Screening and Inheritance Study of F$_1$, F$_2$ and F$_3$ Population for Brown Planthopper Resistant in Rice (*Oryza sativa* L.)

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A B S T R A C T

Observations on parent lines, F$_2$ and F$_3$ lines were recorded when the susceptible check, TN1 shown complete susceptibility to BPH. Scoring for BPH reaction was done following the guidelines of Standard Evaluation System for Rice (IRRI, 1998). The male parent IR64 showed resistance to BPH with score 1.33 where as the female parent CG Zn Rice I showed susceptibility with a score of 9.0, the female parent Muskan showed susceptibility with a score of 6.7 and another female IET22290 showed susceptibility with a score of 7.0 under glasshouse conditions. The resistant check, PTB33 showed complete resistance with a score of 0, and susceptible check, TN1 exhibited complete susceptibility with 9 as score.

Genetics of BPH resistance in F$_2$ and F$_3$ population derived from CG Zn Rice I x IR64 for BPH resistance show Mendelian segregation. They show 3:1 and 1:2:1 segregation ratio in F$_2$ and F$_3$ respectively possess only single dominant gene for resistance which is indicated by 3:1 (3 resistant: 1 susceptible) segregation observed in F$_2$ generation. This is also supported by F$_1$ showing resistance and classification of F$_3$ progenies in the ratio of 1: 2: 1 (1 breeding true for resistance: 2 segregating for resistance and susceptibility: 1 breeding true for susceptibility). This confirmed the inheritance of a single dominant gene present in these resistant parent IR64.

Keywords: BPH screening, Chi-square, F$_1$ population, F$_2$ population, F$_3$ population and Rice

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Introduction

Rice (*Oryza sativa* L.) is the food source for billions of people in the world (Normile, 2008), which rely on this crop for more than 20% of daily calorie intake (IRRI, Africa Rice and CIAT, 2010). To guarantee global food security for continuing population expansion it is crucial to control the different insect pests that harm rice crop (Normile, 2008) leading to influential and unpredictable decrease of yield (Jairin et al., 2007). The Brown planthopper (BPH), *Nilaparvata lugens* Stål, is one of the most important devastating insects in Asia.
where rice is widely produced (Hu et al., 2014). The BPH obtains the nutrients from the phloem sap of rice plant through its stylet mouth parts (Huang et al., 2001). So the heavy infestation of BPH causes complete drying of plants to the field known as “hopperburn”, whereas the light infestation reduces growth vigor, plant weight and number of productive tillers (Sogawa, 1982). Popular varieties are almost susceptible to BPH and control methods are dependent on insecticides, which is expensive in terms of demanding more labor, money and unfavorable environmental effects (Tanaka, 2000; Heinrichs et al., 1982). Several sprayings upset natural balance between the BPH and its natural enemies enhancing, in the other side, its resistance to insecticides, which lead to BPH resurgence (Heinrichs and Mochida, 1984). To grow genetically rice resistant variety is seen as the most economical and affective method for controlling the BPH.

IR64 is a semi dwarf indica rice variety, with average mature plant height of approximately 100 cm in the Philippines. It is a relatively early duration variety, with total growth duration of about 117 days (Khush and Virk, 2005). It inherits the same semidwarf sd1 allele as other IRRI semi dwarf varieties, ultimately derived from Dee-geo-woo-gen.

According to Wei et al., (2016) it has the loss of function alleles for Hd1 and Ehd1, which confer earlier duration and insensitivity to photoperiod. At the time of its release, IRRI (1986) listed the valuable traits as resistance to brown planthopper (BPH) biotypes 1 and 3. IR64 has relatively durable resistance to BPH, and it is known to carry the major gene Bph1. However, it is reported to have better resistance than other varieties carrying Bph1 and has good field resistance to the pest, exhibiting antibiosis, antixenosis and tolerance (Cohen et al., 1997). This is partly attributed to its possessing additional QTLs controlling BPH resistance which confer greater durability of the resistance (Alam and Cohen, 1998). It is also relatively sensitive to Zn deficiency (Impa et al., 2013). The excellent grain quality of IR64 has become the standard for rice quality requirements in a number of countries. Because of its popularity with farmers, IR64 has been used widely as a parent in rice breeding, as a recipient of new genes through marker-assisted backcrossing and genetic transformation and as a standard check for basic studies by many rice researchers.

Materials and Methods

Identification and monitoring of functional resistance genes over the years

Three different crosses are made between 1. CG Zn Rice I × IR64, 2. Muskanx IR64 and 3. IET2290 × IR64. Total 11 crosses were made viz., 5 crosses from CG Zn Rice I × IR64, 3 crosses from Muskan x IR64 and 3 crosses IET2290 × IR64. 2105 plants taken from F1 population and advanced to F2 population. A set of 2105 progenies were selected in F3 generation.

The crosses were made between CG Zn Rice I and IR64 where CG Zn Rice I is as female parent and IR64 is used as a male parent. IR64 shows the resistant character in Chhattisgarh region while CG Zn Rice I shows susceptibility. Susceptible checks viz., TN1, CG Zn Rice I, IET22290 and Muskan along with two resistant checks viz., PTB33 and IR64 were screened against brown plant hopper population in glass house condition of the Department of Entomology, College of Agriculture, Raipur during Kharif 2018, 2019 and 2020. Variation in the reactions of these populations over the years was expected to give an insight to the stability of resistance possessed.
Inheritance studies

All the F₁ seeds of the crosses made during Kharif 2017 were used for advancing the generation from F₁ to F₂. All the F₂ seeds of each cross obtained from individual F₁ plants were grown in Kharif 2018 for advancing the generation. The number of progenies tested for each cross is given in Table 1. Out of 2105 plants of F₂ generation, 2105 plants F₃ panicles were harvested in two sets for future study purpose. Seeds from single panicle were used in glasshouse for screening purpose in two seasons (2019 and 2020) and same panicle seeds were used in field for sowing purpose to know the morphological characters as well as for molecular study in the laboratory. The F₂ and F₃ seeds were screened against the brown plant hopper during Summer 2019 and 2020 respectively and genetic ratio was worked out on F₂ and F₃ data. The 2105 plants of F₂ and 2105 plants of F₃ generation were screened in glass house is given in Table 1. In F₃ generation each plant was screened against BPH and confirmation of the genetic ratio obtained in F₂ was ascertained. For morphological and molecular purpose CG Zn Rice I x IR64 cross plants were studied.

Screening procedure

Insect rearing

In the study standard seed box technique was used as described by IRRI (Pathak and Khush, 1977) to rear the BPH. The source insects were collected from the field and continuously reared in greenhouse for screening purpose that infested cultivated variety of rice in the field in Raipur (CG). The insects were reared on 40 to 50 day sold rice plants (susceptible variety TN1) inside a 0.5 × 0.5 × 1.0 m cage. This cage consisted of a steel frame covered with a fine mesh wire screen. The cage bottom was open and setting in water. Potted plants were changed as needed. Each cage could accommodate several potted plants that could support 2,000 to 3,000 late-instar BPH nymphs. The original colony per cage was started by 30–40 gravid adults. Eggs of about the same day age were obtained by placing the plants in a cage with gravid adults for two days. Screening for resistance to the BPH was conducted at the seedling stage in the greenhouse. The screening procedures standardized at IRRI and described by Heinrichs et al., (1985) were adopted in this study. A row of the susceptible check variety (TN1) and a resistant check variety (PTB33) was planted in a proper sequence in the seed boxes. At the sixth day after seeding, plants were thinned to 20 to 30 seedlings per row. The seed boxes were placed upon water inside a screened room in the glasshouse. To provide suitable humidity for insect survival and avoid the disturbance of watering on the tested insects, we maintained a depth of about 5 cm standing water in the tray. Screening of rice lines were conducted, under controlled conditions of glass house, as per methodology suggested by Kalode and Krishna (1979). The test and check varieties were pre germinated in petri dishes and these germinated seeds were transferred to wooden boxes of size 60 x 40 x 10 cm, containing well mixed homogeneous soil. Each seed box contained 24 test lines with 20 seedlings of each including two middle rows of resistant check (PTB33) and susceptible check (TN1) and four border rows of susceptible check (TN1). The boxes were covered so as to enhance seedling growth. After sowing the seed boxes were placed on cemented platform with 6-8 cm border and 3-4 inches water level to provide adequate humidity for the insects and protection against ants.

The seedlings were infested at the one to two leaf stage (about 7 days after seeding) by uniformly scattering a large number of 2nd to 3rd instar BPH nymphs on them. The seed boxes were covered with nylon nets after
infestation. An average of 5–7 insects per seedling constituted an optimum population to differentiate the resistant level of tested lines. The damage rating was taken when about 90% of the plants of the susceptible check variety were killed, usually about 5 to 7 days after infestation. The varieties were rated using the standard evaluation system for rice (IRRI 1988). We first conducted an initial evaluation of 2105 F2plants. The 2105 plants whose resistance fell into grade 0 to 5 as well as 5 to 9 were selected for further evaluation, using the same technique. All of the screening was conducted in Raipur (CG) during the period 2019 and 2020 Summer season.

**Recording of observations**

During the process of slowly moving the potted plants over the boxes, the dropped nymphs were visually estimated to drop approximately 8–10 nymphs onto each seedling. Thereafter, the boxes were returned to the cages individually. Observations were recorded 7-10 days after releasing insects, when 90% of the plants in the susceptible check line TN1 were killed. The entries were scored for damage following the criteria for scoring the damage of individual plants. When the TN1 seedlings in a box had become completely wilted due to plant hopper feeding, the tests were terminated and the damage to all seedlings in a box was scored according to Horgan *et al.*, (2015) (Table.2), where higher scores indicated greater susceptibility to BPH.

**Analysis and interpretation of results**

Plants showing score of 0 were rated as immune, 1 as resistant (HR), 3 as resistant (R), 5 as moderately resistant (MR), 7 as susceptible (MS) and 9 as highly susceptible (S), (IRRI, 1996). In F1 and F2, plants were individually scored. The F3 progenies were classified as breeding true for resistance (all plants in the line being resistant), segregating (both resistant and susceptible occurring) or breeding true for susceptibility (all plants in the line being susceptible). The reaction of F1 indicated the dominance or recessive nature of the resistance gene(s) involved in resistant parent IR 64.

**Results and Discussion**

**Phenotyping of Parents along with advanced population F2 and F3**

In this study, 2105 F2 plants along with parents and two checks *i.e.*, TN1 (susceptible) and PTB33 (resistant) were evaluated for BPH reaction under glasshouse condition at IGKV, Raipur during 2018-2019. F2 population of three crosses were made. Cross first that was made between CG Zn Rice I x IR64 had 753 plants, Cross second that was made between Muskan x IR64 had 563 plants and cross third that was made between IET22290 x IR64 had 789 plants. From 2105 F2 plants, two panicles were harvested and kept in two individual packets. The seeds of individual panicles were used for the screening and molecular purpose. So the 2105 plants along with parents (CG Zn Rice I and IR64) and two checks *i.e.*, TN1 (susceptible) and PTB33 (resistant) were evaluated for BPH reaction under glasshouse condition at IGKV, Raipur during 2019-2020. For phenotypic screening all 2105 lines of F3 populations of three crosses were used to screen against know the BPH resistance.

**Scoring of BPH resistance**

Observations on parent lines, F2 and F3 lines were recorded when the susceptible check, TN1 shown complete susceptibility to BPH. Scoring for BPH reaction was done following the guidelines of Standard Evaluation System for Rice (IRRI, 1998). The male parent IR64 showed resistance to BPH with score 1.33 whereas the female parent CG Zn Rice I showed susceptibility with a score of 9.0, the
female parent Muskan showed susceptibility with a score of 6.7 and another female IET22290 showed susceptibility with a score of 7.0 under glasshouse conditions. The resistant check, PTB33 showed complete resistance with a score of 0, and susceptible check TN1 exhibited complete susceptibility with 9 as score.

Classification of the 2105 F₂ individuals of cross I (CG Zn Rice I x IR64), based on BPH reaction indicated that 552 fell into the resistant class and 201 plants were in the susceptible class (Fig. 1). Classification of the 2105 F₂ individuals of cross II (Muskan x IR64), based on BPH reaction indicated that 414 fell into the resistant class and 149 plants were in the susceptible class (Fig. 2). Classification of the 2105 F₂ individuals of cross III (IET22290 x IR64), based on BPH reaction indicated that 602 fell into the resistant class and 187 plants were in the susceptible class (Fig. 3). Classification of the 2105 F₃ individuals of cross I (CG Zn Rice I x IR64), based on BPH reaction indicated that 289 fell into the resistant class, 370 fell in to segregating and 94 plants were in the susceptible class (Fig. 4). Classification of the 2105 F₃ individuals of cross II (Muskan x IR64), based on BPH reaction indicated that 225 fell into the resistant class, 256 fell in to segregating and 82 plants were in the susceptible class (Fig. 5). Classification of the 2105 F₃ individuals of cross III (IET22290 x IR64), based on BPH reaction indicated that 230 fell into the resistant class, 367 fell in to segregating and 192 plants were in the susceptible class (Fig. 6). Several studies reported the presence of strong quantitative resistance and involvement of polygenes for BPH resistance in rice (Soundararajan et al., 2004). All the observations suggest that BPH resistance in this population was qualitative and involve the polygenes.

**Genetical studies**

Three crosses were attempted to analyze the inheritance study of the genes involved in the resistant parents. The F₂ and F₃ population of the crosses were generated and screened against the brown plant hopper population for inheritance studies, for classification of the plants/progenies to fit the appropriate genetic ratios.

**Inheritance studies**

Inheritance studies of BPH resistance was studied on variety IR64 by carrying it with susceptible F₃ plants of CG Zn Rice I, Muskan and IET22290. The donor IR64 was crossed with three susceptible varieties i.e. CG Zn Rice I, Muskan and IET22290. Reaction of F₁, F₂ and F₃ population of above generated crosses are presented in Table.3.

**Table.1** List of crosses made, F₁ and F₂ plants harvested and populations of F₂ and F₃ screened in glass house for inheritance studies

| S.No. | Cross combinations     | Screening in glass house |
|-------|------------------------|--------------------------|
|       | F₁ Plants harvested | No. of F₂ Plants | No. of F₃ progenies |
| 1     | CG Zn Rice I x IR64  | 5             | 753            | 753            |
| 2     | Muskan x IR64        | 3             | 563            | 563            |
| 3     | IET 22290 x IR64     | 3             | 789            | 789            |
| Total |                        | 11            | 2105           | 2105           |
Table 2 Evaluation standard for rice resistance to plant hoppers based on seedling mortality (adapted from Horgan et al., 2015)

| Score | Rice damage                                                                 | Resistance level               |
|-------|------------------------------------------------------------------------------|--------------------------------|
| 0     | No damage                                                                    | Immune                        |
| 1     | Slight damage to a few plants within a row                                   | Highly resistant               |
| 3     | First and second leaves of each plant partially yellowing                    | Resistant                     |
| 5     | Pronounced yellowing or stunting of plants, or 10–25% of plants wilted within a row | Moderately resistant          |
| 7     | More than 50% of plants wilted or dead and the remaining plants severely stunted or dying | Moderately susceptible       |
| 9     | All plants wilted or dead                                                    | Susceptible                   |

Table 3 Distribution of BPH resistance among the F2 and F3 plants (Including cross I, II and III)

| Phenotypic class (Score) | CG Zn Rice I x IR64 | Muskan x IR64 | IET22290 x IR64 |
|--------------------------|---------------------|--------------|-----------------|
|                          | No. of F2 plants    | No. of F3 plants | No. of F2 plants | No. of F3 plants | No. of F2 plants | No. of F3 plants |
| Highly Resistant (1)     | 12                  | 6             | 5               | 12              | 15              | 10              |
| Resistant (1-3)          | 286                 | 283           | 211             | 213             | 351             | 220             |
| Moderately Resistant (>3-5) | 254             | 270           | 160             | 186             | 236             | 339             |
| Moderately Susceptible (>5-7) | 76               | 100           | 67              | 70              | 68              | 20              |
| Susceptible (7-9)        | 20                  | 57            | 53              | 27              | 43              | 87              |
| Highly Susceptible (9)   | 105                 | 37            | 67              | 55              | 76              | 105             |
| Total                    | 753                 | 753           | 563             | 563             | 789             | 789             |
**Table 4** Inheritance pattern of F₁, F₂ and F₃ populations of crosses resistant parents with susceptible parents in rice for BPH resistance

| S.No. | Cross Name       | Reaction of F₁ plants | Reaction of F₂ plants | Reaction of F₃ Progenies |
|-------|------------------|-----------------------|-----------------------|--------------------------|
|       |                  | No. of Plants | Expected Ratio | Chi Sq. value | Table value | No. of Progenies | Expected Ratio | Chi Sq. value | Table value |
|       |                  | R   | S   | Total | R:S | R   | Sg  | S   | Total | R:Sg:S |
| 1     | CG Zn Rice I x IR64 | R   | 552 | 201 | 753 | 3:1 | 1.197 | 3.841*-6.635** | 289 | 370 | 94 | 753 | 1:2:1 | 0.2568 | 5.991*9.210** |
| 2     | Muskan x IR64   | R   | 414 | 149 | 563 | 3:1 | 0.6055 | 3.841*-6.635** | 225 | 256 | 82 | 563 | 1:2:1 | 1.1448 | 5.991*9.210** |
| 3     | IET22290 x IR64 | R   | 602 | 187 | 789 | 3:1 | 0.6765 | 3.841*-6.635** | 230 | 367 | 192 | 789 | 1:2:1 | 1.5519 | 5.991*9.210** |

Note: R - Resistance, S - Susceptible, Sg - Segregating
** 1% level of significance * 5% level of significance
Fig. 1 Distribution pattern of BPH response for cross of CG Zn Rice I x IR64 during F$_2$ generation

![Distribution of BPH response for CG Zn Rice I x IR64 during F$_2$ generation](image1)

*BPH reaction score as per SES, IRRI, 1996

Fig. 2 Distribution pattern of BPH response for cross of Muskan x IR64 during F$_2$ generation

![Distribution of BPH response for Muskan x IR64 during F$_2$ generation](image2)
**Fig. 3** Distribution pattern of BPH response for cross of IET22290 x IR64 during F$_2$ generation

![Distribution of BPH response for IET22290 x IR64 during F$_2$ generation](image)

**Fig. 4** Distribution pattern of BPH response for cross of CG Zn Rice I x IR64 during F$_3$ generation

![Distribution of BPH response for CG Zn Rice I x IR64 during F$_3$ generation](image)
Fig. 5 Distribution pattern of BPH response for cross of Muskan x IR64 during F₃ generation

The F₁ populations of the crosses CG Zn Rice I x IR64, Muskan x IR64 and IET22290 x IR64 showed resistant reaction against the brown plant hopper population and shows presence of a single dominant gene for resistance in donor IR64. The reaction of BPH evaluated for segregation in F₂ population of the crosses CG Zn Rice I x IR64, Muskan x IR64 and IET22290 x IR64 with their respective susceptible parents was observed in a frequency of three resistant plants : one susceptible plant (3R: 1S) confirms the presence of single dominant gene in the resistant parent IR64. Further, the F₃ progenies of these crosses for each resistant parent were also analyzed for segregation pattern. Data reveals that, a segregation pattern of one homozygous
resistant: two segregating (homozygous): one homozygous susceptible, (1R: 2Sg: 1S) was observed for these crosses as expected in simple Mendelian inheritance pattern. This confirmed the inheritance of a single dominant gene present in this resistant parent IR64.

These results suggested that there was Mendelian segregation for BPH resistance in the $F_2$ and $F_3$ population. Resistance to BPH in the population appeared to be qualitative as indicated by frequency distribution of phenotypic values of $F_2$ and $F_3$ population (Ram et al., 2010).

References

Alam, S.N. and Cohen, M.B. 1998. Detection and analysis of QTLs for resistance to brown planthopper (Nilaparvata lugensStal.) in a double haploid population. Theor. Appl. Genet., 97: 1370-1379.

Cohen MB, Alam SN, Medina EB, Bernal CC. 1997. Brown planthopper, Nilaparvata lugens, resistance in rice cultivar IR64: mechanism and role in successful N. lugens management in central Luzon, Philippines. Entomol Exp Appl 85:221–229.

Heinrichs E. A., F. D. Medrano and H. R. Rapusas, 1985. In: Heinrichs E. A., Rapusas H. and Medrano F. (eds) Genetic Evaluation for Insect Resistance in rice. International Rice Research Institute, Los Banos, Philippines, pp 1-356.

Heinrichs, E. A., Reissig, W. H., Valencia, S., and Chelliliah, S. 1982. Rates and effect of resurgence-inducing insecticides on populations of Nilaparvata lugens (Homoptera: Delphacidae) and its predators. Environmental Entomology, 11(6), 1269-1273.

Heinrichs, E.A. and Mochida, O. 1984. From secondary to major pest status: the case of insecticide-induced rice brown planthopper, Nilaparvata lugens, resurgence. Protection Ecol., 7: 201-218.

Hu G, Lu F, Zhai BP, Lu MH, Liu WC, Zhu F, Wu XW, Chen GH, Zhang XX. 2014. Outbreaks of the brown planthopper Nilaparvata lugens (Stål) in the Yangtze River Delta: Immigration or local reproduction? PLoS One 9: e88973.

Huang, Z., He, G., Shu, L., Li, X., and Zhang, Q. 2001. Identification and mapping of two brown plant hopper resistance genes in rice. Theor. Appl. Genet., 102: 929-934.

Horgan, F. G., Ramal, A. F., Bentur, J. S., Kumar, R., Bhanu, K. V., Sarao, P. S. and Almazan, M. L. P. 2015. Virulence of brown planthopper (Nilaparvata lugens) populations from South and South East Asia against resistant rice varieties. Crop Protection, 78, 222-231.

Impa SM, Morete MJ, Ismail AM, Schulin R, Johnson-Beebout SE. 2013. Zn uptake, translocation and grain Zn loading in rice (Oryza sativa L.) genotypes selected for Zn deficiency tolerance and high grain Zn. J Exp Bot 64:2739–2751.

Jairin, J., Phengrat, K., Teangdeérith, S., Vanavichit, A., Toojinda, T. 2007. Mapping of broad spectrum brown plant hopper resistance gene, Bph3, on rice chromosome 6. Mol. breed. 19: 35-44.

Kalode, M. B., and Krishna, T. S. 1979. Varietal resistance to brown planthopper in India. Brown planthopper: Threat to rice production in Asia, 187-199.

Khush, G.S. and Virk, P.S. 2005. Selection criteria. In: IR Varieties and their Impact, International Rice Research Institute, Los Baños, Philippines, pp. 6–15.

Normile, D., 2008. “Reinventing rice to feed
the world,” Science, vol. 321:330- 333.
Pathak, M. D. and Khush, G. S. 1977, April.
Studies on varietal resistance to brown plant hopper at IRRI. In Brown Planthopper Symposium.
Ram, T., Deen, R., Gautam, S. K., Ramesh, K., Rao, Y. K., and Brar, D. S. 2010.
Identification of new genes for brown planthopper resistance in rice introgressed from O. glaberrima and O. minuta. Rice Genet Newsl, 25, 67-69.
Sogawa, K. 1982. The rice brown planthopper: feeding physiology and host plant interactions. Annu. Rev. Entomol., 27: 49-73.
Soundararajan, R.P., Kadirvel, P., Gunathilagaraj, K. and Maheswaran, M. 2004. Mapping of quantitative trait loci associated with resistance to brown planthopper in rice by means of a doubled haploid population. Crop Sci., 44(6): 2214-2220.
Tanaka, K. 2000. A simple method for evaluating the virulence of the brown planthopper. International Rice Research Notes, 25(1), 18-19.
Wei, F. J., Tsai, Y. C., Wu, H. P., Huang, L. T., Chen, Y. C., Chen, Y. F. and Yue-ie, C. H. 2016. Both Hd1 and Ehd1 are important for artificial selection of flowering time in cultivated rice. Plant Science, 242, 187-194.

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