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Evaluation of red rice genotypes against brown planthopper, BPH (*Nilaparvata lugens* Stal.) by phenotypic analysis and study of mechanism of resistance involved

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Abstract

Red rice genotypes are characterized by their huge nutritional values. Apart from this property, they also possess valuable sources of resistance to many biotic and abiotic stresses. In the present investigation, a total of 215 red rice accessions collected from north east and other parts of India were screened for their resistance against brown plant hopper (BPH) at National Rice Research Institute (NRRI), Cuttack by following modified screening technique. The results showed, among 215 genotypes, 4 were highly resistant, 11 were resistant and 13 were moderately resistant against BPH. The rest 187 genotypes were either susceptible or highly susceptible. The mechanism of resistance in these identified lines was studied. The nymphal survivility and development was lower in resistant genotypes (Mata Meher 43.33%) after 5day of release as compared to susceptible check TN-1 (100% survivility). Similarly the nymphal developmental period was less in resistant lines than TN-1 (100% nymphs were developed in to adult) after 15th days of release. The highly resistant genotype Matameher has shown lowest FPLI index (6.75) as compared to resistant(R), moderately resistant (MR) and susceptible (S) reactions.

Keywords: Red rice, resistance, brown plant hopper, screening

1. Introduction

Rice plays a significant role in food security of Asia where more than 90 per cent of the rice is produced and consumed [1]. Among the major cereal crops grown in India, rice alone contributes to 44.11 million hectares which is more than any other cereals. The nation produced 112.91 million tonnes of rice during 2017-18 [2]. The consumption of rice around the world place next only to wheat. There is a huge diversity among the rice cultivars with respect to different characters. Among them, pigmented or coloured rice varieties have gained most popularity and attention among the rice growing countries because of their nutritional and other properties such as presence of flavonoides and antioxidant compounds which play a significant role in daily health benefits [3-4]. They are also a good source of anthocyanins, flavonaoides and other phenolic compounds along with some of the essential minerals [5]. Pigmented rices are of different colours as they are characterized by brown, red, black or dark purple in their bran layers. The mixer of anthocyanin compounds mostly located in aleuronic layer of the rice kernels and they are belongs to the family of flavonaoides [6]. As the health concerns among the people increasing day by day and the many of the diseases such as diabetes, cancer and heart problems are directly related to food which we consume daily. So the scientists are looking for other quality traits (other than carbohydrates, proteins and fat) in food stuffs. The food stuffs are being evaluated for their antioxidant properties like glycemic index and mineral content. In this context, the pigmented rices, especially red rices have gained popularity in almost every country because of their health and nutritional benefits desired from presence of phenolic compounds which are anti allergic, antioxidants, anticarcinogenic and other benefits [7].

Rice (*Oryza sativa* L) also encounters many biotic and abiotic constraints in production and productivity. Among them, insects are most important biotic stresses causing significant yield loss. Among the destructive pests, brown planthopper (*Nilaparvata lugens* Stal.) is the most destructive monophagous insect pest of rice which sucks the phloem sap of plants leading to 'hopper burn' symptom and huge yield loss every year throughout tropical, subtropical and temperate areas in Asia [8]. Like other rices, red rice is also prone to brown plant hopper attack. Management of BPH through application of chemical insecticides can cause resurgence and play a major role in inducing outbreaks [9].Continuous application of insecticides also creates environmental pollution and harmful effect to human and animal health. Growing resistant varieties is an economical and efficient way for the management of BPH. But resistant varieties break down within few years of their introduction, because of continuous infestation of the pest or development of biotypes. So, understanding the mechanism of resistance is important before developing resistant varieties. Keeping this in view, a study was undertaken to identify new source of resistance among Indian red rices so that these resistant sources can be utilized effectively in the breeding programme to develop new BPH-resistant varieties. Identification of resistant genotypes was carried out through standard procedure of screening the red rice genotypes for their reaction to BPH, along with understanding the mechanism of resistance of the identified resistant donors.

2. Materials and methods

2.1 Mass rearing of brown planthopper (BPH), *Nilaparvatha lugens* Stal.

The present experiment was conducted in controlled condition of green house at National Rice Research Institute (NRRI), Cuttack, Odisha during the years 2017 and 2018. A total of 215 red rice accessions collected from north east India and stored in the gene bank of NRRI, were screened against BPH with standard susceptible check variety TN-1 and two resistant checks, PTB-33 (national check) and Salkathi (NRRI check). The screening was carried out as per the modified standard screening protocol developed by Jena *et al* [10]. Brown planthopper of Cuttack population was maintained in the glasshouse at a temperature of 30 ± 3 ºC with a relative humidity of 75±5% on potted plants of susceptible variety TN1. Adult gravid female hoppers were released on 50-60 day old plant @ 20 numbers females per pot and placed in oviposition cages. After 48 hours of release, the healthy gravid females were separated and released on fresh TN1 plants for further egg laying. Fresh plants were placed in the cages for nymphal feeding as and when required [11]. Mass screening of red rice genotypes against NRRI (Cuttack) population of BPH for their resistance (R)/ susceptible (S) reaction was carried out. The mechanism of resistance was studied through the methods of antibiosis *i.e.* nymphal survivility and developmental study, tolerance *i.e.* functional plant loss index (FPLI), plant dry weight loss to BPH dry weight gain (PDWL) and per cent plant wilted and days to wilt. All the experiments were repeated thrice for the confirmation of results.

2.2 Screening of red rice accessions

The test genotypes were screened in mass screening followed by replicated screening under green house conditions. A standard seed box technique (SSST) as suggested by IRRI [12] was followed with suitable modifications made by Jena *et al* [10]. The genotypes were screened for their level of resistance to Cuttack population of insect. Seeds of all red rice genotypes along with universal susceptible check TN-1, national resistant check Ptb-33 and NRRI resistant check Salkathi were sown in screening tray @ 25seeds/genotype. 2nd instar nymphs were released artificially on 10 days old test plant at 10-12 insects per plant. The seedlings were observed daily for damage symptoms. The percent dead seedlings for each test genotype was recorded when all the seedlings in susceptible check TN1 were died due to BPH feeding. The percent dead seedlings in each genotypes was converted to different scores (Resistant and susceptible) using standard evaluation system (SES) scale, 0-9 rating provided by [13]. The details of the scores are given in below table-1.

Table 1: Standard Evaluation System (SES) Scoring

Sl No	Score	Per cent dead seedlings	Reaction
1	1	0-10	Highly Resistant (HS)
2	3	11-30	Resistant (R)
3	5	31-50	Moderately Resistant (MR)
4	7	51-70	Susceptible (S)
5	9	71-100	Highly Susceptible (HS)

2.3 Nymphal survivility and development

A total of fifty number of first instar healthy BPH nymphs were released on 30 days old potted plants of all the 28 resistant red rice accessions along with TN1, Salkathi and Ptb-33. Insects were kept confined to the plants by using mylar cages whose open end was covered with muslin cloth. The number of nymphs survived after 5th, 10th, 12th and 15th day was counted and per cent of survivility was calculated. Each genotype replicated thrice. The stage of nymphs was also recorded after 5th, 10th, 12th and 15th day after release. Besides, nymphal moulting was recorded at each 24-hour interval until the insects attain adulthood.

2.4 Growth index

Growth index of BPH of resistant red rice accession along with resistance check was calculated by using the data of nymphal developmental period and nymphal survival following formula.

$$\text{Growth Index} = \frac{\text{Per cent survival of nymph}}{\text{Nymphal developmental period}} \times 100$$

2.5 Tolerance Study

Thirty days old seedlings of each test genotype were taken to study different level of tolerance. 1st instar nymphs were introduced on each plant at 25 insects/plant. Uninfected plant was included as control for each accession along with resistant check. The plants wilts due to insect feeding and when wilting was started, the insects were collected, oven dried for 48 hours and weighed. Similarly the infested and un-infested plants were removed from pots along with roots, washed thoroughly under running tap water, air dried for 3 hr followed by oven dried at 70 ºC for 60 hr and weighed. The functional plant loss index (FPLI) and plant dry weight loss per mg of insect dry weight produced were calculated for all the genotypes using the formula given by Panda and Heinrichs [14].

The functional plant loss index (FPLI) and plant dry weight loss per mg of insect dry weight produced were calculated for all the genotypes by using the following formulae (Panda and Heinrichs 1983) [14].

1. Functional Plant Loss Index (FPLI) $= 1 - \frac{\text{Dry weight of the infested plant}}{\text{Dry weight of un-infested plant}} \times 100$

2. Plant dry weight loss per mg of *Nilaparvata lugens* dry weight produced

$$= \frac{\text{Dry weight of uninfected plant- Dry weight of infested plant}}{\text{Dry weight of the } \textit{Nilaparvata lugens} \text{ progeny on infested plant}}$$

2.6 Days to wilting

About 25 days old seedlings were covered with Mylar cages with ventilating windows. Second instar nymphs @25/pot were released on the plants of Mylar cages and open end of the tube was covered by muslin cloth fastened with a rubber band. The plants were daily observed for their health. Number of plants wilted with all leaves dried and per cent plant wilted was recorded. The experiment was terminated at 40 days after the release of nymphs and recorded the number of plants that did not wilt at the end of the study.

2.7 Data Analysis

The data collected from all the experiments were analyzed statistically using completely randomized design using analysis of variance (ANOVA) using Windostat statistical software. The treatment means were separated by least significant difference test (LSD) at P=0.05 [15]. The data was transformed using arcsine and square root transformations as per requirement before analysis.

3. Results

The details of the results obtained in the present study are presented as follows. Mass screening of 215 red rice genotypes revealed that, out of 215 genotypes, 6 were found to be highly resistant (Score1), 9 genotypes were resistant (score 3) and 13 genotypes were moderately resistant (score 5) against BPH. Rest 187 accessions of the total 215 red rice varieties screened were found to be either susceptible or highly susceptible to brown plant hopper. The detail of the genotypes with reaction to BPH is presented in Table-2. All the genotypes showing different categories of resistant reaction when further screened in replicated screening, only 4 accessions were highly resistant (score 1), 11 were resistant (score 3), and 13 were moderately resistant (score 5) is presented in Table-3. A total of 28 genotypes identified as promising with BPH resistance were taken up for further studies on different resistance mechanism and results are presented below.

3.1 Nymphal survivility and Development

The genotypes with resistant reaction showed lower survivility of BPH when compared to susceptible check TN1. On 5th day after release all the released nymphs survived in the susceptible check TN1 wherein on all the other red rice accessions and resistant checks Salkathi, Ptb33 reduced number of nymphs survived. As the day prolonged the nymphal survival per cent shown reducing trend on all the red rice accessions and the resistant checks and lowest survivility was found on 15 days after release. The rate of survivility was less in highly resistant red rice accession followed by resistant and moderately resistant accessions. Among 28 resistant red rice accessions nymphal survivility was less in Mata Meher (43.33%) after 5day of release which was statistically on par with resistant checks i.e. Ptb33 (45.00%) and Salkathi (38.33%). The susceptible check TN1 showed highest survivility (100%) after 5th day of release. As the time elapsed the survivility percentage decreased gradually and only 6.67% survivility of BPH was found in Matameher and Manipur black accessions which were statistically on par with PTB-33 (1.67%) and Salkathi (1.67%). Among all the plant varieties tested for nymphal survival the susceptible check TN1 has recorded significantly highest survivility (91.67%) per cent indicating more preferred by BPH.

Nymphal development rate of BPH nymphs on resistant genotypes was lower than on the susceptible check TN-1. Growth of survived nymphs was slowest in Matameher, Manipuri black, Sonahanan and Hermonona in which they could not attain adulthood but remained in 2nd and 3rd instar stage towards 15 days after release, against 100% adult in TN1. All the resistant (score-3) genotypes also showed retarded development restricted to 3rd and 4th instar while in moderately resistant accessions, most of the nymphs were in 4th and 5th instar stage with about 24.83 – 32.47 % nymphs attained adulthood. (Table-3).

3.2 Tolerance

All the 28 genotypes along with susceptible and resistant checks were subjected to tolerance test. The results found that, there was a significant variation among the genotypes. The results of the experiment are presented in Table 4. Among the highly resistant genotypes Mata meher (6.74) had lowest FPLI followed by Sonahanan (7.84), Manipuri black and Hermonona; Likewise among resistant accessions Bavdi (10.70) recorded lowest FPLI followed by Bandimarhan (12.07) and Uttarabanga local-3(12.20). All these moderately genotypes were on par with each other and were significantly lower than susceptible check TN-1 (38.59) and significantly higher than resistant check Salkathi (7.30) and Ptb-33 (6.07).

The result on plant dry loss per mg of insect dry weight is presented in Table 4. The plant dry weight loss per mg of insect dry weight produced was lower in Ptb-33(10.42 mg) and Salkathi (19.08 mg) followed by highly resistant red rice genotypes Matameher (21.05 mg), Manipuri black (21.56mg), Sonahanan (21.98 mg) and Hermonona (22.03 mg) and also among resistant accessions Bavdi (22.70 mg) followed by Bacharya Khuta (23.21 mg) and Bandi marhan (32.07 mg). TN1 was shown 58.89 mg pdwl which was significantly high as compared to other tested resistant red rice genotypes.

Similarly in case of number of days to wilt also follow the similar trend as of FPLI and weight loss; where resistant check Ptb-33 and Salkathi recorded 17.33 and 16 days whereas TN 1 obtained wilt only in 5.33 days (Table-4). Among the red-rice genotypes, Mata meher required 37.18 days to wilt which was significantly higher and Maha Baisur required 15.67 days to wilt than all other tested resistant red rice accessions (Table.4).

4. Discussion

Identification of resistance to brown plant hopper (BPH) has been started since long back and huge number of accessions were screened and identified many valuable and promising resistant sources from different parts of the world (Jena *et al*. 2010) [16]. A number of genes and QTLs have been identified and mapped on different chromosomes of rice (Jena *et al*. 2010; Jena *et al*. 2015) [10, 16]. The destructiveness and monophagous nature of BPH has lead to the identification of new sources of resistance as the breakdown of resistance in newly bread varieties are either by knocking down of resistant genes or evolution of new races in insect. In this context the traditional land races gave a hope of having many resistance sources against the BPH (Kalode and Krishna, 1979; Jena *et* *al* 2006) [17-18]. Here in our study, the red rice accessions collected from north east India which are well known for their nutritional and other benefits have been screened for BPH resistance to Cuttack population. Saxena and Pathak (1979) [19] have studied that, the less ingestion of food and its utilization did not promote the growth and survival of BPH on resistant varieties. Many researchers reported varied reaction of genotypes to BPH under score 1, 3, 5, 7 and 9 which is a common phenomena (Bodhnapod, 2018; Behera, 2018) [20-21]. As far as nymphal survivility is concerned, the less nymphal survivility was observed in resistant Matameher as compared to susceptible TN-1. Similar results were obtained by Reddy and Kalode (1985) [22] and they reported that, on resistant varieties, nymphal survival was much lower (18.5–28.4%) and nymphal duration was prolonged by 5–7 days. Song *et al.* (1972) [23] reported that BPH reared on resistant varieties (Suwan 214, Kara samba and ASD 7) showed less nymphal duration, rate of adult emergence, length of adult life and fecundity compared to susceptible varieties. Similar results were also reported by Reddy *et al.* (2005) [24], Uma *et al.* (2006) [25], Alagar and Suresh (2007a) [26]. So, in the present study, the resistance of red rice to BPH is also correlated with low survivility rate, low FPLI, low PDWL, more days to wilt and low percentage of plant mortality. The identified highly resistant and resistant red rice genotypes can be grown as varieties in BPH endemic areas such as north-eastern hill region and different tribal areas with traditional rice cultivation. They can also be utilized resistance breeding for developing resistant varieties with desired traits.

Table 2: The detail of the phenotyping of red rice accessions to brown planthopper (BPH), Cuttack population

Sl No	Variety name	Dead %	Scoring	Reaction	Sl No	Variety name	Dead %	Scoring	Reaction
1	Boroungoda Dhan	100.00	9	Highly Susceptible	28	Meher Dhan	100.00	9	Highly Susceptible
2	Jndra Sail	100.00	9	Highly Susceptible	29	Kelesh-1981	100.00	9	Highly Susceptible
3	Karanga goda	100.00	9	Highly Susceptible	30	Langal-Muthi	100.00	9	Highly Susceptible
4	Kalo nuniya	100.00	9	Highly Susceptible	31	Medi-WB	100.00	9	Highly Susceptible
5	Malabati Rao	100.00	9	Highly Susceptible	32	Marchal	100.00	9	Highly Susceptible
6	Biroi	100.00	9	Highly Susceptible	33	Goindi	87.50	9	Highly Susceptible
7	Kusuma Dhan	100.00	9	Highly Susceptible	34	Dhani goda	100.00	9	Highly Susceptible
8	Nirjhara	100.00	9	Highly Susceptible	35	Motar mala	100.00	9	Highly Susceptible
9	Ure Banya	100.00	9	Highly Susceptible	36	Olko Churi	83.33	9	Highly Susceptible
10	Bhajna	100.00	9	Highly Susceptible	37	Koya ho Baby	100.00	9	Highly Susceptible
11	Badka gora	100.00	9	Highly Susceptible	38	Kalo bhat	100.00	9	Highly Susceptible
12	Sindoor Sal	100.00	9	Highly Susceptible	39	Like Kakua	100.00	9	Highly Susceptible
13	Jatri Pakhi	100.00	9	Highly Susceptible	40	Pal Bari	100.00	9	Highly Susceptible
14	Kak Sal	100.00	9	Highly Susceptible	41	Shiv Dharhar-3	100.00	9	Highly Susceptible
15	Choto didi	100.00	9	Highly Susceptible	42	Tendumari Dhan	87.50	9	Highly Susceptible
16	Sona gari	100.00	9	Highly Susceptible	43	Bada Swarna-11	53.85	7	Susceptible
17	Rajesh	41.18	5	Moderately Resistant	44	Birohi	100.00	9	Highly Susceptible
18	Chongair	100.00	9	Highly Susceptible	45	Bhojanbaba-H-4	100.00	9	Highly Susceptible
19	Champei Suali	75.00	9	Highly Susceptible	46	Karhani	100.00	9	Highly Susceptible
20	Bhursi Dhan	100.00	9	Highly Susceptible	47	Bamru Baba-3	100.00	9	Highly Susceptible
21	Bhasakaema	100.00	9	Highly Susceptible	48	Kapsar Kh-16	100.00	9	Highly Susceptible
22	Kaya-4	100.00	9	Highly Susceptible	49	Sanfui Dhan- Kh-16	91.67	9	Highly Susceptible
23	Duchara Dhan	100.00	9	Highly Susceptible	50	Kele- Kh-16	76.00	9	Highly Susceptible
24	Nagheri	100.00	9	Highly Susceptible	51	Jabsal-Kh-1	92.59	9	Highly Susceptible
25	Karni Dhan	100.00	9	Highly Susceptible	52	Jhingesal- Kh-16	100.00	9	Highly Susceptible
26	Chhetka	100.00	9	Highly Susceptible	53	Sadamala-Kh-16	86.67	9	Highly Susceptible
27	Argir Ban	100.00	9	Highly Susceptible	54	Keshabsal-Kh-16	91.67	9	Highly Susceptible
Sl No	**Variety name**	**Dead %**	**Scoring**	**Reaction**	**Sl No**	**Variety name**	**Dead %**	**Scoring**	**Reaction**
55	Sathip- Kh- 16	82.14	9	Highly Susceptible	83	Maria Dhan-2 Kh-16	50.00	5	Moderately Resistant
56	Baku	92.00	9	Highly Susceptible	84	Khara Kh-16	92.59	9	Highly Susceptible
57	Meghi-Kh-16	84.00	9	Highly Susceptible	85	Uttar Bangi Local-8	88.00	9	Highly Susceptible
58	Kouka-Kh-16	90.48	9	Highly Susceptible	86	Lal Dhyapa Kh-16	80.00	9	Highly Susceptible
59	Kall Bank- Kh-16	82.14	9	Highly Susceptible	87	Tora Pokri Kh-16	72.00	9	Highly Susceptible
60	Sathia-Kh-16	100.00	9	Highly Susceptible	88	Khama	92.24	9	Highly Susceptible
61	Sathi Dhan-1-Kh-16	100.00	9	Highly Susceptible	89	Chingri Fuli Kh-16	100.00	9	Highly Susceptible
62	Sungo bora- Kh-16	100.00	9	Highly Susceptible	90	Seshaphal-1 (Kh-1)	100.00	9	Highly Susceptible
63	Manga Muthi-Kh-16	71.43	9	Highly Susceptible	91	Kajal ghorya Kh-16	100.00	9	Highly Susceptible
64	Gochi-Kh-16	56.67	7	Susceptible	92	Jonrai Buna Kh-8	73.33	9	Highly Susceptible
65	Dhan Sirhatti- Kh-16	100.00	9	Highly Susceptible	93	Polina Dhan-2 Kh-16	51.43	7	Susceptible
66	Dhusuri barata- Kh-16	100.00	9	Highly Susceptible	94	Bonni Dhan Kh-16	100.00	9	Highly Susceptible
67	Sankene	83.33	9	Highly Susceptible	95	Jashoya	100.00	9	Highly Susceptible
68	Lolka Dhan- Kh-16	100.00	9	Highly Susceptible	96	Uttar banga local-3 Kh-3	12.50	3	Moderately Resistant
69	ShialBhomra- Kh-16	46.43	5	Moderately Resistant	97	Kathi Kh-16	86.96	9	Highly Susceptible
70	Koshiya binni – Kh-16	100.00	9	Highly Susceptible	98	Lalkusuma	90.48	9	Highly Susceptible
71	Hetomari- Kh-16	100.00	9	Highly Susceptible	99	Manipuri black	0.00	1	Highly resistant
72	Rohi Dhan-1	100.00	9	Highly Susceptible	100	Palbari	84.00	9	Highly Susceptible
73	Chingri Full	100.00	9	Highly Susceptible	101	Kalo haosu	100.00	9	Highly Susceptible
74	Balangi Saria	100.00	9	Highly Susceptible	102	Jenjale dhan	100.00	9	Highly Susceptible

75	Harinkajali Kh-16	96.00	9	Highly Susceptible	103	Goda dhan	83.33	9	Highly Susceptible
76	Uttara Banga Local-2 Kh-16	56.52	7	Susceptible	104	Aadanchilya (Kh-15)	76.92	9	Highly Susceptible
77	Sital Kuchi 3 Kh-16	69.23	7	Susceptible	105	Agiyasal Kh-15	100.00	9	Highly Susceptible
78	Koike Kh-16	100.00	9	Highly Susceptible	106	Assambiroin	100.00	9	Highly Susceptible
79	Binni	33.33	5	Moderately Resistant	107	Annapurna	100.00	9	Highly Susceptible
80	Sati Kh-16	14.29	3	Moderately Resistant	108	Barbali	100.00	9	Highly Susceptible
81	Bitti	86.66	9	Highly Susceptible	109	Kariglass	100.00	9	Highly Susceptible
82	Kalshepa Kh-16	50.00	5	Moderately Resistant	110	Hermanona	7.69	1	Highly Resistant

Sl No	Variety name	Dead %	Scoring	Reaction	Sl No	Variety name	Dead %	Scoring	Reaction
111	Jool	100.00	9	Highly Susceptible	138	Kuti Chudi	68.18	7	Susceptible
112	Goda dani	95.83	9	Highly Susceptible	139	Sakta-2	68.00	7	Susceptible
113	Klabhat	79.17	9	Highly Susceptible	140	Khuti dhan	50.00	5	Moderately resistant
114	Barcharya Khuta	4.16	1	Highly Resistant	141	Lechade dhan	21.05	3	Moderately resistant
115	Kardhan	88.00	9	Highly Susceptible	142	Bavdi	4.00	1	Highly Resistant
116	Lokharpuhi	92.00	9	Highly Susceptible	143	Bandi Marhan	28.00	3	Moderately resistant
117	Bamboi Mugai	87.50	9	Highly Susceptible	144	Mata Meher	0.00	1	Highly Resistant
118	Meghi	44.44	5	Moderately resistant	145	Boudh Champei Siali	91.30	9	Highly susceptible
119	Balam	33.33	5	Moderately resistant	146	Boishali	80.00	9	Highly susceptible
120	Bandi Marhaandhan (Kh-15)	100.00	9	Highly Susceptible	147	Binni Dhan-Ran	100.00	9	Highly susceptible
121	Kakdi	72.41	9	Highly Susceptible	148	Bhurkunda	62.5	7	Susceptible
122	Chapa Khuli-1	100.00	9	Highly Susceptible	149	Bandi Goyandi	60.0	7	Susceptible
123	Gudmadhan	100.00	9	Highly Susceptible	150	Bhadui	84.00	9	Highly Susceptible
124	Paatdhan	100.00	9	Highly Susceptible	151	Badka Gora	80.00	9	Highly Susceptible
125	Nalbora	75.00	9	Highly Susceptible	152	Salma	76.92	9	Highly Susceptible
126	Mugai	85.71	9	Highly Susceptible	153	ChapaKhusi-1	24.00	3	Moderately resistant
127	Bhudeb-1(Kh-15)	95.10	9	Highly Susceptible	154	Chadai Guda	24.00	3	Moderately resistant
128	Chhota Dahiya	80.00	9	Highly Susceptible	155	Do Dana	87.50	9	Highly Susceptible
129	Ajirman	84.00	9	Highly Susceptible	156	Dhusuri	64.00	7	Susceptible
130					157	Godadani Dhan	100.00	9	Highly Susceptible
131	Aadan Chilya	73.08	9	Highly Susceptible	158	Goyandi Dharohar	56.00	7	Susceptible
132	Boudh Kusuma	77.77	9	Highly Susceptible	159	Bhuri Kargi	95.83	9	Highly Susceptible
133	Badari	100.00	9	Highly Susceptible	160	Bhudeb-1	80.00	9	Highly Susceptible
134	Kakharua	26.92	3	Moderately resistant	161	Bhari Bhojanya	80.77	9	Highly Susceptible
135	Korchobandi	76.00	7	Susceptible	162	Bacha Kalma	76.00	9	Highly Susceptible
136	Kaenidhan	100.00	9	Highly Susceptible	163	BadamiDhan	100.00	9	Highly Susceptible
137	Satia	100.00	9	Highly Susceptible	164	Bacha Kakamadani	84.00	9	Highly Susceptible

Sl No	Variety name	Dead %	Scoring	Reaction	Sl No	Variety name	Dead %	Scoring	Reaction
165	Bagoi Chudi	87.50	9	Highly Susceptible	192	Karchobandi	76.00	7	Susceptible
166	Bagudi	60.00	7	Susceptible	193	Sakta-1	50.00	5	Moderately resistant
167	Dhan Sathiya	100.00	9	Highly Susceptible	194	Hermonona	0.00	1	Highly Resistant
168	Dhan (Desi)	70.83	9	Highly Susceptible	195	Sarya Dhan	73.08	9	Highly Susceptible
169	Devmati	96.00	9	Highly Susceptible	196	Gerua Mudi	40.00	5	Moderately resistant
170	Gadha Khuta	92.00	9	Highly Susceptible	197	Dhanigoda dhan	100.00	9	Highly Susceptible
171	Sariya	92.00	9	Highly Susceptible	198	Sonahanan	0.00	1	
172	Ghoda Sail	87.50	9	Highly Susceptible	199	Ramshir	92.00	9	Highly Susceptible
173	Goda Dhan	100.00	9	Highly Susceptible	200	Ratanchudi	100.00	9	Highly Susceptible
174	Kalpana	84.00	9	Highly Susceptible	201	Lokhar puhi	96.00	9	Highly Susceptible
175	KanduPhool	100.00	9	Highly Susceptible	202	Lanchi	66.67	7	Susceptible
176	Kardhana	100.00	9	Highly Susceptible	203	Maha Baisur	45.00	5	Moderately resistant
177	Kari glass	68.00	7	Susceptible	204	Manipuri	26.31	3	Moderately resistant
178	Karelia	79.17	9	Highly Susceptible	205	Mijdi bala	64.00	7	Susceptible
179	Lamsduri	72.00	9	Highly Susceptible	206	Mudi Futa	32.00	5	Moderately resistant
180	Janjale Dhan	64.00	7	Susceptible	207	Mujni	15.00	3	Moderately resistant
181	Kala Dani	100.00	9	Highly Susceptible	208	Munda Ghotiya	79.17	9	Highly Susceptible
182	Kakad godo	76.19	9	Highly Susceptible	209	Pakheya	75.00	9	Highly Susceptible
183	Kakdi	55.00	7	Susceptible	210	Pandrikuda dhan	76.00	9	Highly Susceptible
184	Karhani Lalitpur	85.18	9	Highly Susceptible	211	Peel Kormal	54.54	7	Susceptible
185	Karrhni Ghughara	60.00	7	Susceptible	212	Petre	83.33	9	Highly Susceptible
186	Sarka Dhan	48.27	5	Moderately resistant	213	Pundi Roisi	86.36	9	Highly Susceptible
187	Goyandi	68.00	7	Susceptible	214	Rais Dhan	72.00	9	Highly Susceptible
188	Gudma Dhan	92.00	9	Highly Susceptible	215	Rakhi dhanRamshir	91.30	9	Highly Susceptible
189	Kurso Bhog	71.43	9	Highly Susceptible					
190	Duchara Dhan	100.00	9	Highly Susceptible					
191	Meher Dhan	100.00	9	Highly Susceptible					

Table 3: The detail of the nymphal survivility of red rice accessions to brown planthopper (BPH), Cuttack population

Sl No	Variety name	Score	% dead plant (RS)	Survivility % (5th day)	Survivility % (10th day)	Survivility % (12th day)	Survivility % (15th day)	Development 15 DAS				
								2nd	3rd	4th	5th	Adult
1	Bavdi	3	15.06	55.00 (47.88)**	33.33 (35.17)**	21.67 (27.71) **	11.67 (19.31)**	0.00	50.00	50.00	0.00	0.00
2	Bacharya khuta	3	27.22	60.00 (50.79)	36.67 (37.20)	20.00 (26.45)	13.33 (20.45)	0.00	55.56	44.44	0.00	0.00
3	Sonahanan	1	3.12	50.00 (45.00)	30.00 (33.16)	15.00 (22.60)	10.00 (16.35)	0.00	100.00	0.00	0.00	0.00
4	Mata Meher	1	1.67	43.33 (41.16)	18.33 (25.00)	11.67 (17.80)	6.67 (13.64)	40.00	60.00	0.00	0.00	0.00
5	Hermonona	1	6.39	53.33 (46.91)	31.67 (34.15)	16.67 (24.05)	10.00 (18.05)	0.00	100.00	0.00	0.00	0.00
6	Manipuri Black	1	2.38	52.33 (46.34)	26.67 (30.95)	15.00 (22.60)	6.67 (13.25)	36.67	63.33	0.00	0.00	0.00
7	Sati kh-16	3	26.73	85.00 (67.41)	60.00 (50.79)	40.00 (39.21)	28.33 (32.02)	0.00	37.30	62.70	0.00	0.00
8	Uttara banga local-3	3	24.22	65.00 (53.76)	53.33 (46.92)	35.00 (36.24)	23.33 (28.08)	0.00	33.33	66.67	0.00	0.00
9	Bandi Marhan	3	29.33	71.67 (57.98)	43.33 (41.12)	33.33 (34.22)	25.00 (28.45)	0.00	18.06	81.94	0.00	0.00
10	Chapa khusi-1	3	25.67	66.67 (54.83)	50.00 (45.00)	36.67 (37.12)	26.67 (30.76)	0.00	42.86	57.14	0.00	0.00
11	Chadaiguda	3	19.40	70.00 (57.00)	56.67 (48.87)	53.33 (46.92)	41.67 (40.17)	0.00	37.38	62.62	0.00	0.00
12	Manipuri	3	24.09	53.33(46.94)	41.67 (40.18)	41.67 (40.17)	28.33 (32.02)	0.00	23.97	76.03	0.00	0.00
13	Mujni	3	18.33	61.67 (51.81)	43.33 (40.96)	30.00 (32.76)	31.67 (33.27)	0.00	36.57	63.43	0.00	0.00
14	Kakharua	3	24.33	71.67 (57.98)	55.00 (47.88)	46.67 (43.08)	25.00 (29.93)	0.00	34.44	65.56	0.00	0.00
15	Lechade dhan	3	22.67	80.00 (63.55)	55.00 (47.88)	48.33 (44.03)	35.00 (36.24)	0.00	44.25	55.75	0.00	0.00
16	Rajesh	5	41.11	85.00 (67.41)	71.67 (57.86)	60.00 (50.79)	51.67 (45.97)	0.00	0.00	0.00	70.37	29.63
17	Meghi	5	42.67	86.67 (68.66)	61.67 (51.81)	55.00 (47.97)	53.33 (46.92)	0.00	0.00	0.00	75.17	24.83
18	Balam	5	39.09	93.33 (75.24)	73.33 (59.06)	65.00 (53.76)	60.00 (50.79)	0.00	0.00	0.00	75.10	24.90
19	Khuti dhan	5	40.00	90.00 (71.95)	78.33 (62.48)	71.67 (57.98)	56.67 (48.84)	0.00	0.00	0.00	70.71	29.29
20	Gerua mudi	5	40.49	86.67 (69.24)	73.33 (59.06)	71.67 (57.86)	60.00 (50.79)	0.00	0.00	0.00	72.36	27.64
21	Sakta-1	5	43.33	90.00 (71.95)	81.67 (64.69)	80.00 (63.55)	63.33 (52.78)	0.00	0.00	0.00	67.53	32.47
22	Shial bhomra	5	42.73	95.00 (78.20)	78.33 (62.79)	60.00 (50.85)	56.67 (48.93)	0.00	0.00	0.00	72.70	27.30
23	Binni	5	43.16	91.67 (73.40)	75.00 (60.08)	70.00 (57.00)	55.00 (47.91)	0.00	0.00	0.00	68.91	31.09
24	Kalshepa kh-16	5	43.22	96.67 (80.03)	81.67 (65.19)	80.00 (63.55)	60.00 (50.82)	0.00	0.00	0.00	72.05	27.95
25	Maria dhan-2	5	42.97	90.00 (71.95)	76.67 (61.22)	60.00 (50.85)	58.33 (49.90)	0.00	0.00	0.00	71.95	28.05
26	Maha baisur	5	41.67	91.67 (75.49)	70.00 (57.41)	56.67 (48.93)	56.67 (48.93)	0.00	0.00	0.00	68.65	31.35
27	mudi futa	5	42.50	88.33 (70.12)	75.00 (60.08)	70.00 (56.84)	58.33 (49.80)	0.00	0.00	0.00	68.69	31.31
28	Sarka dhan	5	40.11	91.67 (73.79)	85.00 (67.41)	83.33 (66.64)	61.67 (51.84)	0.00	0.00	0.00	63.55	36.45
29	Salkathi	1	0.00	38.33 (38.19)	15.00 (22.60)	3.33 (8.85)	1.67 (7.01)	0.00	0.00	0.00	0.00	0.00
30	PTB-33	1	0.00	45.00 (42.12)	20.00 (26.45)	1.67 (7.01)	1.67 (7.01)	0.00	0.00	0.00	0.00	0.00
31	TN1	9	100.00	100.00 (85.95)	96.67 (80.03)	91.67 (73.40)	91.67 (4.06)	0.00	0.00	0.00	0.00	100.00
	SEm±			3.87	4.23	4.90	5.68					
	CD at 5%			7.75	8.46	9.80	11.36					

RS : Replicated Screening, SEm: standard error mean, CD: critical difference, **Figures in parenthesis are transformed arc sin values.

Table 4: Details of the reaction of red rice genotypes to BPH (*Nilaparvata lugens*) Tolerance mechanism

SL no	Scoring	Variety name	FPLI%	PDWL (mg)	Days to wilt	% Plt wilted
1	3	Bavdi	10.70 (19.09)**	22.70 (4.82)	29.67(5.49)	43.58(41.31)
2	3	Bacharya khuta	14.54 (22.42)	23.21 (4.87)	28.21(5.36)	44.46 (41.82)
3	1	Sonahanan	7.84 (16.26)	21.98 (4.74)	35.78(6.02)	40.21 (39.35)
4	1	Mata Meher	6.74(15.05)	21.05 (4.64)	37.18(6.14)	39.98 (39.22)
5	1	Hermonona	10.30 (18.72)	22.03 (4.75)	34.68(5.93)	40.79 (39.69)
6	1	Manipuri Black	8.09(16.52)	21.56 (4.69)	36.79(6.11)	39.78 (39.10)
7	3	Sati kh-16	16.57(24.02)	31.75 (5.68)	26.35(5.18)	45.67 (42.52)
8	3	Uttara banga local-3	12.20 (20.44)	33.21 (5.81)	27.45(5.29)	47.68 (43.67)
9	3	Bandi Marhan	12.07 (20.33)	32.07 (5.71)	26.98(5.24)	44.21 (41.68)
10	3	Chapa khusi-1	15.83 (23.45)	36.23 (6.06)	27.38(5.29)	43.78 (41.43)
11	3	Chadai guda	13.85 (21.85)	32.69 (5.76)	26.55(5.20)	45.29 (42.30)
12	3	Manipuri	14.56 (22.43)	34.10 (5.88)	28.00(5.34)	46.65 (43.08)
13	3	Mujni	17.26 (24.55)	38.23 (6.22)	27.32(5.28)	44.87 (42.06)
14	3	Kakharua	15.27 (23.00)	35.28 (5.98)	26.12(5.16)	46.98 (43.27)
15	3	Lechade dhan	16.27 (23.79)	37.58 (6.17)	25.98(5.15)	45.88 (42.64)
16	5	Rajesh	24.64(29.76)	54.79 (7.44)	25.33(5.08)	58.98 (50.17)
17	5	Meghi	25.15 (30.10)	56.17(7.53)	22.67(4.81)	59.98 (50.76)
18	5	Balam	21.42 (27.57)	45.98 (6.82)	21.67(4.71)	64.67 (53.53)
19	5	Khuti dhan	23.81 (29.21)	48.74 (7.02)	20.33(4.57)	68.76 (56.02)
20	5	Gerua mudi	24.00 (29.33)	52.76 (7.29)	24.00(4.95)	69.34 (56.38)
21	5	Sakta-1	25.22 (30.15)	56.87 (7.57)	20.67(4.60)	71.90 (57.99)
22	5	Shial bhomra	26.07 (30.70)	57.89 (7.64	21.67(4.71)	72.39 (58.30)
23	5	Binni	25.02 (30.01)	55.88 (7.51)	19.33(4.45)	76.89 (61.27)
24	5	Kalshepa kh-16	24.38 (29.59)	54.21 (7.40)	17.67(4.26)	77.63 (61.77)
25	5	Maria dhan-2	29.55 (32.93)	62.39 (7.93)	18.67(4.38)	81.25 (64.34)
26	5	maha baisur	25.69 (30.45)	57.13 (7.59)	15.67(4.02)	69.78 (56.65)
27	5	mudi futa	28.05 (31.98)	61.66 (7.88)	16.00(4.06)	71.67 (57.84)
28	5	sarka dhan	27.28 (31.49)	58.89 (7.71)	17.89(4.29)	79.89 (63.36)
29	1	Salkathi	7.30 (15.68)	19.08 (4.43)	38.12(6.21)	39.21 (38.77)
30	1	PTB-33	6.07 (14.26)	10.42 (3.31)	38.33(6.23)	37.63 (37.84)
31	9	TN1	38.59 (38.40)	124.05(11.15)	14.00(3.81)	100 (90.00)
		SEm±		0.004	0.003	
		CD at 5%		0.01	0.01	

FPLI : Functional plant loss index, PDWL**:** Plant dry weight loss to BPH dry weight produced
mg: milligram, Plt :Plant, SEm: standard error difference, CD: critical difference
**Figures in parenthesis are transformed arc sin values.

5. Conclusion

Red rice, like other rice genotypes, are infested by brown plant hopper during their growing period. Host plant resistance has the potential to play a major role in BPH management which is cost-effective and eco-friendly. The present study provided an insight to the reaction of such varieties against this damaging pest so that the resistant genotypes can be grown in BPH-endemic area. At the same time, the highly resistant and resistant genotypes can be utilized in the rice breeding programme to develop resistant donors against BPH. These donors would be utilized in refining the popular rice varieties by introgressing the BPH resistant from donors.

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7. References

1. Khush GS. What it will take to feed 5.0 billion rice consumers in 2030. Plant Molecular Biology. 2005; 59:1-6.
2. Press and Information Bureau. Year End Review 2018 Ministry of Agriculture, Cooperation and Farmers Welfare. Following are the major highlights of the Department of Agriculture, Cooperation and Farmers Welfare during the year 2018.Production Scenario of Major Agricultural Crops 2018-19 as per 1st Advance Estimates Posted On: 26 DEC, 2018.
3. Zhang MW, Guo BJ, Chi JW, Wei ZC, Xu ZH, Zhang Y *et al*. Antioxidations and their correlation with total flavonoid and anthocyanin contents in different black rice varieties. Scientia Agricultura Sinica. 2005; 38(7):1324-1331.
4. Bhat FM, Singh RC. Characterizing the pigmented traditional rice cultivars grown in temperate regions of Kashmir (India) for free and bound phenolics compounds and *in vitro* antioxidant properties. Journal of Cereal Science. 2017; 276:253-262.
5. Pathak K, Rathi S, Sarma RN, Baishya S. Assessment of physical, chemical and antioxidant properties of few pigmented glutinous rice grown in Northeast India. Indian Journal of Plant Physiology. 2016; 21(3) DOI: 10.1007/s40502-016-0237-0
6. Yawadio R, Tanimori S, Morita N. Identification of phenolic compounds isolated from pigmented rices and their aldose reductase inhibitory activities. Food Chemistry. 2007; 101 (4):1616-1625.
7. Deng GF, Xu XR, Zhang Y, Li D, Gan RY, Li HB. Phenolic compounds and bioactivities of pigmented rice. Critical Reviews in Food Science and Nutrition. 2013; 53(3):209-306.
8. Park DS, Song MY, Park SK, Lee SK, Lee JH. Molecular tagging of the Bph locus for resistance to brown planthopper (*Nilaparvata lugens* Stal) through representational divergence analysis. Molecular Genetics and Genomics. 2008; 280:163-172.
9. Tanaka K, Endo S, Kazana H. Toxicity of insecticides to predators of rice planthoppers: Spiders, the mirid bug and the dryinid wasp. Applied Entomology and Zoology. 2000; 35:177-187
10. Jena M, Panda RS, Sahu RK, Mukherjee AK, Dhua U. Evaluation of rice genotypes for rice brown plant hopper resistance through phenotypic reaction and genotypic analysis. Crop Protection. 2015; 78:119-126.
11. Pati P, Jena M, Annamalai M, Behera SK, Raghu S, Bhattacharya S *et al*. Screening of red rice accessions for resistance to brown planthopper, *Nilaparvata lugens* (Stal.). Oryza. 2018; 55(4):596-601
12. IRRI, Standard Evaluation System for Rice. International Rice Research Institute, Manila, Philippines, 2002.
13. IRRI, Standard Evaluation System for Rice. International Rice Research Institute, Manila, Philippines, 2003.
14. Panda N, Heinrichs EA. Levels of tolerance and antibiosis in rice varieties having moderate resistance to the brown planthopper, *Nilaparvata lugens* (Stål.) (Homoptera: Delphacidae). Environmental Entomology. 1983; 12(4):1204-1214.
15. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research, pp. 1-680 Alagar M, Suresh S. 2007b. Population buildup of brown planthopper, *Nilaparvata lugens* on selected rice genotypes. Indian journal of Plant Protection. 1984; 35(1):32-35.
16. Jena KK, Kim SM. Current Status of Brown Planthopper (BPH) Resistance and Genetics. 2010; 2010; 3:161-171 DOI 10.1007/s12284-010-9050-y
17. Kalode MB, Khrishna TS. Varietal resistance to brown planthopper in India. In: Brown Planthopper: Threat to Rice Production in Asia. International Rice Research Institute, Philippines. 2006; 187-200.
18. Jena M, Sahu RK, Marandi BC. Screening of rice varieties for resistance against brown plant hopper (*Nilaparvata lugens* Stal.). Oryza. 2006; 43(4):334-335.
19. Saxena RC, Pathak MD. Factors governing susceptibility and resistance of certain rice varieties to the brown planthopper. In: Brown Planthopper: Threat to Rice Production in Asia. International Rice Research Institute, Philippines. 1979, 303-320.
20. Bodhnapod NG. Evaluation of rice genotypes of Sikkim and Tripura for resistance to brown planthopper, *Nilaparvatha lugens* (Stal.) M.Sc (Agri) Thesis submitted to Indira Gandhi Krishi Vishwavidyalaya. Raipur, Chhattisgarh, India. 2018
21. Behera SK. Identification and molecular characterization of new source of resistance and its mechanism against brown planthopper, *Nilaparvatha lugens* (Stal.) from Manipur rice accessions. M.Sc (Agri) Thesis submitted to Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India, 2018.
22. Reddy KV, Kalode MB. Mechanism of resistance in rice varieties showing differential reaction to brown planthopper; Proceedings. Indian Academy of Sciences. (Animal Sciences). 1985; 94:37-48.
23. Song YM, Choi SY, Park JS. Studies on the resistance of Tong-11 variety (IR 667) to the brown planthopper, *Nilaparvata lugens* (Stal). Korean Journal of Plant Protection. 1972; 11(2):61-68.
24. Reddy KL, Pasalu IC, Reddy DDR. Studies on antibiosis mechanism of resistance in rice against brown plant hopper *Nilaparvata lugens* (Stal.). Indian Journal of Entomology. 2005; 67(2):140-143.
25. Uma MM, Suresh S, Emmanuel N. Evaluation of mechanisms of resistance in conventional and hybrid rice varieties against *Nilaparvata lugens* Stal. Annals of Plant Protection Sciences. 2006; 14(2):319-322.
26. Alagar M, Suresh S. Settling and ovipositional preference of *Nilaparvata lugens* (Stal.) on selected rice genotypes. Annals of Plant Protection Sciences. 2007a; 15(1):43-46.