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Niche regulation between brown planthopper (BPH) and white backed planthopper (WBPH) in association with their natural enemy population in the rice ecosystem

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Abstract
Present study showed niche regulation between brown planthopper (BPH), *Nilaparavata lugens (*Stal.) and whitebacked planhopper (WBPH), *Sogatella furcifera* (Horvath) with regards to their natural enemy populations in early and late transplanted crop of Pusa Basmati 1121 during *kharif* 2015 and 2016. The BPH and WBPH populations were associated with predator population range of 20–120 predators/50 hills in early and late transplanted rice during 2015 and with 20–120 predators/50 hills in early and 20–160 predators/50 hills in late transplanted crop during 2016. With respect to predator association, BPH had broader niche in early transplanted and late transplanted crops compared to WBPH as the BPH population showed greater association with natural enemy population than WBPH during the cropping seasons of both the years. The overlap between BPH and WBPH in relation to association with predator population in early transplanted rice during 2016 was greater than 2015. The BPH thus proved to be a generalistic species compared to WBPH, which acted as more specialist species as its population occurred in lower number during the both the cropping season on rice crop.

Keywords: Brown planthopper, Whitebacked planthopper, Pusa Basmati, Predator

1. Introduction

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. The rice is produced in warm and humid environment, which is also very much congenial for proliferation of insect pests. Intensive agriculture practices such as high synthetic fertilizer applications, high tillering varieties and multicropping practices favour the development of pest populations throughout the year. With the advent of green revolution in 1960s, high yielding varieties with intensive monoculture and excessive fertilizer and pesticide applications made distinct changes in the rice insect pest complex in Asia [1]. Many species, which were considered as minor pests earlier, have now became as major pests.

The two important planthoppers of rice are brown plant hopper (BPH), *Nilaparvata lugens* Stal. and white-backed plant hopper (WBPH), *Sogatella furcifera* (Horvath) (Homoptera: Delphacidae), 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. The WBPH, though not a virus disease vector, occurs widely and can become sufficiently numerous to kill plants by hopper burn [2]. The BPH is characterized by its monsoon migration, morphological diversity and r-strategy life pattern [3]. Widespread outbreaks of the BPH occurred in northern states of India in 2008 [4], 2013 [5] and 2016 (unpublished) that resulted in substantial yield losses. In normal years also, sporadic outbreaks have been reported from one region or another of these states. The BPH and WBPH occur simultaneously on the crop, however, the latter has been observed to attain peak population earlier than the former during the rice season. Early maturing cultivars of rice, have been found to escape peak infestations of the BPH, however the WBPH attains importance for such cultivars.

BPH has been observed to infest the crop towards later stages of the crop growth and remain until crop harvest thereby causing maximum loss of yield. The BPH infestation occured in all rice growing areas of Asian countries and cause huge yield losses by destruction of the crop [6]. This small insect species was sound to causes huge yield losses than its counterpart huge lepidopterans like stem borers and leaf folders [7].

BPH caused both direct and indirect damage to the rice crop, directly through sucking of sap from phloem that made infested plant parts change to brown colour from yellow before wilting. The symptoms called as “hopper burn”, and the pest destroyed the crop severely, causing almost complete loss of crop yield [8]. Indirectly, it damaged the rice plant through transmission of many deadly viruses of rice such as rice ragged stunt virus, rice grassy stunt virus, rice stripe virus, south rice black streaked dwarf virus and rice black streaked dwarf virus [9-10].

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. There are many benefits of control of agricultural pests by means of parasitic and predatory natural enemies [11]. Large numbers of natural enemy populations are available in the paddy field. Their roles in suppressing planthopper population have been for a long period of time. Most important of natural enemies of planthopper in rice field includes spiders, mirid bugs, water striders, and various egg parasitoids.

Materials and methods

Raising of rice nursery

The plot meant for rice nursery was puddled and brought to fine tilth and bunds were prepared around the plot area. Fertilizers were applied at recommended dosage of 120:60:40 kg ha^{-1} NPK. Pusa Basmati 1121, a susceptible rice variety to BPH was sown on the finely prepared nursery bed during *kharif* 2015 and *kharif* 2016 for early and late transplanted rice crop, respectively at a seed rate of 20 kg ha^{-1}.

Main field preparation and transplanting of rice seedlings

Disc plough was used for ploughing the main field and tractor drawn cultivator for getting the fine tilth with better aeration and all the stubbles, weeds were removed to remove the dormant stages of pests. Ridges were prepared and recommended dosages of fertilizers were applied. Plot size was 3×3m with plant and row spacing of 15 and 20 cm respectively. Channels of 50cm size were maintained between plots to facilitate irrigation, fertilizer application and recording of observations. On 6th July and 7th August during *kharif* 2015 and on 10th July and 6th August during *kharif*, 2016 transplanting was done with 30-day old seedlings and three seedlings per hill. One week after transplanting, gap filling was done in each plot to get uniform plant population. Buffer space of one meter was left out from the border areas of the field to minimize the pest incidence and border effect on the crop.

Irrigation and fertilizer application in the main field

Irrigation was applied at regular intervals in the field until the well establishment of rice seedlings. Thereafter, the field was irrigated at weekly intervals until 10 days before harvesting of the crop. A recommended dosage of 120:60:40 kg ha^{-1} Nitrogen (N_2), phosphorous (P_2O_5) and potassium (K_2O) fertilizers were applied in the form of urea, single super phosphate and muriate of potash. Nitrogen was applied in three splits *i.e.*, at basal dose, tillering and panicle emergence stage but phosphorous and potassium were applied after puddling as basal dose. The method followed for application of fertilizers in the field was broadcasting for uniform distribution of the fertilizers.

Time of experiment

Experiment on niche partitioning between BPH and WBPH with regards to crop phenology, stem space, microhabitat temperature and microhabitat relative humidity regimes, and natural enemy association was undertaken. The experiment consisted of ten plots, each measuring 3×3 m with plant and row spacing of 15×20 cm, respectively in early and late transplanting each during 2015 and 2016. In the experiments, hygrometer and dry-wet bulb thermometers were placed in the field to record temperature and humidity in microhabitat as compared to ambient temperature and relative humidity. Hygrometer and thermometers were placed 24 hours before recording of observations.

The BPH and WBPH populations were enumerated on five randomly selected hills per plot from each of 10 plots at 10 days intervals, beginning with 30 days after transplanting (DAT) both in early and late the transplanted crops. The BPH and WBPH populations were thus recorded on 50 hills. Simultaneously, natural enemy population was also counted on randomly selected 50 hills.

Experimental analysis

Quantitative determination of competition between BPH and WBPH for utilization of similar resources was done through computation of Niche breadth and Niche overlap by Levin’s measure of niche breadth and Pianka’s measure of niche overlap.

Niche breadth and niche overlap of the two species with respect to predator population were also determined. Overall natural enemy populations observed during the experimental period were arranged from minimum to maximum in subunits based on total predator population observed. Total BPH and WBPH counts observed during the same day were assigned to relevant subunit on predator population range.

Results

Spiders, mirid bugs and rove beetles were the natural enemies of BPH and WBPH observed during the cropping season. The BPH and WBPH populations were associated with predator population range of 20–120 predators/50 hills in early and late transplanted rice during 2015, and with 20–120 predators/50 hills in early and 20–160 predators/50 hills in late transplanted crop during 2016. Peak BPH population was associated with 100-120 predators /50 hills in early transplanted crop and 100-120 predators/50 hills in late crop during 2015. On the other hand, during 2016, peak BPH population was associated with 100-120 predators /50 hills in early crop and 140-160 predators /50 hills in late crop. On the other hand, the peak WBPH population in early as well as late transplanted rice was associated with 40-60 predators/50 hills during two years. With respect to association with predator in early transplanted rice during 2015, niche breadth (NB = 2.664) and standardized niche breadth (SNB = 0.416) of BPH was greater than WBPH (NB = 2.42; SNB = 0.355) (Table 1). Similarly in early transplanted rice during 2016, BPH possessed broader niche (NB = 2.71; SNB = 0.43) than WBPH (NB = 2.571; SNB =0.393) (Table 3). Likewise, in late transplanted crop during 2015, BPH occupied broader niche (NB = 2.885; SNB = 0.471) compared to WBPH (NB = 2.673; SNB = 0.418) (Table 2). In late transplanted crop during 2016 also, BPH had broader niche (NB = 2.694; SNB = 0.339) than WBPH (NB = 2.661; SNB = 0.332) (Table 4).

Between early and late transplanted rice, BPH in early transplanted rice had broader niche than late transplanted rice during both the years. Likewise, WBPH as such had broader niche in early transplanted rice than late transplanted rice during both the years of 2015 and 2016 (Fig. 1). BPH thus exhibited broader niche with regard to association with natural enemy populations. The BPH population thus showed greater association with natural enemy population than WBPH during the two cropping seasons.

The niche overlap (O) between BPH and WBPH in relation to association with predator population in early transplanted rice during 2016 (O = 0.284) (Table 3) was greater than 2015 (O = 0.241) (Table 1). However, greater overlap was observed in late transplanted rice during 2015 (O = 0.392) (Table 2) compared to 2016 (O = 0.137) (Table 4). Niche overlap with respect to association with predator population revealed that predator association of the two species overlapped by 13-39% during the two crop seasons.

Table 1: Niche breadth (NB), standardized niche breadth (SNB) and niche overlap (O) of BPH and WBPH with reference to association with predator population in early transplanted rice during *kharif* 2015

Predator population range (No. /50 hills)	**20-40**	**40-60**	**60-80**	**80-100**	**100-120**	**Sum**
BPH Population	32	51	100	256	426	865
P_1 (Proportion of total population)	0.020	0.059	0.131	0.250	0.540	1.000
P_1^2	0.000	0.003	0.017	0.063	0.292	0.375
NB	2.664					
SNB	0.416					
WBPH Population	23	129	52	9	7	220
P_2	0.105	0.586	0.236	0.041	0.032	1.000
P_2^2	0.011	0.344	0.056	0.002	0.001	0.413
NB	2.420					
SNB	0.355					
$P_1 \times P_2$	0.002	0.034	0.031	0.010	0.017	0.095
M_{12}	0.253					
M_{21}	0.230					
O	0.241					

Table 2: Niche breadth (NB), standardized niche breadth (SNB) and niche overlap (O) of BPH and WBPH with reference to association with predator population in late transplanted rice during *kharif* 2015

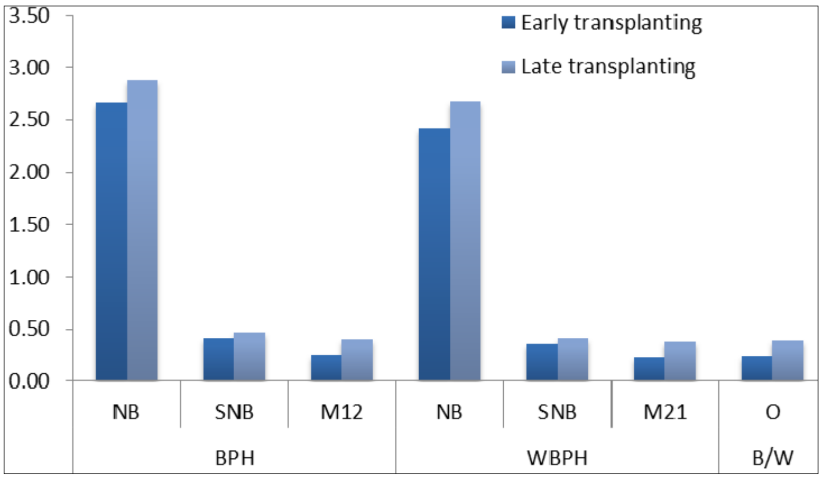
Predator population range (No. /50 hills)	**20-40**	**40-60**	**60-80**	**80-100**	**100-120**	**Sum**
BPH Population	21	72	89	287	427	896
P_1 (Proportion of total population)	0.023	0.080	0.099	0.320	0.477	1.000
P_1^2	0.001	0.006	0.010	0.103	0.227	0.347
NB	2.885					
SNB	0.471					
WBPH Population	8	97	32	27	10	174
P_2	0.046	0.557	0.184	0.155	0.057	1.000
P_2^2	0.002	0.311	0.034	0.024	0.003	0.374
NB	2.673					
SNB	0.418					
$P_1 \times P_2$	0.001	0.045	0.018	0.050	0.027	0.141
M_{12}	0.408					
M_{21}	0.378					
O	0.392					

Table 3: Niche breadth (NB), standardized niche breadth (SNB) and niche overlap (O) of BPH and WBPH with reference to association with predator population in early transplanted rice during *kharif* 2016

Predator population range (No. /50 hills)	**20-40**	**40-60**	**60-80**	**80-100**	**100-120**	**Sum**
BPH Population	34	100	224	427	922	1657
P_1 (Proportion of total population)	0.02	0.06	0.13	0.25	0.54	1.0
P_1^2	0.0004	0.003	0.02	0.06	0.29	0.37
NB	2.71					
SNB	0.43					
WBPH Population	9	99	48	14	9	179
P_2	0.05	0.56	0.268	0.078	0.050	1.000
P_2^2	0.003	0.306	0.072	0.006	0.003	0.389
NB	2.571					
SNB	0.393					
$P_1 \times P_2$	0.001	0.01	0.027	0.02	0.13	0.26
M_{12}	0.52					
M_{21}	0.276					
O	0.284					

Table 4: Niche breadth (NB), standardized niche breadth (SNB) and niche overlap (O) of BPH and WBPH with reference to association with predator population in late transplanted rice during *kharif* 2016

Predator population range (No. /50 hills)	20-40	40-60	60-80	80-100	100-120	140-160	Sum
BPH Population	60	225	328	786	1613	3550	6562
P_1 (Proportion of total population)	0.009	0.034	0.05	0.12	0.246	0.541	1.0
P_1^2	0.0001	0.0012	0.003	0.014	0.061	0.293	0.37
NB	2.694						
SNB	0.339						
WBPH Population	27	118	40	16	8	1	210
P_2	0.129	0.562	0.191	0.076	0.038	0.0048	1.0
P_2^2	0.017	0.316	0.0363	0.0058	0.0015	0.00002	0.376
NB	2.661						
SNB	0.332						
$P_1 \times P_2$	0.0012	0.02	0.01	0.01	0.0094	0.0026	0.051
M_{12}	0.60						
M_{21}	0.136						
O	0.137						



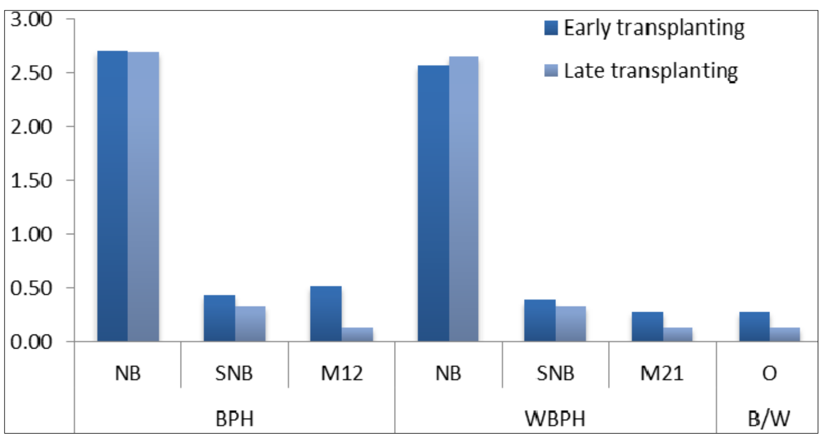


Fig 1: Niche breadth (NB), standard niche breadth (SNB) and niche overlap (O) of brown planthopper (BPH) and whitebacked planthopper (WBPH) with reference to predator population during 2015 and 2016

Discussion

Use of same set of resource by the individuals of the species in the community is known as niche breadth. Utilization of different resources by each species in biotic community is measured by niche breadth (Levin's, 1968). The BPH and WBPH are the two important insect species in the rice ecosystem. Their populations depend upon both abiotic components and also their association with the natural enemy population in the rice ecosystem. Niche breadth and standard niche breadth were used to measure the uniform utilization of different resources by species. On the other hand, niche overlap measures the commonality of BPH and WBPH with respect to utilization of abiotic and biotic components in rice ecosystem.

BPH showed broader niche in early transplanted and late transplanted crops compared to WBPH. The BPH population thus showed greater association with natural enemy population than WBPH during the two cropping seasons. Broader niche of BPH was observed in respect of its association with predators in the rice ecosystem. Spiders, mirid bugs and rove beetles were the natural enemies associated with BPH and WBPH during the cropping season. In spiders, *Lycosa pseudoannulata* is the dominant spider observed in the rice field. Population of predators attained its maxima during the peak population of BPH. The BPH thus maintained stronger association with the predators and they might thus play an important role in population regulation of BPH. Species niche breadth increases with their distribution [12]. Intraspecific variation existed in niche breadth in BPH and WBPH between early and late transplantation.

Conclusion

Present study on niche regulation between BPH and WBPH in association with their natural enemy population in the rice ecosystem revealed that BPH had broader niche in early transplanted and late transplanted crops compared to WBPH. The BPH population thus showed greater association with natural enemy population than WBPH during the two cropping seasons. The BPH thus proved to be a generalistic species compared to WBPH, which acted as more specialist species as its population occurred in lower number during the both the cropping season on rice crop.

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