated CO_2 have been affected indirectly through food chain *i.e.*, trophic cascade. Plants under elevated CO_2 are deficient in nutrients due to low C:N ratio, which makes herbivores to feed on them for a longer period of time to compensate for nutrients. However, several reports have shown weak effect of elevated CO_2 on natural enemies. Aphid population might increase, decrease, or not be affected under elevated CO_2 (Chen *et al.*, 2005 and Gao *et al*., 2008).

RESOURCES AND METHODS

Collection of brown planthopper population:

Brown planthopper 3rd and 4th instar nymphs required to study the feeding potential of wolf spider, under elevated CO_2 condition were collected from open top chamber (OTC) under elevated CO_2. Similarly, 3rd and 4th instar BPH nymphs were collected from OTC under ambient CO_2 condition. Feeding potential experiment in glass jar arena was conducted under laboratory condition at 25±2 °C temperature and 70±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 (Xaaceph and Butt, 2014). 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. Three experiments were conducted using one, two and three spiders, respectively at each of the prey densities under both ambient CO_2 and elevated CO_2 condition. Each experiment was replicated thrice.

BPH densities provided to spider at elevated CO_2 (570 ± 25 ppm) *vis-à-vis* ambient CO_2 Three spiders per BPH density

T_1: 3:10 (3 spiders/ 10 BPH)
T_2: 3:20 (3 spiders/ 20 BPH)
T_3: 3:30 (3 spiders/ 30 BPH)
T_4: 3:40 (3 spiders/ 40 BPH)
T_5: 3:50 (3 spiders/ 50 BPH).

Predator feeding rate in jar under laboratory condition was observed for BPH populations reared under ambient CO_2 and elevated CO_2 separately in OTCs.

Analysis of feeding potential of wolf spider :

The functional response of spider with respect to BPH reared under elevated CO_2 and ambient CO_2 was analyzed using Holling disc equation. The functional response parameters *i.e*. handling time (T^h) and attack rate (a) were determined using Holling disc equation and modified by reciprocal linear transformation at different prey densities.

Predator activites involved:

–Prey searching and

–Prey handling (chasing, killing, eating and digesting).

OBSERVATIONS AND ANALYSIS

Study on functional response of wolf spider in relation to different prey densities of 3rd-4th instar BPH nymphs were undertaken in laboratory using glass jar. The study was undertaken with BPH nymphs reared under under elevated CO_2 and ambient CO_2 conditions using 3 spiders respectively. In the experiment, three spiders were used with five BPH densities *viz*., 10, 20, 30, 40 and 50 BPH nymphs of 3rd and 4th instars over three days. Under ambient condition, mean number of prey killed was 10 to 31 hoppers /3 spiders and predator consumption rate was 100 - 62% with increase of prey density (Table 1). Under elevated CO_2, mean number of prey killed increased from 10 to 33 hoppers /3 spiders and predator consumption rate decreased from 100-64% with increase of prey density (Table 2). It was observed that prey killing rate was slightly higher under elevated condition compared to ambient CO_2 (Fig. 2).

Based on predation study, number of attacked prey (H_a) and prey density per unit area over a period of time (HT) were determined. Regression of $1/H_a$ on 1/HT in the jar under ambient CO_2 as well as elevated CO_2 revealed functional type II response of wolf spider on BPH nymph (Fig. 1). The attack rate, maximum attack rate and efficiency parameters of predator, respectively were higher but handling time was lower under elevated CO_2 compared to ambient CO_2 (Table 3) because

Table 1 : Functional response parameters of the wolf spider *Pardosa pseudoannulata* on different BPH nymph densities in jar (19cm× 15cm) under ambient CO_2

Prey density (H)	Spider density	Total prey offered	Total prey killed	Mean no. of prey killed(H_a)	1/Ha	1/HT	Proportion killed
10	3	30	30	10.0±0.0	0.1	0.03	1
20	3	60	58	19.34±0.34	0.0517	0.017	0.97
30	3	90	82	27.67±0.88	0.036	0.01	0.91
40	3	120	89	29.67±.67	0.034	0.008	0.74
50	3	150	93	31.0±1.0	0.032	0.0067	0.62

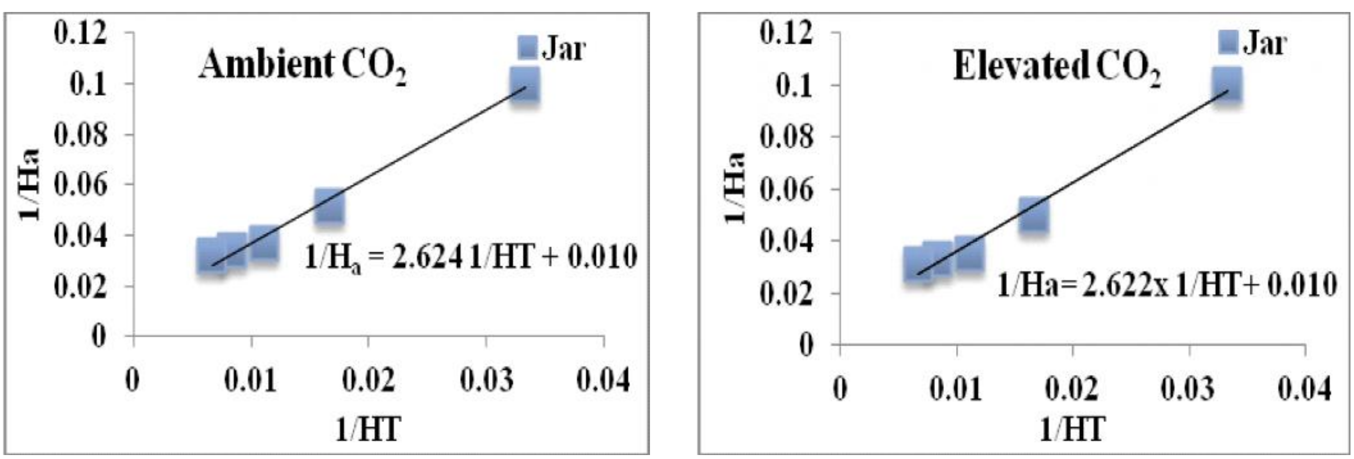

Fig. 1: Relationship between $1/H_a$ and 1/HT of wolf spider in laboratory under ambient CO_2 and elevated CO_2

elevated CO_2 probably lowered the quality of rice plant and ultimately reduced the quality of prey. In order to compensate for poor nutrient quality of prey, predator might have consumed more number of prey under elevated CO_2 compared to ambient CO_2.

In this study, feeding potential of spider, *Lycosa pseudoannulta* was examined in glass jar under laboratory condition under both ambient and elevated CO_2. In the experiment, With increase of prey density consumption rate decreased in all the experiments, 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* (Xaaceph and Butt, 2014), *Adalia fasciatopunctata revelierei* (Atlihan and Borra, 2010). Earlier, functional type-II response of predator has been found to be most commonly fitted response to the insect predator behaviour (Saleh *et al*., 2010; Xaaceph and Butt, 2014). Claver *et al*. (2003) reported that 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. The functional response of predators provided good information for understanding the effects of bio control agents in the field (Waage and Greathead, 1988).

Plants under elevated CO_2 are deficient in nutrients due to low C:N ratio, which makes herbivores to feed on them for a longer period of time to compensate for nutrients. Herbivores thus, prolong their exposure to natural enemies, which inturn leads to higher predation rates (Barbosa *et al*., 1982) or parasitism rates (Stiling *et al*., 2002). In present study, feeding rate of wolf spiders was higher under elevated CO_2 compared to ambient CO_2 and showed that killing rate of wolf spider was 8.34 to 22.34 under elevated CO_2 and 8 to 21.3 hoppers under ambient CO_2 condition. Predator attack rate, maximum

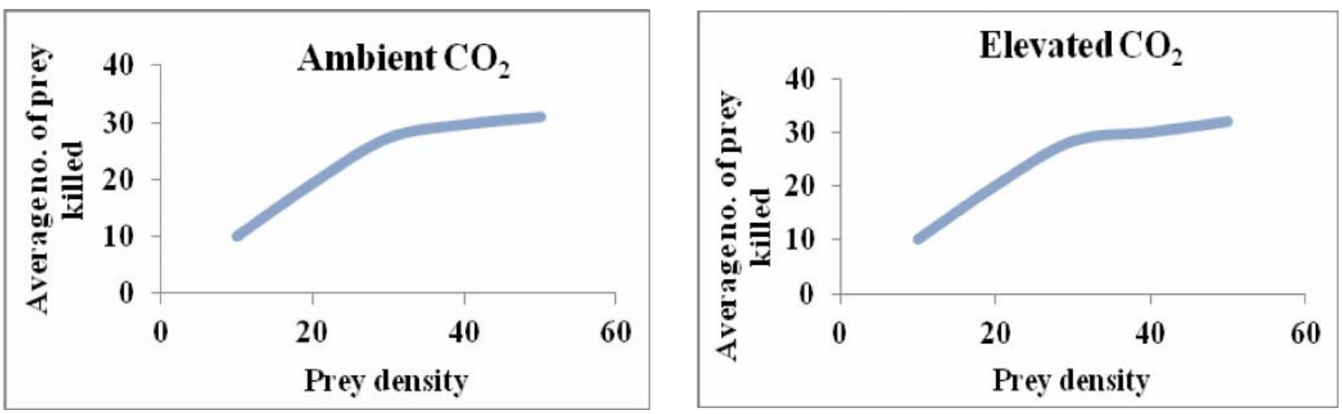

Fig. 2: Comparison of predatory efficiency of wolf spider in laboratory under ambient CO_2 and elevated CO_2

Table 2 : Functional response parameters of the wolf spider *Pardosa pseudoannulata* on different BPH nymph densities in jar (19cm× 15cm) under elevated CO_2

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	3	30	30	10.0±0.0	0.1	0.033	1
20	3	60	60	20.0±0.0	0.05	0.0167	1
30	3	90	85	28.34±0.88	0.035	0.01	0.94
40	3	120	90	30.0±1.15	0.0333	0.008	0.75
50	3	150	96	32.0±0.34	0.0329	0.0067	0.61

Table 3 : Estimation of functional response parameters of wolf spider in jar under ambient and elevated CO_2 condition from linearization of Holling type II model

	Condition	Handling time	Attack rate	Maximum attack	Efficiency parameter	Search rate (Area in mts.)
Ambient	Laboratory	0.72	0.411	4.167	0.529	0.0114
Elevated	Laboratory	0.71	0.431	4.267	0.532	0.0114

attack rate and efficiency parameters increased but handling time decreased upto certain level under elevated CO_2 compared to ambient CO_2, earlier also Chen *et al*. (2007) reported that parasitism of *Aphidius picipes* on wheat aphid, *Sitobion avenae* increased under elevated CO_2. It could be ascribed to the fact that elevated CO_2 decreased the plant protein level, which might affect herbivore protein content (Guerenstein and Hildebrand, 2008) thereby decreasing their nutritional value to natural enemies depending on them. Poor quality of prey might increase predator attack rate as well as reduce the fitness of the natural enemies (Chen *et al*., 2005). According to Boullis *et al*. (2015) conflicting results have been obtained in regard to insect pest vulnerability to their predators under elevated CO_2.

Elevated CO_2 also influenced interaction between wolf spider and BPH wherein predation rate was observed to be slightly higher compared to ambient CO_2 because elevated CO_2 probably lowered the quality of rice plant and ultimately reduced the quality of prey. In order to compensate for poor nutrient quality of prey, predators might have consumed more number of prey under elevated CO_2 compared to ambient CO_2. These results on variable effect of elevated CO_2 on natural enemies might help in development of futuristic pest management strategies in view of threat of increasing CO_2 in atmosphere.

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