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Antibiosis and tolerance of certain elite rice genotypes against brown Planthopper *Nilaparvata lugen*s (Stal.)

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Abstract
Thirteen elite rice genotypes were evaluated for their antibiosis and tolerance resistance mechanisms against Brown Planthopper, *Nilaparvata lugen*s under polyhouse conditions using standard susceptible (TN1) and resistant checks (PTB-33). Nymphal survival, nymphal developmental period and growth index were studied under antibiosis mechanism of resistance while days to wilt was studied under tolerance mechanism. Among the thirteen rice genotypes significant lowest nymphal survival of 40.0 per cent was recorded in rice genotypes RNR-26111 and RNR-21571 followed by RNR-23079 and KNM-2305 (43.33%) which were slightly above resistant check PTB-33(36.67%). Highest nymphal developmental period was recorded in RNR-23079 (17.66 days) followed by RNR-21571 and MTU-1010(17.33 days). RNR-26111 and KNM-2305 which recorded lowest nymphal survival also recorded slightly lowest nymphal developmental period (16.33 days) compared to RNR-23079. The resistant check PTB-33 recorded significant highest nymphal developmental period of 20.33 days while the genotype MTU-1010 with 17.33 days was on par with PTB-33. Lowest growth index of 2.09 was recorded on PTB-33 indicating unsuitability of the cultivar for growth and development of BPH followed by RNR-23079 (2.43), RNR-26111 (2.45), MTU-1010 (2.58), KNM-2305 (2.67), RNR-21571 (2.77) and KNM-2307 (2.78). The measure of tolerance of rice genotypes which was based on days to wilt of the BPH infested plants showed among the six rice genotypes which showed good antibiosis mechanism only four genotypes *viz.,* RNR-23079 and RNR-26111 MTU-1010, and KNM -2305 possessed good tolerance against BPH and these genotypes took maximum of 30 and 27 days to wilt which was on par with the resistant check, PTB-33.

Keywords: Antibiosis, BPH, resistance

Introduction
Rice is a major staple food grain as well as a major source of carbohydrate and energy in the daily diet of an average Indian and demand for rice is likely to increase with an ever growing population of the country. More than 90 per cent of the world's rice is grown and consumed in Asia where 60 per cent of the global population lives. It is cultivated in about 154 million hectares annually which is equivalent to 11 per cent of the world's cultivated land. Rice is affected by more than hundred insect pests of which twenty are economically important and brown plant hopper is one among them (Prakash *et al.*, 2007) [15]. The brown Planthopper, is a phloem-sap-sucking insect pest of rice with its nymphs and adults suck sap from the lower portion of the plant, resulting in yellowing of leaves, reduction in tiller number, plant height, and finally chaffy grains (Sogawa, 1982) [22]. Feeding also causes reduction in chlorophyll and protein content of leaves followed by reduced rate of photosynthesis, in case of severe attack, it causes extensive plant mortality referred to as 'hopper burn' symptom (Watanabe and Kitagawa, 2000) [27]. BPH also acts as a vector and transmits rice grassy stunt virus (GSV) and ragged stunt virus (RSV) (Khush and Brar, 1991) [10]. The international conference held in 2010 exclusively on rice planthoppers analyzed the causes and consequences of BPH outbreak in many Asian countries (IRRI, 2010). Many insecticides have been recommended for the management of this pest from time to time but blanket application of these chemicals disrupts the natural balance of rice ecosystem (Sarao and Mangat, 2014) [21]. Cultivation of resistant varieties is the better and environmentally safe alternative (Song *et al.*, 2002) [23]. Such varieties will also help in conservation of natural enemies, increasing their effectiveness (Gurr *et al.*, 2011) and minimizing the pesticide applications (Panda and Khush, 1995) [10]. Hence, breeding programme for development of BPH resistant varieties with different mode of host plant resistance is extremely important. Screening rice germplasm at global level and breeding BPH resistant rice varieties were initiated during 1970s, and several resistant varieties have been released for cultivation (Bentur *et al.*, 2011) [1].

However, resistance in many of these varieties has been overcome by virulent biotypes. Keeping this objective in mind, present experiments were conducted to study antibiosis and tolerance levels in selected elite rice genotypes with diverse genetic background so as to use them in breeding programme for development of BPH resistant varieties.

Material and Methods

Rice genotypes

Thirteen elite rice genotypes were selected from a set of 39 rice genotypes having desirable yield traits after screening through Standard Seed box Screening Technique (Heinrichs *et al.,* 1985) [6] long with resistant (PTB33) and susceptible check (TN1). Screening was conducted in the polyhouse of Rice Research center, Rajendranagar, Hyderabad. The seeds of selected cultures were soaked in water for 24 hours by placing them in petri plates containing optimum quantity of water. The water was drained out after 24 hours and the soaked seeds were kept in the same petri plate for another 24 hours to allow proper germination. The pre-germinated seeds were planted in the plastic trays of size (45 x 35 x 10 cm) filled with fertilizer enriched puddled soil. The sown seeds were covered with thin layer of soil and watered as and when required. These seedlings were used for conducting different experiments.

Insects

The source BPH population was collected from rice fields of Professor Jayashankar Telangana state Agricultural University, Rajendranagar, Hyderabad. Insects collected were continuously reared under polyhouse conditions on 30-day-old TN1 (susceptible) rice plants at the Rice Research Centre, Rajendranagar at (28 ± 2) °C, 75% ± 5% relative humidity and 14 h light/10 h dark photoperiod according to Heinrichs *et al* (1985) [6].

Antibiosis Mechanism

Nymphal survival (%)

Ten first instar nymphs were released on 45 days old potted rice plants. The pots were covered with mylar tube (4 cm × 45 cm) and muslin cloth on the top to prevent BPH escape. Each test entry was replicated thrice. Plants were observed regularly for nymphal development and the number of adults emerged were counted on daily basis. The newly emerged adults were immediately removed from the plant. The number of released nymphs that reached adult stage were recorded on each rice genotype and the per cent nymphal survival was calculated by using the following formula (Heinrichs *et al.*, 1985) [6].

$$\text{Per cent Nymphal survival} = \frac{\text{Number of adults emerged}}{\text{Number of nymphs released}} \times 100$$

Nymphal developmental period

Nymphal developmental period on selected rice genotypes along with resistant and susceptible checks was studied by releasing 20 first instar BPH nymphs on 30 days old plants which were caged in mylar film cage. The plants were observed daily for adult emergence and the number of days taken for the nymphs to reach adult stage on each rice entry was recorded (Pongprasert and Weeraput, 1979) [14].

Growth Index

Growth index of BPH on the selected entries and the resistant and susceptible checks was computed by using the data obtained from the experiments on nymphal survival and nymphal developmental period (Panda and Heinrichs, 1983) [12] as per the formula

$$\text{Growth Index} = \frac{\text{\% Nymphs survived on test culture}}{\text{Developmental period of nymphs on the test culture}}$$

Tolerance Mechanism

Days to wilt

The experiment on identification of level of tolerance for BPH in the selected rice germplasm was conducted on 30 days old potted rice plants under polyhouse conditions. Five, first instar BPH nymphs were released on potted rice plant covered with a Mylar cage and muslin cloth tightly placed with the help of rubber band. Plants were then observed daily for a period of 30 days and the number of days taken by each of the selected lines to wilt completely was recorded. The experiment was terminated after 30 days after release of nymphs and data on the lines that did not wilt at the end of the study as well as wilted lines during the period of study were recorded. The experiment was replicated thrice per treatment and their average was recorded as the average days taken to wilt.

Results and Discussion

Nymphal survival

Results on nymphal survival of BPH on selected rice genotypes indicated wide difference in the survival pattern ragging from 36.67 per cent to 73.33 per cent with lowest in the resistant check PTB 33 and highest in the susceptible check TN1 (Table 1). The nymphal survival though significantly different but slightly higher compared to resistant check PTB-33 was recorded in genotypes RNR -26111 and RNR-21571 with a survival percentage of 40.00. It was followed by genotypes RNR-23079 and KNM-2305 with little higher survival percentage of 43.33. The test entries MTU 1010, KNM 2307 and Sabita recorded similar nymphal survival percentage of 46.67 and were found to be on par with each other. The rest of the test entries *viz.,* JGL 24423, Sinnasivappu, IET 23993, RNR 25993/2 and RNR 25838 were found to show highest nymphal (50.00 to 63.33%) survival but were significantly different from each other. Testing the nymphal survival is the most direct way of measuring the antibiotic component of host plant resistance. He *et al.*, 2013 suggested that even the most resistant lines exhibited nymphal survival in the range of 30–50 per cent. Based on it the present investigation draws support that the resistant and moderately genotypes exhibit a nymphal survival of 30- 50 per cent Hence, the genotypes RNR -26111 and RNR-21571 with 40.00 per nymphal survival as well as RNR-23079 and KNM-2305 with 43.33 per cent survival can be considered as moderately resistant. However, However, Myint *et al.,* (2009) [11] suggested rarely nil nymphal survival was exhibited by few resistant or immune rice genotypes. Based on which it can be concluded that the survival rate being recorded in all the test genotypes is due to lack of acute toxins in the tested rice genotypes which acts as antibiotic factors in rice against BPH.

Nymphal Developmental Period

Nymphal developmental period is the duration of days taken by the nymphs to turn into mature adults. The results on nymphal development period varied across the rice genotypes and ranged from 12.66 in the susceptible genotypes TN1 to 20.33 days in the resistant check PTB-33. The highest nymphal development period was observed in RNR 23079 (17.66 days) followed by RNR-21571 and MTU 1010 and (17.33 days) which were on par with the resistant check – PTB-33. The other test entries MTU 1001, RNR 26111, KNM-2305, RNR 25993/2, Sabita recorded nymphal development period of 16.66, 16.33, 16.33, 16.00 and 16.00 days respectively which were on par with each other but significantly lower than that of resistant check**.** The rest of test cultures, Sinnasivappu, RNR 25838, and JGL 24423 recorded 15.66, 14.66 and 14.00 nymphal development days which were near equivalent to susceptible check TN1 that recorded lowest nymphal development period of 12.66 days.

In general in insects the nymphal or larval development period is inversely proportional availability of suitable nutrition. The better the nutritional availability the faster will be the development of the insect. The rice genotypes with different proportions of growth promoting nutritional components such as proteins, carbohydrates and vitamins as well as antifeedant secondary metabolites like phenols etc. show antibiotic effect on the insect. It is evident from the earlier reports that BPH prefers sugars like sucrose, glucose and dextrose and hence low sugar was always considered as one of the desirable qualities of a resistant plant (Samala *et al*, 1982). Sujatha *et al.* (1987) [24] indicated that protein content was negatively correlated with resistance. Vanitha *et al*. (2011) [24] reported that protein content in the basal stem of rice was higher in susceptible plants compared to resistant plants. Similarly, Grayer *et al*. (1994) [4] found higher levels of phenols in the resistant rice varieties compared to susceptible varieties and suggested their involvement in offering resistance to BPH. The phenolic compounds were found to be feeding deterrents to leaf and planthoppers and in general, resistant varieties were found to have more phenolic compounds than susceptible varieties (1979). Sable and Rana (2011) [18] working with rice genotypes reported nymphal developmental period in the range of 13.2 and 19.2 days, which was significantly higher than the susceptible check TN1 (11.1 days). Hitendra Kumar *et al*. (2012) [7] studied antibiosis mechanism against BPH in 30 rice entries with different levels of resistance and revealed that the per cent nymphal survival was significantly low, while nymphal duration was longer on resistant entries compared to susceptible check (TN1).

The results of nymphal developmental correlated with nymphal survival clearly suggests the antibiotic effect of rice genotypes RNR 23079, RNR-21571, MTU 1010 RNR 26111, and KNM-2305 on BPH.

Growth Index

Insect growth under no-choice experiment is yet another direct measurement of plant resistance influencing the life cycle of a pest. This index computes the adverse influence of a plant on insect survival and development rate. The results pertaining to the growth index of BPH on different rice genotypes show lowest growth index of 2.09 on PTB 33 indicating unsuitability of the cultivar for growth and development of BPH followed by RNR 23079 (2.43) and RNR 26111 (2.45), KNM 2305 (2.67), RNR 21571 (2.77), KNM 2307 (2.78) which were found to be on par with resistant check PTB 33. The test culture RNR 25838 recorded highest growth index value of 4.41 for BPH and was found to be on par with susceptible check, TN1 (5.90).

In the present study all the rice genotypes exhibited lower growth index for BPH than the susceptible check, TN1 (5.90) which may be due to low per cent nymphal survival and longer nymphal development period. The current study also revealed that lowest growth index was due to high level of antibiosis exhibited by the rice genotypes at different growth stages of BPH.

Thamarai and Soundararajan (2017) [25] investigated antibiosis parameters of resistance *viz.*, nymphal survival, nymphal duration and growth index on 26 rice genotypes under glasshouse conditions and recorded low survival rate of 26.67 per cent on PTB 33 and 30 per cent on cultures PY 1 and Mapillai Samba whereas prolonged developmental period of nymphs was recorded on PTB 41 (14.37 days) and Karuthakar (14.23 days).

Days to Wilt test

Tolerance is the capacity of a given plant type to produce desirable or on par yield compared to uninfested plant despite of insect infestation. To assess the level of tolerance in different rice genotypes, days to wilt test was performed and perusal of the results showed significant differences in days to wilting across the rice genotypes that ranged from 14.67 to 30.00 days. The susceptible check (TN1) succumbed to BPH attack within 14.67 days followed by KNM 2307 (24.00 days). Among the other genotypes evaluated MTU 1001, RNR 21571, KNM 2305 wilted within 25.00, 26.67, 27.00 days respectively. The resistant check, PTB33 took 30 days to wilt. The other test entries *viz.*, MTU 1010, RNR 23079, IET 23993, Sabita, Sinnasivappu, RNR 25993/2 and RNR 26111 also took 30 days for wilting which was on par with the resistant check. The results suggested that the resistant and moderately resistant rice genotypes took more time to wilt compared to susceptible genotypes. Panda and Heinrichs (1983) [12] identified rice varieties like Triveni, Kanchana and UtriRajapan with tolerance as predominant component of BPH resistance. Similarly, Geethanjali *et al.*, (2009) [2] proposed a simple test of day to wilt for tolerance parameter, which is being rapidly accepted. Qiu *et al.* (2014) [16] reported that a gene *Bph7* in rice variety T12 majorly contribute to the tolerance component of resistance against BPH. Likewise, Ramesh *et al.*, (2014) [17] suggested a major dominant gene *Wbph12*(t) to confer tolerance to WBPH in Sinnasivappu. Since tolerant trait is believed to exert less selection pressure on the insect, such gene may contribute to durable resistance. Sarao and Bentur (2016) [20] working with different rice genotypes for their tolerance to BPH also reported that rice genotypes *viz.*, PTB33 and RP2068-18-3-5 took significantly longer time for wilting compared to susceptible check TN1 and revealed that the test genotypes differed significantly with respect to days to wilt under constant pest pressure.

Summary of tolerance studies showed that among the six rice genotypes which showed good antibiosis mechanism only four genotypes *viz.*, RNR-23079 and RNR-26111 MTU-1010, and KNM -2305 possessed good tolerance against BPH and these genotypes took maximum of 30 and 27 days to wilt which was on par with the resistant check, PTB-33.

It can be concluded from these experiments, that the key mechanism of host plant resistance *i.e.*, antibiosis effect the biology of BPH in such a way that without exerting high selection pressure on pest it gradually suppress pest population on one side by reducing the number of possible generations and also increases their vulnerability to the natural enemies. The tolerance mechanism on the other way tries to survive under intense infestation providing us a larger window gap to take steps in the form of chemical insecticidal applications to manage the pest rather than getting succumbed to pest infestation and wilting in a shorter span of time giving no scope for human intervention.

The elite rice genotypes RNR-23079, RNR-26111, MTU-1010, and KNM -2305 displayed high levels of antibiosis and tolerance to BPH. This will provide better option for plant breeders and biotechnologists to develop suitable varieties to combat BPH. It is apparent from our study that development of a variety which can exhibit high levels of antibiosis and tolerance mechanisms against BPH could play a pivotal role in pest management strategies.

Table 1: Effect of different rice genotypes on Nymphal survival, Nymphal Developmental Period and Growth Index of BPH and level of tolerance exhibited by rice genotypes infested with BPH.

S. No.	Rice genotype	Antibiosis Mechanisms			Tolerance mechanism
		Nymphal survival (%)	Nymphal Developmental Period (Days)	Growth Index	Days to wilt
1	MTU 1001	56.67^{g} (13.68)	16.66^{b}	3.24^{ab}	25.00^{bc}
2	MTU 1010	46.67^{d} (12.35)	17.33^{ab}	2.58^{ab}	30.00^{a}
3	RNR 23079	43.33^{c} (11.89)	17.66^{ab}	2.43^{ab}	30.00^{a}
4	IET 23993	56.67^{g} (48.82)	14.33^{bc}	3.22^{ab}	30.00^{a}
5	JGL 24423	50.00^{e} (12.87)	14.00^{bc}	3.56^{ab}	28.33^{ab}
6	SABITA	46.67^{d} (12.41)	16.00^{bc}	3.00^{ab}	30.00^{a}
7	KNM 2307	46.67^{d} (12.41)	14.66^{bc}	2.78^{ab}	26.67^{b}
8	RNR 21571	40.00^{b} (11.47)	17.33^{ab}	2.77^{ab}	24.00^{bc}
9	SINNA SIVAPPU	53.33^{f} (13.29)	15.66^{bc}	3.48^{ab}	30.00^{a}
10	RNR 25838	63.33^{h} (14.43)	14.66^{bc}	4.41^{bc}	29.67^{ab}
11	RNR 25993/2	60.00^{g} (14.14)	16.00^{bc}	3.74^{b}	30.00^{a}
12	RNR 26111	40.00^{b} (11.47)	16.33^{bc}	2.45^{ab}	30.00^{a}
13	KNM 2305	43.33^{c} (11.99)	16.33^{bc}	2.67^{ab}	27.00^{ab}
14	PTB 33	36.67^{a} (10.95)	20.33^{a}	2.09^{a}	30.00^{a}
15	TN 1	73.33^{i} (15.67)	12.66^{cd}	5.90^{bc}	14.67^{c}
	C.D.	2.09 (2.768)	3.43	1.60	3.84
	SE(m)	0.72	1.18	0.55	1.32
	SE(d)	1.02	1.67	0.78	1.86
	C.V.	25.12	12.95	29.57	8.10

*Values in the parenthesis are angular transformed

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References

1. Bentur JS, Padmakumari AP, Lakshmi VJ, Padmavathi Ch, Kondala YR, Amudhan S *et al*. Insect Resistance in Rice. Technical Bulletin, Hyderabad, India: Directorate of Rice Research 2011, 15.
2. Geethanjali S, Kadirvel P, Gunathilagaraj K, Maheswaran M. Detection of quantitative trait loci (QTL) associated with resistance to white backed planthopper (*Sogatella furcifera*) in rice (*Oryza sativa* L.). Plant Breeding 2009;128:130-136.
3. Gurr GM, Liu J, Read DMY, Catindig JLA, Cheng JA, Lan LP *et al*. Parasitoids of Asian rice planthopper (Hemiptera: Delphacidae) pests and prospects for enhancing biological control by ecological engineering. Annals of Applied Biology 2011;158:149-176.
4. Grayer RJ, Kimmins FM, Stevenson PC, Harborne JB, Wijayagunesekera HNP. Phenolics in rice phloem sap as sucking deterrents to the brown planthopper (*Nilaparvata lugens*). Acta Hortic 1994;381:391-394.
5. He J, Liu Y, Jiang L, Wu H, Kang H, Liu S *et al*. High-resolution mapping of brown planthopper (BPH) resistance gene Bph27(t) in rice (*Oryza sativa* L.). *Molecular Breeding*. 2013;31:549-557.
6. Heinrichs EA, Medrano FD, Rapusas HR. *Genetic Evaluation for Insect Resistance in rice*. In: Heinrichs E. A., Rapusas H and Medrano F. (eds) International Rice Research Institute, Los Banos, Philippines 1985, 1-356.
7. Hitendra kumar, Maurya RP, Tiwari SN. Study on antibiosis mechanism of resistance in rice against brown planthopper, *Nilaparvta lugens* (Stal.). Annals of Plant Protection Sciences 2012;20(1):98-101.
8. International Rice Research Institute. 2010. Annual Report for 2009.
9. International Rice Research Institute, Los Banos, Philippines.
10. Khush GS, Brar DS. Genetics of resistance to insects in crop plants. *Advances in Agronomy*. 1991;45:223-274.
11. Myint KKM, Hideshi Y, Masami T, Masaya M. Virulence of long-term laboratory populations of the brown planthopper, *Nilaparvata lugens* (Stål) and white backed planthopper, *Sogatella furcifera* (Horváth) (Homoptera: Delphacidae), on rice differential varieties. Applied Entomology and Zoology 2009;44:149-153.
12. Panda N, Heinrichs EA. Levels of tolerance in rice varieties having moderate resistance to the brown planthopper, *Nilaparvata lugens*. Paper presented at the International Rice Research Institute Saturday Seminar, 1983.
13. Panda N, Khush GA. Host Plant Resistance to Insects. CAB International, Wallingford, Oxon, UK 1995, 413.
14. Pongprasert S, Weerapat P. Varietal resistance to the brown planthopper in Thailand. In Brown planthopper: Threat to rice production. *International Rice Research Institute Newsletter*. Las Banos. Philippines 1979, 273-283.
15. Prakash A, Rao J, Singh ON, Tyagi JP, Singh S, Rath PC.

Rice: the Queen of Cereals. Cuttack, India: Applied Zoologist Research Association Publication 2007, 1-215.
16. Qiu YF, Guo JP, Jing SQ, Zhu LL, He GC. Fine mapping of the rice brown planthopper resistance gene Bph7 and characterization of its resistance in the 93-11 background. Euphytica 2014;198(3):369-379.
17. Ramesh K, Padmavathi G, Deen R, Pandey MK, Jhansi Lakshmi V, Bentur JS. White backed planthopper *Sogatella furcifera* (Horváth) (Homoptera: Delphacidae) resistance in rice variety Sinna Sivappu. Euphytica. 2014;200:139-148.
18. Sable MG, Rana DK. Study on antibiosis mechanism of resistance to BPH (*Nilaparvata lugens* Stal.) on resistant rice genotypes. Journal of Soils and Crops 2011;21(2):196-202.
19. Samal P, Misra BC, Lodh SB. Biochemical basis of resistance in rice to brown plant hoppers. Oryza 1982;19:58-59.
20. Sarao PS, Bentur JS. Antixenosis and Tolerance of Rice Genotypes against Brown Planthopper. Rice Science. 2016;23(2):96-103.
21. Sarao PS, Mangat GS. Manage rice insect-pests to get higher crop yield. Progressive Farming 2014;50:4-6.
22. Sogawa K. The rice brown Planthopper: Feeding physiology and host plant interactions. Annual Review of Entomology 1982;27:49-73.
23. Song XL, Qiang S, Liu LL, Xu YH, Liu YL. Gene flow of pollen cross between *Oryza officinalis* and transgenic rice with bar gene. Journal of Nanjing Agriculture University 2002;25:5-8.
24. Sujatha G, Reddy GPV, Murthy MMK. Effect of certain biochemical factors in the expression of resistance of rice varieties to brown Planthopper (*Nilaparvata lugens*). Journal of Research APAU 1987;15(2):124-128.
25. Thamarai M, Soundararajan RP. Reaction of Rice genotypes against specific population of brown planthopper, *Nilaparvata lugens* (Stal.). Annals of Plant Protection Science 2017;25(1):74-77.
26. Vanitha K, Suresh S, Gunathilagaraj K. Influence of brown planthopper *Nilaparvava lugens* (Stal.) feeding on nutritional biochemistry of rice plant. Oryza. 2011;48(2):142-146.
27. Watanabe T, Kitagawa H. Photosynthesis and translocation of assimilates in rice plants following phloem feeding by the Planthopper *Nilaparvata lugens* (Homoptera: Delphacidae). Journal of Economic Entomology 2000;93:1192-1198.