STUDIES ON ANTIBIOSIS AND TOLERANCE MECHANISM OF RESISTANCE TO BROWN PLANTHOPPER, NILAPARVATA LUGENS (STAL) (HEMIPTERA: DELPHACIDAE) IN THE SELECTED RICE ENTRIES

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STUDIES ON ANTIBIOSIS AND TOLERANCE MECHANISM OF RESISTANCE TO BROWN PLANTHOPPER, *NILAPARVATA LUGENS* (STAL) (HEMIPTERA: DELPHACIDAE) IN THE SELECTED RICE ENTRIES

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ABSTRACT

Antibiosis and tolerance mechanism of resistance to brown planthopper, *Nilaparvata lugens* were studied in the selected resistant, moderately resistant and moderately susceptible NSN-2 entries along with TN1 as susceptible check, Ptb 33 as resistant check. The selected resistant entries, IET Nos 23739, 23661 and 23620 were exhibited low fecundity recorded 22.0, 39.3 and 39.7 eggs/ female respectively, compared to TN1 recorded 213.0 eggs/female. Similarly low hatching was observed in resistant check Ptb 33 (28.7%) followed by resistant entry IET 23620 (41.9%), where in highest hatching percentage was observed in susceptible check TN1 (88.6%). The resistance entry, IET No. 23620 recorded prolonged nymphal duration (15.9 days), less nymphal survival (25.0), less growth index (1.6) compared to all tested entries including resistance check, Ptb 33. More number of days (49.0 days) for wilting was observed in resistance entry, IET No. 23739

KEY WORDS
Brown planthopper
Nilaparvata lugens
Insect resistance
Nymphal Survival

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INTRODUCTION

Rice, one of the world's most important staple food crops. There are many constrains in the rice production among which insect pests remain a constant problem in all rice growing areas (Narayanasamy *et al.,* 2014). One of the most economically important insect is the brown planthopper (BPH), *Nilaparvata lugens* (Stal) (Hemiptera: Delphacidae) which can cause huge damage where both nymphs and adults suck the plant sap directly and indirectly transmits viral diseases such as ragged stunt and grassy stunt (Jena *et al.,* 2006). Due to the infestation, plants turn yellow, dry up rapidly. At early infestation stage yellow patches appear, which soon turn brownish due to the drying up of the plants resulting in 'hopper burn', and could result in causing yield loss (Park *et al.,* 2008). The control of BPH with chemical insecticides not only resulted in development of resistance to BPH, but also found to have detrimental impact on natural enemies (Jhansi Lakshmi *et al.,* 2010 and BalaKrishna and Satyanarayana, 2013). So, it is consider, a resistant plant variety that reduces the insect population by 50 per cent in each generation is sufficient to eliminate an insect of economic importance within few generations (Painter, 1951). The necessity to identify suitable new resistant donors for BPH from different sources is important in order to combat the pest and develop material resistant to BPH. It is also necessary to understand the mechanisms responsible for manifesting resistance into the selected cultures with desirable characters, so that these can be utilized effectively in the breeding programme. Keeping this in view, present investigation was planned with the following objective to study antibiosis and tolerance mechanisms of resistance to BPH.

MATERIALS AND METHODS

Mass rearing of brown planthopper

BPH population was initially collected from rice fields and pure culture was maintained in the glasshouse at a temperature of 30 ± 5ºC with a relative humidity of 60±5% on 40 -50 day old potted plants of susceptible variety TN1. Mass rearing was done in cages of 70 cm x 62 cm x 75 cm dimension with glass panels on one side and wire mesh on all other sides. Twenty adult gravid female hoppers were collected with an aspirator and were released on pre-cleaned potted plants of TN1 and are placed in oviposition cages. After four days of egg laying, the gravid females were collected and released on to fresh TN1 plants for further egg laying. The oviposited plants were taken from cages and placed in another cage for nymphal hatching. Fresh plants were placed in the cages with nymphs as and when required (Heinrichis *et al.,* 1985). The hatched nymphs were utilized for experiments as and when they attain the desired age. Necessary precautions were taken to keep the culture free from predators such as mirid bugs, spiders, other natural enemies and other hoppers like WBPH and GLH. Using this technique, a continuous pure culture of BPH was maintained during the period of study.

Antibiosis mechanism

Antibiosis is the tendency to prevent injury or destroy insect life due to the adverse effect will be observed when insect feeds on host plant. The effects on the insect may interms of reduced fecundity, decreased size, abnormal length of life and increased mortality. Antibiosis mechanism was studied by conducting per cent hatching, per cent nymphal survival, nymphal duration, growth index and weight gain in adults.

Fecundity, Ovicidal test / per cent Egg hatching

Seeds of the test entries were soaked in Petri dishes and the germinated seeds were sown in 1000 ml plastic pots filled with fertilizer enriched puddled soil. Two germinated seeds were planted in each pot and for each test entry seedlings were raised in 8-10 pots. When the plants were 30 days old, they were thoroughly examined and cleaned to make them free from adults and eggs of other hoppers or mirid bugs before release of adults. They were covered with mylar tubes with ventilating windows. One pair of one day old adults were released with the help of an aspirator in the mylar cage and the open end of the tube was covered with a muslin cloth and tied with a rubber band. The adults were allowed to lay the eggs till their death. The plants were observed for nymphal hatching after one week of release. The hatched nymphs were counted, number was recorded and later removed from the plant. After hatching of all the eggs, or when nymphs stop coming out, the plants were cut at the base and examined under stereo binocular microscope to record the number of unhatched eggs. The plants were dissected 72 hours after infestation and counted the eggs under a microscope to study the antibiosis of adults for oviposition among cultures (Heinrichs *et al*., 1985). There were three replications for each test entry and the data was reported as percentage of unhatched eggs.

$$\text{Percent of unhatched eggs} = \frac{\text{Number of unhatched eggs}}{(\text{Number of nymphs} + \text{number of unhatched eggs})} \text{x100}$$

Nymphal survival (%)

The seeds of the test entries were soaked in Petri dishes and the germinated seeds were sown in 1000 ml plastic/earthen pots filled with fertilizer enriched puddled soil. Two germinated seeds were planted in each pot and for each entry, seedlings were raised in 8-10 pots. When the plants were thirty days old, they were thoroughly examined and cleaned to make them free from adults and eggs of other planthoppers and mirid bugs before the release of BPH nymphs. The plants were covered with mylar tubes provided with fine muslin cloth pasted on the ventilating windows and 20 one day old first instar nymphs were released onto the plant in the mylar tube and the open end of the tube was covered with a muslin cloth and tied with a rubber band. The plants were observed daily and number of adults was counted whenever they emerged and removed from plant. The sex and winged adults were recorded. The per cent females, males, winged females, males, wingless females and males was calculated. There were three replications for each test entry (Kalode *et al.,* 1978). The per cent nymphal survival was calculated by the following formula (Heinrichs *et al.,* 1985)

$$\text{Percent Nymphal survival} = \frac{\text{Number of adults emerged}}{\text{Number of nymphs released}} \text{X100}$$

Nymphal developmental period

Nymphal developmental period on selected rice entries 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 number of days taken for the nymphs to reach adult stage on each rice entry was recorded (Pongprasert and Weeraput, 1979). There were three replications.

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 developmental period (Panda and Heinrichs, 1983) as per the formula

$$\text{Growth index} = \frac{\text{Percent nymphs survived on the test culture}}{\text{Developmental period of nymphs on the test culture}}$$

Weight gain by adults

Newly emerged brown planthopper females were weighed individually in small vials and were released on the test entries covered with mylar tubes. The open end of mylar tube was covered with muslin cloth and tied with a rubber band. The insects were allowed to feed for 48 hours, then collected individually, and reweighed to record the difference in weight (Reddy *et al.,* 2005). Twenty insects were tested on each test entry.

Tolerance mechanism

Days to wilt

Experiments were conducted to investigate tolerance mechanism in the test entries as indicated by number of days required to wilt a rice plant after release of 25 first instar nymphs per plant on 30 days aged plants. The plants were observed daily for plant health and observations were recorded on the wilted test plants with all dried leaves. In the entries which survived for more days nymphs were released two to three times. The experiment was terminated at 50 days after release of nymphs and the number of plants which did not wilt at end of the study was recorded (Soundararajan *et al.,* 2003).

Days to wilt = Date of wilting of the test entry - date of release of nymphs

RESULTS AND DISCUSSION

Fecundity, Ovicidal test / per cent Egg hatching

The resistant and moderately resistant rice cultures, which served as hosts for BPH, had adverse effect on biology of BPH, while the susceptible check, TN 1 favoured multiplication of the pest. Resistant and moderately resistant entries were proved

Table 1: Fecundity and Hatching of BPH on selected NSN-2 entries

S.No	Entry IET No.	DS	Fecundity*	No. of Unhatched*	Hatching (%)**
1	23739	2.65 (R)	22.0 (4.7)^{g}	11.3 (3.4)^{i}	48.5 (44.1)^{ghi}
2	23620	2.8 (R)	39.7 (6.2)^{f}	23.0 (4.8)^{gh}	41.9 (40.3)^{i}
3	23660	3.0 (R)	53.0 (7.3)^{f}	29.0 (5.4)^{defgh}	45.4 (42.4)^{hi}
4	23661	3.25 (MR)	39.3 (6.2)^{f}	19.0 (4.3)^{hi}	53.2 (46.9)^{fgh}
5	23705	3.45 (MR)	50.7 (7.1)^{f}	28.3 (5.3)^{efgh}	44.8 (41.9)^{hi}
6	23702	3.5 (MR)	54.0 (7.3)^{f}	23.7 (4.8)^{gh}	56.3 (48.6)^{fg}
7	23665	3.75 (MR)	43.0 (6.5)^{f}	17.7 (4.2)^{hi}	58.7 (50.0)^{ef}
8	23223	3.95 (MR)	42.7 (6.4)^{f}	25.3 (4.8)^{gh}	43.5 (41.2)^{i}
9	23894	4.2 (MR)	135.3 (11.6)^{bcde}	52.0 (7.2)^{ab}	61.5 (51.6)^{def}
10	Purnendu (RC)	4.75 (MR)	126.7 (11.2)^{bcde}	56.3 (7.5)^{a}	55.7 (48.3)^{fg}
11	23656	4.85 (MR)	118.0 (10.9)^{e}	46.3 (6.8)^{abc}	60.7 (51.1)^{def}
12	23696	5.0 (MR)	128.7 (11.3)^{bcde}	41.3 (6.4)^{abcde}	67.8 (55.4)^{bcde}
13	23658	5.1 (MS)	122.7 (11.0)^{cde}	42.0 (6.5)^{abcd}	67.6 (55.3)^{bcde}
14	23391	5.1 (MS)	135.0 (11.6)^{bcde}	46.7 (6.8)^{abc}	65.9 (54.4)^{cde}
15	23942	5.15 (MS)	148.3 (12.2)^{bc}	39.3 (6.3)^{bcde}	73.9 (59.2)^{bc}
16	23221	5.2 (MS)	135.3 (11.6)^{bcde}	34.0 (5.8)^{cdefg}	74.6 (59.8)^{bc}
17	23741	5.25 (MS)	120.7 (11.0)^{de}	30.0 (5.5)^{defg}	75.1 (60.1)^{b}
18	23771	5.25 (MS)	132.0 (11.5)^{bcde}	37.3 (6.1)^{bcdef}	71.8 (58.0)^{bc}
19	23687	5.45 (MS)	150.3 (12.3)^{b}	47.0 (6.8)^{abc}	68.8 (56.1)^{bcd}
20	23723	5.5 (MS)	146.3 (12.1)^{bcd}	38.0 (6.1)^{bcde}	74.3 (59.5)^{bc}
21	TN1	9.0 (HS)	213.0 (14.6)^{a}	24.3 (4.9)^{fgh}	88.6 (70.2)^{a}
22	Ptb 33	2.1 (R)	42.0 (6.5)^{f}	30.0 (5.5)^{defg}	28.7 (32.3)^{j}
	SEm±		0.4	0.4	1.9
	CD (P = 0.05%)		1.2	1.2	5.5

R= Resistant; MR= Moderately Resistant; MS= Moderately Susceptible; HS= Highly Susceptible; * Figures in parentheses are square root transformed values; **Figures in parentheses are angular transformed values;Means with same letter are not significantly different at 5% level by DMRT

Table 2: Nymphal Survival and Nymphal duration and Growth index of BPH on selected NSN-2 entries

S.No	IET No.	D.S.	Nymphal Survival (%)	Female (%)	Male (%)	Sex Ratio	Nymphal Duration (Days)	Growth Index
1	23739	2.65 (R)	48.3 (44.0)^{jkl}	59.8 (51.2)^{bc}	40.2 (38.8)^{bc}	1.2	14.0^{bc}	3.4^{jk}
2	23620	2.8 (R)	25.0 (29.5)^{m}	87.5 (74.4)^{a}	12.5 (12.6)^{d}	4.0	15.9^{a}	1.6^{l}
3	23660	3.0 (R)	31.7 (34.1)^{lm}	49.2 (44.5)^{bcd}	50.8 (45.5)^{abc}	0.9	12.7^{fgh}	2.5^{kl}
4	23661	3.25 (MR)	55.0 (48.0)^{ijk}	59.3 (50.6)^{bc}	40.7 (39.4)^{abc}	1.4	13.6^{cde}	4.0^{ij}
5	23705	3.45 (MR)	91.7 (73.7)^{abc}	49.0 (44.4)^{bcd}	51.0 (45.6)^{abc}	1.0	14.6^{b}	6.3^{cdef}
6	23702	3.5 (MR)	93.3 (75.2)^{abc}	48.1 (43.9)^{bcd}	51.9 (46.1)^{abc}	0.9	15.4^{a}	6.0^{cdef}
7	23665	3.75 (MR)	65.0 (53.8)^{fghij}	51.5 (45.9)^{bcd}	48.5 (44.1)^{abc}	1.1	12.6^{fghi}	5.2^{fghi}
8	23223	3.95 (MR)	60.0 (50.9)^{hijk}	47.6 (43.6)^{bcd}	52.4 (46.4)^{abc}	0.9	13.4^{de}	4.5^{hij}
9	23894	4.2 (MR)	80.0 (63.8)^{cdefg}	58.1 (49.7)^{bc}	41.9 (40.3)^{bc}	1.4	12.4ghij	6.5^{bcde}
10	Purnendu (RC)	4.75 (MR)	70.0 (57.1)^{fghi}	50.4 (45.2)^{bcd}	49.6 (44.8)^{abc}	1.0	13.1ef	5.3^{efgh}
11	23656	4.85 (MR)	65.0 (53.7)^{ghij}	40.6 (39.4)^{cd}	59.4 (50.6)^{ab}	0.7	12.0^{j}	5.4^{defgh}
12	23696	5.0 (MR)	63.3 (52.7)^{ghij}	55.2 (48.0)^{bcd}	44.8 (42.0)^{abc}	1.2	13.4^{de}	4.7^{ghi}
13	23658	5.1 (MS)	83.3 (66.2)^{bcdef}	52.0 (46.1)^{bcd}	48.0 (43.9)^{abc}	1.1	12.6^{fghi}	6.6^{bcd}
14	23391	5.1 (MS)	76.7 (61.2)^{defgh}	48.2 (44.0)^{bcd}	51.8 (46.0)^{abc}	0.9	12.2^{hij}	6.3^{cdef}
15	23942	5.15 (MS)	75.0 (60.3)^{efghi}	59.5 (50.5)^{bc}	40.5 (39.5)^{bc}	1.5	12.8fg	5.8^{cdefg}
16	23221	5.2 (MS)	71.7 (58.0)^{fghi}	58.0 (49.6)^{bc}	42.0 (40.3)^{bc}	1.4	13.7^{cd}	5.2^{fgh}
17	23741	5.25 (MS)	73.3 (59.2)^{efghi}	55.6 (48.5)^{bcd}	44.4 (41.5)^{abc}	1.2	12.1^{ij}	6.0^{cdef}
18	23771	5.25 (MS)	70.0 (57.2)^{fghi}	66.1 (55.0)^{b}	33.9 (35.0)^{c}	1.8	12.3^{hij}	5.7^{defg}
19	23687	5.45 (MS)	91.7 (73.3)^{abcd}	51.0 (45.6)^{bcd}	49.0 (44.4)^{abc}	1.0	12.2^{hij}	7.5^{ab}
20	23723	5.5 (MS)	68.3 (56.0)^{fghij}	50.0 (45.0)^{bcd}	50.0 (45.0)^{abc}	1.0	12.3^{ghij}	5.5^{defgh}
21	TN1	9.0 (HS)	95.0 (79.5)^{a}	52.4 (46.3)^{bcd}	47.6 (43.6)^{abc}	1.1	11.9^{j}	8.0^{a}
22	Ptb 33	2.1 (R)	40.0 (39.1)^{klm}	50.0 (45.0)^{bcd}	50.0 (45.0)^{abc}	1.0	15.9^{a}	2.5^{kl}
	SEm±		4.4	4.5	4.5		0.2	0.4
	CD (P = 0.05%)		12.5	12.8	12.8		0.5	1.2

detrimental to BPH. Effect of different rice entries on fecundity and egg hatching are presented in Table 1. that indicated decrease in fecundity of BPH when fed on resistant and moderately resistant entries compared to the susceptible check, TN 1. Among the NSN-2 entries, IET 23739 recorded nine times lower fecundity compared to the susceptible check, TN 1 and the decrease was on par with the resistant check, Ptb 33. This phenomenon was observed among all resistant and moderately resistant entries, where fecundity ranged between 22.0 to 135.3 eggs/female compared to 213.0 eggs in susceptible check, TN 1. Among all the NSN-2 entries, IET 23739 has recorded less number of eggs (22.0 eggs) followed

Table 3: Weight gain in BPH adults fed on selected NSN- 2 entries

S.No	Entry IET No.	DS	Average weight BPH adults(mg) Before feeding	After feeding	Average weight Gain (mg)	Gain in the body weight (%)
1	23739	2.65 (R)	3.1	3.3[f]	0.2[l]	6.6 (14.5) [j]
2	23620	2.8 (R)	3.1	3.3[f]	0.2[l]	7.4 (15.3) [hij]
3	23660	3.0 (R)	3.1	3.4[ef]	0.3[jkl]	11.6 (19.5) [ghij]
4	23661	3.25 (MR)	3.6	3.9[bcdef]	0.3[kl]	7.4 (15.7) [ij]
5	23705	3.45 (MR)	3.6	4.2[abcd]	0.6[ghij]	18.0 (24.9) [fgh]
6	23702	3.5 (MR)	3.4	3.7[cdef]	0.3[kl]	8.0 (16.3) [hij]
7	23665	3.75 (MR)	3.0	3.5[ef]	0.5[ijkl]	16.1 (23.3) [fghij]
8	23223	3.95 (MR)	3.5	4.4[ab]	0.9[efgh]	24.5 (29.7) [def]
9	23894	4.2 (MR)	3.2	3.7[bcdef]	0.6[hijk]	17.6 (24.8) [fghi]
10	Purnendu (RC)	4.75 (MR)	3.3	4.0[bcdef]	0.7[ghi]	21.3 (27.0) [efg]
11	23656	4.85 (MR)	3.2	4.0[bcdef]	0.8[fgh]	26.0 (30.2) [def]
12	23696	5.0 (MR)	3.1	4.1[bcde]	1.0[def]	32.3 (34.6) [cde]
13	23658	5.1 (MS)	3.1	4.2[abcd]	1.1[cde]	37.3 (37.6) [bcd]
14	23391	5.1 (MS)	2.9	4.3[abc]	1.4[bc]	50.6 (45.5) [ab]
15	23942	5.15 (MS)	3.4	4.4[ab]	0.9[efg]	26.9 (31.2) [def]
16	23221	5.2 (MS)	3.4	4.3[abc]	0.9[efgh]	26.0 (30.3) [def]
17	23741	5.25 (MS)	2.9	4.3[abc]	1.4[bc]	51.0 (45.6) [ab]
18	23771	5.25 (MS)	2.7	3.8[bcdef]	1.0[def]	38.9 (38.5) [bcd]
19	23687	5.45 (MS)	3.0	4.3[abc]	1.3[bcd]	44.1 (41.5) [abc]
20	23723	5.5 (MS)	3.4	4.9[a]	1.5[b]	43.1 (41.0) [bc]
21	TN1	9.0 (HS)	3.0	4.8[a]	1.8[a]	59.5 (50.5) [a]
22	Ptb 33	2.1 (R)	3.3	3.6[def]	0.3[kl]	9.3 (17.6) [hij]
	SE(m+-)		0.24	0.2	0.1	3.2
	CD(0.05%)		NS	0.7	0.3	9.2

R = Resistant; MR = Moderately Resistant; MS = Moderately Susceptible; HS = Highly Susceptible; Figures in parentheses are angular transformed means;Means with same letter are not significantly different at 5% level by DMRT.

Table 4: Days to wilting of selected NSN-2 entries infested with BPH

S.No	Entry IET No.	DS	Days to wilt
1	23739	2.65 (R)	49.0[a]
2	23620	2.8 (R)	44.0[a]
3	23660	3.0 (R)	37.3[b]
4	23661	3.25 (MR)	35.3[bcd]
5	23705	3.45 (MR)	20.7[i]
6	23702	3.5 (MR)	27.3[fgh]
7	23665	3.75 (MR)	34.0[bcde]
8	23894	4.2 (MR)	34.0[bcde]
9	Purnendu (RC)	4.75 (MR)	30.7[defg]
10	23656	4.85 (MR)	29.3[defgh]
11	23696	5.0 (MR)	28.7[efgh]
12	23658	5.1 (MS)	28.0[efgh]
13	23391	5.1 (MS)	27.0[fgh]
14	23942	5.15 (MS)	29.0[efgh]
15	23221	5.2 (MS)	30.7[defg]
16	23741	5.25 (MS)	30.3[defg]
17	23771	5.25 (MS)	31.0[cdef]
18	23241	5.45 (MS)	28.3[efgh]
19	23687	5.45 (MS)	24.7[ghi]
20	23723	5.5 (MS)	24.0[hi]
21	23733	5.5 (MS)	23.3[hi]
22	TN1	9.0 (HS)	11.3[j]
23	Ptb 33	2.1 (R)	37.0[bc]
	SEm±		2.1
	CD (P = 0.05%)		6.1

R = Resistant; MR = moderately resistant; MS = Moderately Susceptible; HS = Highly susceptible; Means with same letter are not significantly different at 5% level by DMRT.

by IET 23661 (39.3 eggs), IET 23620 (39.7 eggs), IET 23223 (42.7 eggs), IET 23665 (43.0 eggs), IET 23705 (50.7 eggs), IET 23660 (53.0 eggs) and IET 23702 (54.0 eggs) which were on par with the resistant check, Ptb- 33 (42.0 eggs).

Eggs laid by BPH reared on resistant, moderately resistant, moderately susceptible, susceptible check and resistant check were allowed for hatching to assess the possible effect of host plants on hatching, if any and the results are furnished in the Table 1. Among different entries, on resistance check, Ptb-33 less hatching percentage of 28.7 was recorded followed by IET 23620 (41.9 %), IET 23223 (43.5 %), IET 23705 (44.8%), IET 23660 (45.4 %) and IET 23739 (48.5 %) which are on par with each other. Per cent egg hatching was more in the susceptible check, TN 1 (88.6 %) and there was a significant reduction in the egg hatching in case of resistant and moderately resistant entries. The per cent egg hatching ranged from 28.7 to 48.5; 43.5 to 67.8; and 65.9 to 75.1 on resistant, moderately resistant and moderately susceptible entries, respectively. Karim (1975) reported lower number of egg deposition on resistant varieties due to insufficient feeding. Similar results were obtained by Alagar *et al.* (2007) who reported that the number of unhatched eggs was significantly higher in resistant varieties than in susceptible varieties. They also reported that fecundity was more in susceptible varieties than resistant varieties. Present findings are in conformity with the findings of Bhanu *et al.* (2014) who reported that resistant variety MTU IJ 206-7-4-1 recorded significantly lowest number of eggs per ten seedlings (79.67) and on par with resistant check, Ptb 33 (109.33) and these were followed by MTU 1075, RGL 7001 and RGL 7002.

Per cent nymphal survival

Data on survival of nymphs of BPH on selected NSN 2 entries indicated wide difference in the survival pattern (Table 2.). In general, nymphal survival was found to be low on resistant and moderately resistant entries compared to susceptible check, TN1. Survival of nymphs ranged from 25.0 per cent to 93.3 per cent on resistant and moderately resistant entries compared to 95.00 per cent on the susceptible check, TN1. Among the resistant entries, IET No. 23620 adversely affected nymphal survival resulting in 25.0 per cent adult emergence. Similarly, resistant entries, IET No. 23660 and IET No. 23739 also affected nymphal survival where in only 31.7 and 48.3 per cent of nymphs became adults respectively, which were on par with resistant check, Ptb 33 (40.0 %).

The per cent survival of nymphs into adults on the moderately resistant entries, ranged between 55.0 to 93.3 per cent and on moderately susceptible entries, it was 68.3 to 93.3 per cent. The resistant entries had certain adverse effects on biology of BPH while the susceptible entries favoured development and multiplication of the same. Both the resistant and moderately resistant entries proved detrimental for the development of BPH. Our results corroborate with the findings of several workers (Sogawa and Pathak, 1970; Soundararajan *et al.*, 2003; Reddy *et al.,* 2005 and Uma *et al.,* 2006), in which only a small proportion of BPH nymphs developed into adults, when forced to stay and feed on resistant entries. In general with regard to adult sex, per cent female emergence was more than males when fed on majority of the entries, *i.e.* highest sex ratio (4.0) was observed with the entry, IET No. 23620 compared to other entries.

Nymphal duration

Developmental period of BPH nymphs varied significantly when fed on resistant, moderately resistant and moderately susceptible entries and ranged from 11.9 to 15.9 days (Table 2.). Among NSN-2 entries tested, IET No. 23620 showed significantly longer nymphal duration of 15.9 days followed by IET No. 23702 (15.4 days) which were on par with each other and as well as with resistant check, Ptb 33 (15.9 days). Shortest nymphal duration was observed on IET No. 23733 recording 11.9 days that was on par with susceptible check TN1 (11.9 days). Similar prolonged nymphal duration on resistant varieties was reported by Sable *et al.* (2014) which might be due to the inadequate feeding by the insects on the resistant entries due to presence of high total sugars and non-reducing sugars, which was also attributed to olfactory and gustatory stimuli of the insect (Alagar and Suresh, 2007). Bhanu *et al.* (2014) also reported that in resistant and moderately resistant rice cultures nymphal development period was significantly prolonged compared to 11.80 days in the susceptible check, TN1. They observed the significantly prolonged development period was in rice culture MTU IJ 206-7-4-1 (26.0 days) and was followed by MTU PLA 99-1-3-1-2 (23.0 days).

Growth index

Growth index values of BPH also varied significantly among resistant, moderately resistant and moderately susceptible entries (Table. 2). Lowest growth index of 1.6 was recorded on IET No. 23620 indicating unsuitability of the cultivar for growth and development of BPH followed by IET No. 23660 (2.5) and IET No. 23739 (3.4) which were on par with each other as well as on par with resistant check, Ptb 33 with a growth index of 2.5. However, highest growth index value for BPH was recorded on IET No. 23733 (7.8), IET No. 23687 (7.5), IET No. 23686 (6.9) and IET No. 23658 (6.6) which are on par with each other as well as with susceptible check, TN1 (8.0). Bhanu *et al.* (2014) reported that all the rice cultures registered growth index range between 1.31 to 6.37 than the susceptible check TN1 (8. 48). They further stated that WGL II 218-5-1 rice culture was significantly recorded lowest growth index (1.33) and was on par with resistant check Ptb 33 (1.91). Mishra *et al.* (2001) stated that growth index was calculated by both nymphal survival and nymphal developmental period so that, it could be considered as most reliable parameter for comparing the suitability of the test entries.

Gain in Body weight of BPH

Adult BPH females were weighed initially and released on to resistant, moderately resistant and moderately susceptible entries along with susceptible and resistant check and allowed to feed for 72 hours to assess possible effect of host plants in terms of increase in body weight and results are presented in Table 3. Results revealed that the weight gain in BPH adult female ranged from 0.2 mg to 1.0 mg per one day old adult female when reared on resistant and moderately resistant entries as compared to 1.8 mg in the susceptible check, TN1. However, in terms of per cent gain in body weight, it ranged from 6.36 to 11.6 on resistant and moderately resistant entries compared to the susceptible check, TN1 with 59.5 per cent gain in body weight in 72 hours. However, in case of resistant check Ptb 33 only 9.3 per cent gain in body weight was observed which is on par with resistant and moderately resistant entries. Among all NSN-2 entries, lowest gain in body weight (0.2 mg) was observed on IET No. 23739 (6.6 per cent gain) followed by IET No. 23620 (0.2 mg and 7.4 per cent gain), IET No. 23660 (0.3 mg gain), IET No. 23661 (0.3 mg gain) and IET No. 23702 (0.3 mg gain) along with the resistant check, Ptb 33 which has recorded 0.3 mg and 9.3 per cent gain in body weight, less body weight gain in BPH feeding on resistant cultures which were attributed to less intake of sap Sogawa (1973). Young adult females became gravid and gained significant weight gain within few days when fed on susceptible varieties, whereas they showed little evidence of maturation within such a short period and less increase in body weight on resistant varieties (Sogawa and Pathak, 1970). Present results are in line with the observations made by Reddy *et al.,* 2005 and Yong *et al.,* 2012 where they stated that BPH fed on resistant and moderately resistant varieties showed slower growth and less body weight compared to BPH fed on susceptible entries.

Therefore, it could be referred from the present work that due to the antibiosis mechanism, the insect fed on resistant entries, less feeding was observed and obtained less nutrients affecting the survival, hatching and weight gain in BPH.

Tolerance mechanism against BPH in terms of Days to wilt

Time taken for wilting of the seedlings after BPH infestation was used as a measure of tolerance in resistant, moderately resistant and moderately susceptible entries along with the susceptible check, TN1 and resistant check, Ptb 33. The susceptible TN1 took 11.3 days (Table 4.) for wilting, moderately susceptible entries took 23.3 days (IET No. 23733) to 31.0 days (IET No. 23771) and moderately resistant entries took 20.7 days (IET No. 23705) to 35.3 days (IET No. 23661) to wilt. However, resistant entries have recorded maximum of 49.0 days (IET No. 23739) and a minimum of 37.3 days (IET No. 23660) for wilting. The resistant entries, IET No. 23739 and IET No. 23620 required more days to wilt 49.0 days and 44.0 days, respectively that were on par with each other, followed by IET No. 23660 (37.3 days) which was on par with resistant check, Ptb 33 (37.0 days) and were significantly different from the susceptible check TN1 (11.3 days). BPH feeding was less on resistant entries and hence the plants could withstand wilting compared to the susceptible TN1 and moderately resistant entries. In the variety, "Utri Rajapan" tolerance was attributed to low feeding activity compared to the susceptible IR 20, more feeding activity and feeding on main shoot of IR 20 were the two possible reasons for getting more plant damage (Paguia *et al.,* 1980). Alagar and Suresh (2007) reported that 30 and 60 day old plants of ARC 10550, KAU1661 and ARC 6650 took significantly longer period (27 to 31 days) for wilting compared to TN1 (18.2 days) due to low population buildup. Inspite of supporting higher population of first generation nymphs, KAU 1661 took longer time for wilting. Jhansi Lakshmi *et al.* (2012) reported that the wild rice accessions survived for more than 34 days after exposure to BPH nymphs as compared to 5-6 days in susceptible check TN1 indicating presence of high level of tolerance mechanism. Similarly Dharshini and Siddegowda (2015) also reported that rice land races and resistance check, PTB-33 were recorded more number of days to wilt. These results are corroborated with the present findings.

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