Indian Journal of Agricultural Sciences **94** (2): 140–144, February 2024/Article
https://doi.org/10.56093/ijas.v94i2.137394

Interactive effect of transplanting time and crop phenology on incidence of brown planthopper and spider population in rice (*Oryza sativa*)

VINOD K PADALA[1,2], RAJNA S[1], VENKATESH Y N[1,3] and SUBHASH CHANDER[4]*

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

Received: 06 June 2023: Accepted: 09 November 2023

ABSTRACT

Brown planthopper (BPH), *Nilaparvata lugens* (Stal 1854) is a destructive insect pest causing severe yield loss every year in rice (*Oryza sativa* L.) crop. An experiment was conducted during during *kharif* (rainy) seasons of 2021 and 2022 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi to study the effect of transplanting time and crop phenology on brown planthopper (BPH) incidence and spider population in rice. BPH and spider populations were recorded at different phenological stages in early, normal and late transplanted rice. Results showed that a significantly higher mean BPH population was observed in late transplanting in 2021 [54.00±5.31 per hill (nymphs and adults)] and 2022 (40.40±2.62 per hill) compared to normal and early tranplanting. Peak BPH population was observed at the heading (225.60±18.83 per hill) and milking stage (131.00±8.30 per hill) of late transplanted rice in 2021 and 2022, respectively. Likewise, more mean spider population was observed in late transplanting [1.87±0.11 per hill (adults) in 2021 and 2.38±0.08 per hill in 2022]. Two-way ANOVA showed a statistically significant interaction between transplanting time and crop phenology with regard to BPH incidence and spider population in both the years. The highest grain yield was recorded in early transplanted rice (36.08±0.75 q/ha; 35.06±0.49 q/ha) followed by normal (27.53±0.80 q/ha; 28.22±0.75 q/ha) and late transplanted rice crop (17.43±0.82 q/ha; 19.37±0.67 q/ha) respectively during two years. The early transplanted rice crop escaped the peak BPH incidence resulted in increased grain yield. The study demonstrated that both transplanting time and crop phenology influenced the BPH and spider populations.

Keywords: Crop phenology, *Nilaparvata lugens*, Paddy, Pest incidence, Spider, Transplanting

Rice (*Oryza sativa* L.) is one of the most important crops in the world, serving as the primary energy source for more than half of the global population. Brown planthopper (BPH), *Nilaparvata lugens* (Stal 1854) is a destructive insect pest causing severe yield loss every year in the countries of east and southeast Asia (Hu *et al.* 2014). BPH damages plants by directly feeding on phloem sap and indirectly by transmitting viral diseases such as grassy stunt and ragged stunt (Sawada *et al.* 1993). Spiders are the most predominant predator in rice ecosystem, where they serve as natural biocontrol agents against insect pests of rice. Biotic and abiotic factors often play an important role in incidence of BPH and spiders (Prasannakumar and Chander 2014). Win *et al.* (2010) reported that BPH and WBPH populations are influenced by temperature, rainfall, and relative humidity. Similarly, Prasannakumar and Chander (2014) also reported weekly maximum temperatures (Tmax), rainfall and evening relative humidity (RHe) are significant weather factors affecting the BPH light trap catches in the rainy season. Another factor that influences the BPH incidence is crop age/crop phenology. Several previous studies reported that the rice pest population differs with different crop phenological stages due to changes in morphological and physiological characteristics of the plant during its development (Alam 1972, Moldenhauer and Slaton 2004). BPH population reaches peak after 60 days post-transplantation, indicating high infestation during maturing stages than other growth stages of rice plant. Besides, the population in pre-planting stage did not differ significantly with vegetative stage but was observed substantially lower than reproductive, maturing and post-harvest stages (Hafizal 2013). Similar results were obtained from the laboratory choice test, where maximum preference was reported on 100–140 days-old plants compared to less than 100 days-old plants. Zhong-xian *et al.* (2006) reported that the BPH population increased from vegetative to reproductive stage and reached its maximum at milking stage. Similarly, there are many studies on the influence of crop phenology on BPH incidence, but the interaction between crop phenology and various transplanting times is lacking. Hence, the present study was carried out with 3 transplanting timings and 7 important

[1]ICAR-Indian Agricultural Research Institute, New Delhi; [2]ICAR-National Research Centre for Makhana, Darbhanga, Bihar; [3]ICAR-Central Agroforestry Research Institute, Jhansi, Uttar Pradesh; [4]ICAR-National Centre for Integrated Pest Management, New Delhi. *Corresponding author email: schanderthakur@gmail.com

plant phenological stages, viz. tillering, booting, heading, anthesis, milking, dough and post-maturity to study their effect on BPH and spider population dynamics.

MATERIALS AND METHODS

Field experiments were conducted during *kharif* (rainy) seasons of 2021 and 2022 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi (Latitude: 28.6432821, Longitude: 77.1683427). Sowing was done with short duration variety Pusa 1509 during 2nd week of June for early transplanting, 4th week of June for normal transplanting and 1st week of July for late transplanting in both the years. During both the years, 25 to 27 days-old seedlings were transplanted in 3 × 3 m^2 plots sized (10 plots) with 15 cm × 20 cm plant and row spacing. Transplantings were done at an interval of 15 days, where early transplanting was done on 6th July and 7th July, normal transplanting on 20th July and 22th July, and late transplanting on 5th August and 6th August in 2021 and 2022, respectively. Fertilizers, nitrogen (in three splits), phosphorous (basal dose) and potassium (basal dose) were applied as per the recommendations (@120:60:40 NPK kg/ha). Pre-emergence herbicide butachlor @1 kg/ha was applied. Regular irrigation was undertaken at 3-days interval until crop maturity. BPH and spider populations were recorded at different phenological stages of crop such as tillering, booting, heading, anthesis, milking, dough and post-maturity during both the years. Nymphs and adults of BPH and adult spiders were counted on 5 random hills from each plot and total 50 hills were observed for each transplanting date. Grain yield data were recorded from each plot and expressed on quintal per hectare basis.

Field data were subjected to normality test by Shapiro-Wilk test and transformed with square root transformation before the analysis. One-way ANOVA was done to find out the significant difference among the three transplanting dates for each phenological stage separately and the means were separated by Tukey's HSD test at α=0.05 level of significance. Two-way ANOVA was undertaken to determine the significant interaction between crop phenology and transplanting date in respect of BPH incidence and spider population. One-way ANOVA was used to compare the yields of three transplanting dates of rice crop and means were separated by Tukey's HSD test at α=0.05 significance level. All the analyses were done by using SPSS 20.0 version.

RESULTS AND DISCUSSION

Observations on BPH incidence in early transplanting during 2021 revealed the highest BPH population at post maturity stage (27.96±3.86 per hill) followed by dough stage (3.04±0.26 per hill). In normal transplanting, highest BPH population was recorded at milking stage (60.04±6.70 per hill), followed by dough (46.62±5.74 per hill) and post maturity (8.66±0.97 per hill) (Table 1). In case of late transplanting the peak BPH population was recorded at heading stage (225.60±18.83 per hill) followed by anthesis (103.46±12.36 per hill) and milking stage (39.28±4.97 per hill) (Table 1). The results were in concordance with previous studies, where low incidence of BPH population was observed at vegetative stage and high incidence at reproductive and maturity stages (Hafizal 2013). In the present study a significant difference was observed in mean BPH population among three transplanting dates, where highest mean BPH population was observed in late transplanting (54.00±5.31 per hill) followed by normal (17.00±1.78 per hill) and lowest in early transplanting (5.00±0.75 per hill) (P<0.0001) (Table 1). Chander and Mohan (2020) also reported a high mean BPH population in late transplanted rice followed by normal and early transplanted rice. In our study, significant difference in mean BPH population was observed among three differential transplanting dates at all phenological stages i.e. tillering, booting, heading, anthesis, milking, dough and post maturity, where the highest population was observed in late transplanting up to anthesis stage compared to early and normal transplanting (P<0.0001) (Table 1). At the heading stage, seasonal highest BPH population was recorded in late transplanting (225.60±18.83 per hill), whereas early and normal transplanting recorded BPH as 0.88±0.16 and 0.24±0.08 per hill, respectively. At milking and dough stage, normal transplanting showed the highest BPH population (60.04±6.70 per hill and 46.62±5.74 per hill respectively) compared to early and late transplanted crop (P<0.0001). At post maturity stage early transplanted crop recorded the highest BPH population (27.96±3.86 per hill) compared to normal (8.66±0.97 per hill) and late transplanted crop (0.50±0.11 per hill) (P<0.0001) (Table 1). No significant difference in BPH population was observed between early and normal transplanting up to anthesis stage but significant difference was found during later stages (Table 1). Similarly Mangalgikar and Harsur (2012) also reported heading to harvesting stages to be favourable crop phenology for BPH development.

The high incidence of BPH in reproductive and maturity stage may perhaps be attributed to changes in morphological and physiological characteristsics of the plant during its development and also due to variations in the micro climate of the crop as reported earlier too, which favours the BPH population build up (Alam 1972, Moldenhauer and Slaton 2004).

During 2022 the highest BPH population was observed at the dough stage (26.22±2.17 per hill) followed by post maturity (19.20±1.19 per hill) and milking stages (2.58±0.32 per hill) in early transplanting. In normal transplanting, highest BPH population was recorded at dough stage (36.20±3.17 per hill) followed by post maturity (26.40±2.50 per hill) and milking stage (25.90±1.75 per hill) (Table 1). In case of late transplanting, peak BPH population was observed at milking stage (131.00±8.30 per hill) followed by dough (54.40±3.82 per hill) and post maturity stage (40.20±3.63 per hill) (Table 1). There was significant difference in mean BPH population among three transplantings, where highest population was observed in late transplanting (40.40±2.62 per hill) followed by normal (13.00±1.00 per hill) and early transplantings (6.89±0.65

Table 1 Brown planthopper population (mean±SE) under three transplanting dates during *kharif*, 2021 and 2022

Crop stage	2021					2022				
	Early (BPH per hill)	Normal (BPH per hill)	Late (BPH per hill)	F value	*P* value	Early (BPH per hill)	Normal (BPH per hill)	Late (BPH per hill)	F value	*P* value
Tillering	0.08 ± 0.0.06^{b} (0.76)	0.06 ± 0.03^{b} (0.74)	0.50 ± 0.10^{a} (1.00)	12.14	<0.0001	0.00 ± 0.00^{b} (0.71)	0.00 ± 0.00^{b} (0.71)	1.80 ± 0.32^{a} (1.52)	36.92	<0.0001
Booting	0.00 ± 0.00^{b} (0.71)	0.30 ± 0.10^{b} (0.91)	4.52 ± 0.43^{a} (2.24)	132.00	<0.0001	0.00 ± 0.00^{b} (0.71)	0.00 ± 0.00^{b} (0.71)	9.24 ± 0.71^{a} (3.12)	302.50	<0.0001
Heading	0.24 ± 0.08^{b} (0.86)	0.88 ± 0.16^{b} (1.17)	225.60 ± 18.83^{a} (15.03)	463.40	<0.0001	0.04 ± 0.03^{b} (0.73)	0.12 ± 0.05^{b} (0.79)	12.00 ± 0.88^{a} (3.54)	289.7	<0.0001
Anthesis	1.12 ± 0.15^{b} (1.27)	2.64 ± 0.32^{b} (1.77)	103.46 ± 12.36^{a} (10.19)	211.90	<0.0001	0.12 ± 0.06^{b} (0.79)	2.1 ± 0.24^{b} (1.61)	35.10 ± 2.40^{a} (5.97)	495.8	<0.0001
Milking	1.66 ± 0.25^{c} (1.46)	60.04 ± 6.70^{b} (7.78)	39.28 ± 4.97^{a} (11.47)	100.40	<0.0001	2.58 ± 0.32^{c} (1.76)	25.9 ± 1.75^{b} (5.08)	131.00 ± 8.30^{a} (11.47)	391.7	<0.0001
Dough	3.04 ± 0.26^{b} (1.88)	46.62 ± 5.74^{a} (6.86)	4.18 ± 0.35^{b} (2.16)	130.40	<0.0001	26.22 ± 2.17^{c} (5.17)	36.20 ± 3.17^{b} (6.06)	54.40 ± 3.82^{a} (7.41)	21.71	<0.0001
Post maturity	27.96 ± 3.86^{a} (5.33)	8.66 ± 0.97^{b} (3.02)	0.50 ± 0.11^{c} (1.00)	86.44	<0.0001	19.2 ± 1.19^{c} (4.44)	26.40 ± 2.50^{b} (5.19)	40.20 ± 3.63^{a} (6.38)	17.49	<0.0001
Overall mean	5.00 ± 0.75^{c} (2.31)	17.00 ± 1.78^{b} (4.18)	54.00 ± 5.31^{a} (7.38)	81.97	<0.0001	6.89 ± 0.65^{c} (2.72)	13.00 ± 1.00^{b} (3.67)	40.40 ± 2.62^{a} (6.40)	161.40	<0.0001

The values in the parenthesis are √X+0.5 transformed. Different lowercase letters in rows represent statistically significant differences at α=0.05 across three transplanting dates.

per hill) (P<0.0001) (Table 1). Significant difference in mean BPH population was observed among the three transplantings at all phenological stages, where highest population was observed in late transplanting across all phonological stages (P<0.0001) (Table 1). At milking stage, seasonal highest BPH population was recorded in late transplanting (131.00±8.30 per hill), whereas early and normal transplanting were recorded with 2.58±0.32 and 25.9±1.75 per hill respectively (Table 1).

Population dynamics studies on spiders were also conducted in relation to phenological stages and transplanting time. In early transplanting spider population increased from tillering (0.88±0.10 per hill) to post maturity stage (2.04±0.15 per hill). Similarly in normal transplanting, it increased from tillering (0.64±0.07 per hill) to dough stage (2.32±0.17 per hill). In case of late transplanting, spider population increased from tillering (0.92±0.11 per hill) to milking stage (3.10±0.57 per hill) that however reduced during further stages i.e. dough (1.24±0.14 per hill) and post maturity (1.52±0.22 per hill) (Table 2). There was significant difference in overall mean spider population between early (1.41±0.05 per hill) and late transplanting (1.87±0.11 per hill) (*P*=0.006) but no difference was observed between early and normal transplanting (*P*=0.322) and between normal and late transplanting (*P*=0.192). There was no significant difference in spider population at initial stages such as tillering (*P*=0.149) and booting (*P*=0.336), but from heading to milking satge, significant differences were observed. At dough and post maturity stages, respectively, significantly maximum number of spiders were reported from normal transplanting (2.32±0.17 per hill and 2.28±0.27 per hill) followed by early (1.56±0.12 per hill and 2.04±0.15 per hill) and late transplanting (1.24±0.14 per hill and 1.52±0.22 per hill) (*P*<0.0001) (Table 2).

During 2022, spider population increased from tillering (0.90±0.10 per hill) to post maturity stage (2.46±0.28 per hill) in early transplanting. Similarly, in normal and late transplanting, respectively, it increased from tillering (0.80±0.13 per hill and 1.12±0.18 per hill) to dough stage (2.72±0.20 per hill and 3.46±0.16 per hill) (Table 2). In 2022 also, a significant difference was observed between early (1.71±0.08 per hill), normal (1.86±0.07 per hill) and late (2.38±0.08 per hill) transplantings (*P*<0.0001), but there was no significant difference between early and normal transplanting (*P*=0.317). There was no significant difference in spider population up to anthesis stage in all

Table 2 Spider population (mean±SE) under three transplanting dates during *kharif*, 2021 and 2022

Crop stage	2021					2022				
	Early (Spider per hill)	Normal (Spider per hill)	Late (Spider per hill)	F value	*P* value	Early (Spider per hill)	Normal (Spider per hill)	Late (Spider per hill)	F value	*P* value
Tillering	0.88 ± 0.10 (1.17)	0.64 ± 0.07 (1.14)	0.92 ± 0.11 (1.27)	1.92	0.149	0.90 ± 0.10 (1.18)	0.8 ± 0.13 (1.14)	1.12 ± 0.18 (1.27)	0.8568	0.426
Booting	1.32 ± 0.11 (1.26)	1.10 ± 0.11 (1.26)	1.46 ± 0.16 (1.37)	1.09	0.336	1.08 ± 0.12 (1.26)	1.16 ± 0.20 (1.29)	1.38 ± 0.18 (1.37)	0.924	0.399
Heading	1.34 ± 0.08[b] (1.35)	1.48 ± 0.16[b] (1.40)	2.52 ± 0.21[a] (1.73)	13.57	<0.0001	1.66 ± 0.18 (1.47)	1.52 ± 0.11 (1.42)	1.90 ± 0.20 (1.55)	0.62	0.539
Anthesis	1.26 ± 0.11[b] (1.32)	1.40 ± 0.10[b] (1.37)	2.32 ± 0.17[a] (1.67)	18.52	<0.0001	1.82 ± 0.19 (1.52)	2.04 ± 0.20 (1.59)	2.34 ± 0.19 (1.69)	1.88	0.155
Milking	1.50 ± 0.09[b] (1.41)	1.98 ± 0.21[b] (1.57)	3.10 ± 0.57[a] (1.89)	7.56	0.0007	1.92 ± 0.18[b] (1.56)	2.30 ± 0.21[b] (1.67)	3.24 ± 0.25[a] (1.93)	9.589	0.0001
Dough	1.56 ± 0.12[b] (1.43)	2.32 ± 0.17[a] (1.67)	1.24 ± 0.14[b] (1.31)	15.19	<0.0001	2.10 ± 0.23[c] (1.61)	2.72 ± 0.20[b] (1.79)	3.46 ± 0.16[a] (1.99)	13.9	<0.0001
Post maturity	2.04 ± 0.15[a] (1.59)	2.28 ± 0.27[a] (1.66)	1.52 ± 0.22[b] (1.42)	5.47	0.0051	2.46 ± 0.28[b] (1.72)	2.48 ± 0.20[b] (1.73)	3.24 ± 0.14[a] (1.93)	6.114	0.0028
Overall	1.41 ± 0.05[b] (1.38)	1.60 ± 0.07[ab] (1.44)	1.87 ± 0.11[a] (1.54)	5.04	<0.0066	1.71 ± 0.08[b] (1.49)	1.86 ± 0.07[b] (1.54)	2.38 ± 0.08[a] (1.70)	18.2	<0.0001

The values in the parenthesis are √X+0.5 transformed. Different lowercase letters in rows represent statistically significant differences at α=0.05 across three transplanting dates.

the transplanting. From milking to post maturity stage, significant differences were observed, where high spider population was found in late transplanting compared to early and normal transplanting, but there was no significant difference between early and normal transplanting except dough stage (Table 2). Yadav *et al.* (2017) also reported increasing trend of spider population during crop growing period from 15 days after transplanting (DAT) to 90 days after transplanting (DAT). Increasing trend in spider population with crop age could be due to high prey availability as reported earlier too (Kumar *et al.* 2020).

Two-way ANOVA was performed to analyze the effect of crop phenology and transplanting time on incidence of BPH and spider population. The results revealed a statistically significant interaction between crop phenology and transplanting time of rice crop on the occurrence of BPH in both 2021 and 2022 ($F_{(12, 1029)}$ = 264.50, *P*<0.0001; $F_{(12, 1029)}$ = 86.09, *P*<0.0001, respectively) (Table 3). The result indicated that BPH population depended on transplanting time and crop phenology, where high BPH population was observed in late transplanting rice at heading stage (225.60±18.83 per hill) but in normal transplanting at milking stage (60.04±6.70 per hill) and in early transplanting at post maturity stage (27.96±3.86 per hill) following a decreasing trend (Table 1). Similar pattern was observed in 2022 too, where peak BPH population was observed at

Table 3 Two-way ANOVA showing interactive effect of crop phenology and transplanting date on BPH and spider in *kharif*, 2021 and 2022

Year	2021					2022				
BPH	SS	DF	MS	F value	*P* value	SS	DF	MS	F value	*P* value
Phenological stages	2551	6	425.1	177.1	<0.0001	4461	6	743.6	539.1	<0.0001
Transplanting dates	1662	2	831.0	346.30	<0.0001	2253	2	1126	816.7	<0.0001
Phenological stage × Transplanting date	7616	12	634.7	264.50	<0.0001	1425	12	118.7	86.09	<0.0001
Residual	2469	1029	2.400			1419	1029	1.379		
Spider										
Phenological stages	15.63	6	3.52	23.82	<0.0001	53.96	6	8.993	46.41	<0.0001
Transplanting dates	1.82	2	0.90	6.16	0.0022	8.955	2	4.477	23.11	<0.0001
Phenological stage × Transplanting date	15.63	12	1.30	8.82	<0.0001	4.193	12	0.3494	1.803	0.0433
Residual	152.00	1029	0.15			199.4	1029	0.1938		

SS, Sum of squares; DF, Degrees of freedom; MS, Mean square.

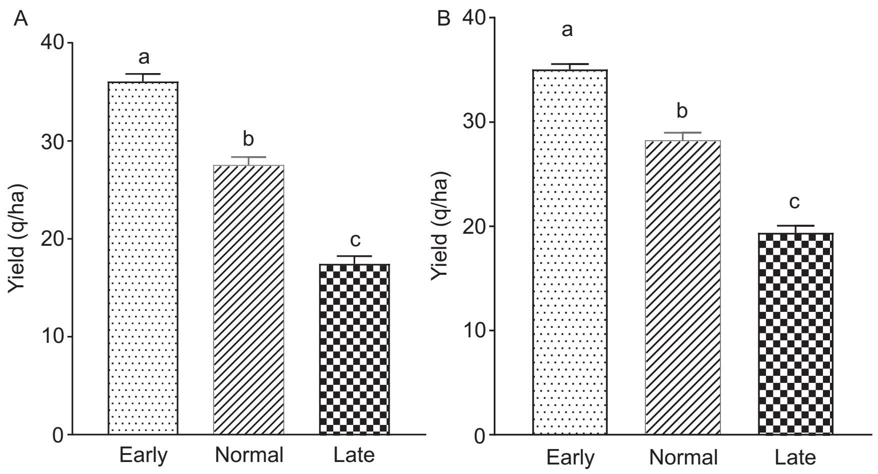

Fig. 1 Grain yield (q/ha) of three transplanting dates of rice in 2021 (A) and 2022 (B). Different lowercase letters indicates statistically significant differences at α=0.05 across three transplanting dates.

different phenological stages for three transplanting dates (Table 1). The peak incidence of BPH from early stages of crop led to heavy damage of crop thereby causing a significant reduction in the yield. Similarly, a two-way ANOVA for spiders revealed statistically significant interaction between crop phenology and transplanting time on occurrence of spiders in both 2021 and 2022 ($F_{(12, 1029)}$ = 8.82, $P<0.0001$; $F_{(12, 1029)}$ = 1.803, $P<0.0433$ respectively) (Table 3). This might be due to change in BPH population with different phenological stages at three transplanting times, which serve as the major prey in rice ecosystem.

A statistical significant yield reduction was observed among the all three transplanting times in both 2021 and 2022 respectively, wherein early transplanted rice had highest yield (36.08 ±0.75 and 35.06±0.49 q/ha), compared to normal (27.53±0.80 q/ha and 28.22±0.75 q/ha) and late transplanting (17.43±0.82 and 19.37±0.67q/ha) ($P<0.0001$) (Fig. 1A and Fig. 1B). In 2021, a yield reduction of 51.67% in late transplanting and 23.68% in normal transplanting were observed when compared with early transplanting. Similarly, in 2022, 44.75% yield loss was observed in late transplanting and 19.49% yield loss in normal transplanting compared to early transplanting. The higher yield in early transplanted rice is due to the escape of peak BPH attack by completing grain deveoplment stages before favourable conditions arrive for BPH. Earlier, early sowing or early planting have been found to escape peak pest population in many crops against several pests (Chander and Mohan 2020, Sahu and Samal 2020).

Insect pests and their natural enemy population are influenced by weather and crop phenology. In the present study, it was found that late transplanting harboured more number of BPH and the generalist predator, spiders. Besides, peak BPH infestation was observed during reproductive stages such as heading and milking stage of late transplanted rice, which could cause severe yield loss. In early transplanted rice, maximum BPH population was observed at post maturity stage, that too in very less number compared to peak BPH population in late transplanted rice crop. Hence, early transplanting is recommended to escape peak BPH population at crucial phenological stages for higher yield.

REFERENCES

Alam S. 1972. 'Population dynamics of the common leafhopper and planthopper pests of rice'. Ph.D Thesis, Cornell University, Ithaca, Newyork, USA.

Chander S and Mohan B. 2020. Effect of planting date of rice on brown planthopper. *Indian Journal of Entomology* **82**(2): 277–79.

Hafizal M M and Idris A B. 2013. Field population abundance of leafhopper (Homoptera: Cicadelidae) and planthopper (Homoptera: Delphacidae) as affected by rice growth stages: *(In) Proceedings of AIP Conference,* American Institute of Physics, pp. 359–62.

Hu G, Lu F, Zhai B P, Lu M H, Liu W C, Zhu F, Wu X W, Chen G H and Zhang X X. 2014. Outbreaks of the brown planthopper *Nilaparvata lugens* (Stal) in the Yangtze river delta: Immigration or local reproduction? *PLoS ONE* 9. e88973. doi:10.1371/journal.pone.0088973

Kumar A, Singh R S, Kripa Shankar, Vikrant and Devendra Singh. 2020. Population dynamics of major insect-pest and natural enemies on maize crop. *International Journal of Current Microbiology and Applied Sciences* **9**(02): 1299–1307.

Mangalgikar P and Harsur M. 2012. Incidence of Brown Planthopper (BPH) *Nilaparvata lugens* Stal. (Delphacidae: Hemiptera) in relation to age of the rice Crop. *International Journal of Agricultural Science* **3**(3): 197–200.

Moldenhauer K and Slaton N. 2004. Rice growth and development. *Rice Production Handbook*, pp. 7–14. Slaton N A (Eds.). Cooperative Extension Service, Division of Agriculture, University of Kansas.

Prasannakumar N R and Chander S. 2014. Weather-based brown planthopper prediction model at Mandya, Karnataka. *Journal of Agrometeorology* **16**(1): 126–29.

Sahu B K and Samal I. 2020. Pest complex of Cucurbits and their management: A review. *Journal of Entomology and Zoology Studies* **8**(3): 89–96.

Sawada H, Kusmayadi A, Gaib Subroto S W and Suwardiwijaya E. 1993. Comparative analysis of population characteristics of the brown planthopper, *Nilaparvata lugens* (Stal), between wet and dry rice cropping seasons in west Java, Indonesia. *Researches on Population Ecology* **35**: 113–37.

Win S S, Muhamad Awang R, Mior Ahmad Z A and Adam N A. 2010. Population fluctuations of brown plant hopper *Nilaparvata lugens* and white backed plant hoper *Sogatella furcifera* on rice. *Journal of Entomology* **8**: 183–190.

Yadav M, Goswami T N and Ray S N. 2017. Study of seasonal variations in population dynamics of spider families in paddy agro-ecosystem, Sabour, Bhagalpur, Bihar, India. *International Journal of Agricultural Science and Research* **7**(4): 479–84.

Zhong-Xian L, Villareal S, Xiao-ping Y U, Heong K L and Cui H U. 2006. Biodiversity and dynamics of planthoppers and their natural enemies in rice fields with different nitrogen regimes. *Rice Science* **13**(3): 218.