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Assessment of Tolerance Level of Different Rice Genotypes Against *Sogatella furcifera* (Homoptera: Delphacidae)

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IH conducted the experiments and wrote the article. MS designed the experiments. MJA supervised the project. MOA, MA, AN and MQ revised the article. MMG helped in statistical analysis.

Key words
Tolerance, Functional plant loss index (FPLI), Plant dry weight loss(PDWL), Days to wilt, *Sogatella furcifera, Oryza sativa,* Controlled conditions

ABSTRACT

Whitebacked planthopper, *Sogatella furcifera* Horvath (Homoptera: Delphacidae) is very dangerous and serious pest of rice crop in the world. It also causes huge damage to rice yield in Pakistan. In this experiment we studied the resistance and tolerance level of different rice genotypes against whitebacked planthopper (WBPH). In standard seed box screening test 45 genotypes were tested against WBPH. Four genotypes showed resistance with damage rating 1 to WBPH, ten with damage rating 3 were moderately resistant to WBPH. Twenty-five genotypes with rating 5 were moderately susceptible, five with damage rating 7 were susceptible to WBPH. TN1 was highly susceptible to WBPH with damage rating 9. Tolerance parameters were also studied RPP 49 was found most tolerant among selected genotypes with FPLI (21.9%), PDWL (13.72 mg) and 15.24 (D) days to wilt followed by IR 72, Basmati Pak, N22 and Super basmati. TN1 was found to be less tolerant variety with FPLI (83.4%), PDWL (121.34mg) and 5.26 (D) days to wilt. The results suggest that RPP49 emerged as tolerant variety followed by N22, Basmati Pak, Super Basmati, IR 72. There are new varieties PKBB 8, PK 10684 and PK 10436 which also showed good level of tolerance against WBPH. These genotypes should be used in future breeding programs for the development of resistance against WBPH.

INTRODUCTION

Rice is an important staple food which feeds half of the global population and it is an important source of human calories (Xu *et al*., 2015). Rice is a major export commodity in Pakistan and it earns US$ 2 billion foreign exchange per annum (Anonymous, 2022-23). Insect pests are one of the major constraints in rice production (Heong and Hardy, 2009). Rice production is seriously affected by insect pests and diseases in Indian subcontinent (Babendreier *et al*., 2020). Both biotic and abiotic factors limit rice production and they cause 25% yield loss equal to Rs. 240 billion and 30 billion US$ (Dhaliwal *et al*., 2010) More than 100 species are described as pests of rice in which 20 are major pest insect species including rice stem borers, rice leaffolder and planthoppers. Rice planthoppers especially white backed planthopper (WBPH) is most serious pest of rice crop throughout Asia (Cheng, 2009; Hu *et al*., 2015). It directly causes damage to the crop by oviposition and it feeds on the plants and transmits the Southern rice black streaked dwarf virus (SRBSDV) (Zhou *et al*., 2008; Guo *et al*., 2013) and rice black streak dwarf virus -2 (RBSDV-2) (Zhang *et al*., 2008). Due to its heavy infestation crop becomes scorched (hopper burn)

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which as a result reduce crop growth and photosynthesis rate (Sumikarsih *et al*., 2019). WBPH is very destructive insect pest of rice which is well distributed on this crop throughout Pakistan (Mochida *et al*., 1982). During 1980's outbreak of this hopper was recorded first time in southern region of Pakistan on semi dwarf varieties which caused approximately 60% yield loss to the crop (Mahar *et al*., 1978; Majid *et al*., 1979; Ghauri, 1979; Rehman *et al*., 1986). After that WBPH has been considered as most widespread and major pest of rice crop. Punjab which is a major rice growing province of Pakistan, planthoppers can cause 7-10% yield loss annually. Estimated yield loss due to planthopper surge was 1.0 metric ton/ha which amounted US $ 250/ha during the growing season of 2017-18. (Sabir *et al*., 2019). Mostly WBPH is controlled by the use of pesticides. But this practice resulted in the development of insecticide resistance, pest resurgence and disruption in natural enemy balance in ecosystem (Wang *et al*., 2014). Furthermore, detection of insecticide residues in exported basmati rice consignments is a serious threat for the foreign exchange earnings (Kumar *et al*., 2015). However, the development of resistant varieties to WBPH is ecofriendly and environmentally safe technique to mitigate the after effects of pesticides. Research work on the development of resistant varieties against planthoppers was started at International Rice Research Institute (IRRI) Philippines in 1970 and many varieties were screened and developed against planthoppers. Many methods to determine tolerance levels among different rice genotypes were developed at IRRI (Heinrichs, 1985; Misra and Misra, 1991; Li *et al*., 2011; Khan and Saxena, 1986; Eickhoff *et al*., 2008). However, in Pakistan no detailed experiments were performed to evaluate the performance of existing rice germplasm for resistance against WBPH. Keeping in sight the above deliberations present project was designed to investigate the resistance and tolerance levels in different rice genotypes against WBPH.

MATERIALS AND METHODS

Study site

The present studies were conducted in the greenhouses of Rice Research Institute Kala Shah Kaku (RRI, KSK) Pakistan positioned at 31° 43' 17" N, 74° 16' 14" E. Rice is being grown here since long time and several insect pests especially WBPH's attack on rice crop is a serious concern during the cropping season. Excessive use of synthetic pesticides, fertilizers and other modern day crop management practices has significantly disturbed the biodiversity of pest insects in the area.

Plant material

The experimental material consisted of 45 rice lines (Table I) acquired from Rice Research institute, Kala Shah Kaku, Pakistan: PK 10680-3-1-2-1, PK 10686-2-1-1, PK 10461-7-2-1-2, PK 10684-6-1-1, PK 10824-9-1-3, PK 10825-5-1-1, PK 10835-9-1-1, PK 10663-6-1-2-1, PK 10436-4-2-2-1, PK 10436-2-1-1, PK10437-14-2-1, PK 10355-13-2-1, PK 10434-6-2-1, PK 10967-30-1, PK 10677-3-1-1, PK 10825-5-1-4, PK 10436-4-2-2-1, PKBB 15-116, PK 8892-4-1-3-1, PK 9444-8-1-2, PK 10683-12-1, PK 9966-10-1, PK 10029-13-2-1, PK 10324-1-1, PKBB 8, PK 10975-25-1-1, Bas Pak(6129), Bas 00515, Super Basmati, PK 1121 aromatic, Kisan Bas, Chenab Basmati, Punjab Basmati, KSK 476, KSK 480, KSK 481, KSK 486, KSK 514 and KSK 515 from Pakistan, N22 from India, DGWG and TN(1) from Taiwan, and IR 64, RPP 49 and IR 72 from IRRI.

Insect culture

Both adults and nymphs of white backed planthopper were collected from the rice crop at RRI, KSK with the help of aspirator. The culture of WBPH was started by shifting these specimens to TN1 (susceptible variety) sown in pots and reared for approximately 10 generations in bottom less hopper rearing cages (L×W×H 60×45×10 cm) placed on the galvanized iron tray. Potted plants were placed on these trays with 8 cm of water inside the cage. When the hopper population increased, older plants were replaced with new ones in the rearing cages. Old plants from the rearing cages with eggs of WBPH females were used to maintain culture in hopper rearing cages. These cages were placed in a greenhouse maintained at 28-30°C temperature and 55-60% RH (Heinrichs *et al*., 1985).

Standard seed box screening test (SSST)

Initial screening of rice germplasm was done in standard seed box screening test (SSST). The wooden seed boxes with 60×40×10 cm dimension and 39 test entries can be evaluated in one box. The seed boxes were filled with 3-4 cm depth with soil. Test entries were sown in replication in the boxes along with resistant (RPP49) and susceptible check (TN1) varieties. In total 30 seeds of each variety were sown in a single row in each replication. After 15 to 20 days of sowing, ten 2nd and 3rd instar nymphs were released per seedling in the seed boxes from hopper rearing cages and the boxes were covered with wire mesh cover. The entries in each seed box were graded when the seedlings of susceptible check in that box are about 90% dead (Heinrichs *et al*., 1985; Horgan, 2009; Han *et al*., 2018). The plant damage was graded using the Standard Evaluation System (SES) scale for rice fifth edition (IRRI, 2013) (Table I).

Table I. SES scale of injuries caused by WBPH to rice plant.

0	No injury	HR
1	Very slight injury	R
3	First and second leaves with orange tips, partially stunting	MR
5	More than half of the leaves with yellow orange tips, pronounced stunting	MS
7	More than half the plants dead, remaining plants severely stunted and wilted	S
9	All plants dead	HS

HR, Highly resistant; R, Resistant; MR, Moderately resistant; MS, Moderately susceptible; S, Susceptible; HS, Highly susceptible.

After this test 14 topmost resistance varieties were selected for further experiments to study tolerance parameters of rice genotypes to *S. furcifera.*

Tolerance of rice genotypes against S. furcifera

For tolerance assessment, seedlings of tested varieties were grown in pots and covered with Mylar cages. When plants reached 30 days, twenty-five *S. furcifera* nymphs were released on each genotype. Similarly, uninfected plants were also maintained alongside. Experiment was replicated five times in a RCBD design. Tested genotypes were planted along with resistant and susceptible check varieties. When infested plants started to wilt, these were removed from the pots with roots. Roots of infested and uninfected plants were washed and soil was removed. The plants were air dried for 2 h. Then plants were dried at 70°C in an oven for 48h. WBPH were also removed from the cages with the help of aspirator and they were oven dried at 60°C for 48h. Functional plant loss index was calculated by formula (Panda and Heinrichs, 1983).

$$\text{Functional plant loss index (FPLI)} = 1 - \frac{\text{Dry weight of infested plants}}{\text{Dry weight of uninfested plants}} \times 100$$

Plant dry weight loss to *S. furcifera* was also calculated by the following formula (Sarao and Bentur, 2016).

$$\text{Dry weight (mg) produced (PDWL)} = 1 - \frac{\text{Dry weight of uninfested plants} - \text{Dry weight of infested plant}}{\text{Dry weight of WBPH progeny on infested plants}} \times 100$$

Statistical analysis

One way and two-way ANOVA was used for the analysis of the variance. Means were separated by Tukey HSD test ($P<0.05$) for significance differences between treatments (Sokal and Rohlf, 1995). Data was expressed as mean±SE. Data was analyzed with Statistix software (version 8.1) (Tallahassee, FL).

RESULTS

Standard seed box screening test

There was significant difference of damage by *S. furcifera* present among rice genotypes in standard seed box screening test (Table II). Among 45 genotypes tested, varied response of different varieties was observed. Genotypes RPP 49, N22, IR72 and IR 64 with damage rating 1 showed resistance to the *S. furcifera*. Basmati Pak, Super Basmati, PKBB 8 and PK 9966 with damage rating 3 were moderately resistant to *S. furcifera*. Basmati 515, PK 1121 aromatic, Kisan Basmati, DGWG, PK 10824-9-1-3 with damage rating 7 were susceptible, TN1 with damage rating 9 was highly susceptible to *S. furcifera* while rest of the genotypes were moderately susceptible to *S. furcifera* with damage rating 5.

Table II. Standard seed box screening test.

Genotypes	Score	Rating
PK 10680-3-1-2-1, PK 10686-2-1-1, PK 10461-7-2-1-2, PK 10825-5-1-1, PK 10835-9-1-1, PK 10663-6-1-2-1, PK 10436-4-2-2-1, PK 10436-2-1-1, PK10437-14-2-1, PK 10434-6-2-1, PK 10967-30-1, PK 10677-3-1-1, PK 10825-5-1-4, PKBB 15-116, PK 8892-4-1-3-1, PK 9444-8-1-2, PK 10029-13-2-1, PK 10324-1-1, PK 10975-25-1-1, Chenab Basmati, Punjab Basmati, KSK 481, KSK 486, KSK 514, KSK 515	MS	5
PK 10684-6-1-1, PK 10355-13-2-1, PK 10436-4-2-2-1, PK 10683-12-1, PK 9966-10-1, PKBB 8, Bas Pak(6129), Super Basmati, KSK 476, KSK 480	MR	3
PK 10824-9-1-3	S	7
N22	R	1
Bas 00515	S	7
PK 1121 aromatic	S	7
Kisan Bas	S	7
DGWG	S	7
TN(1)	HS	9
IR 64	R	1
RPP 49	R	1
IR 72	R	1

R, Resistant; MR, Moderately resistant; MS, Moderately susceptible; S, Susceptible; HS, Highly susceptible.

Tolerance parameters of rice genotypes against S. furcifera

Functional plant loss index (FPLI)

There were significant differences observed among

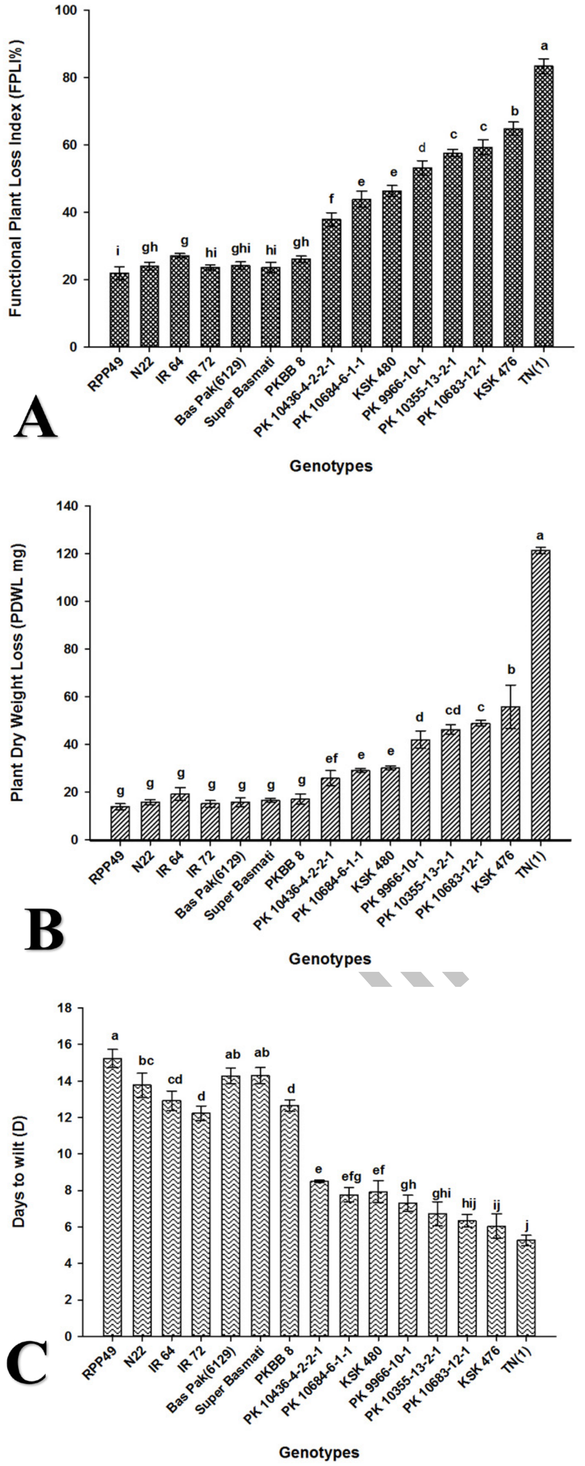

Fig. 1. Functional Plant loss index (FPLI %, A), plant dry weight loss (PDWL, B), and days to wilt (C) of different rice genotypes against Sogatella furcifera. Means with different lower-case letters are significantly different at p≤0.05 (Tukey's HSD test).

different rice genotypes for functional plant loss index (FPLI) ($F_{14, 74}$=806.88, P<0.01). Maximum plant loss (83.4) by *S. furcifera* was recorded on susceptible rice variety TN1. On KSK 476 (64.86), PK 10683(59.32), PK 10355(57.58), PK 9966 (53.16) loss was observed. Minimum plant loss index was recorded on RPP49 followed by IR 72, Super Basmati, N22, PKBB 8 and IR 64 (Fig. 1A).

Plant dry weight loss (PDWL)

PDWL among rice genotypes is also significantly different ($F_{14, 74}$=419.97, P<0.01). Minimum dry weight loss was recorded on RPP49 (13.72). After that minimum weight loss was documented on IR 72, N22, Basmati Pak, Super Basmati and PKBB 8 respectively. TN1 showed maximum dry weight loss by the attack of *S. furcifera* (121.34) followed by KSK 476, PK 10683, PK 10355, PK 9966, KSK 480, PK 10684 and PK 10436 rice genotypes (Fig. 1B).

Days to wilt

Days to wilt differ significantly among different genotypes ($F_{14, 74}$=274.44, P<0.01). Minimum days (5.26) were recorded on TN1 and maximum number of days (15.24) recorded on RPP49 rice genotypes followed by Super Basmati (14.3), Basmati Pak (14.28), N22(13.78), IR 64(12.92), IR 72 (12.24), PKBB 8 (12.66), PK 10436(8.5), KSK 480(7.94), PK 10684 (7.76), PK 9966(7.3), PK 10355(6.72), PK 10683(6.34) and KSK 476(6.04) rice genotypes (Fig. 1C).

DISCUSSION

Host plant resistance is a vital component in pest management programs due to its specificity to the target pests with no adverse effect on the environment and beneficial organisms. Due to the migratory nature of *S. furcifera* spray control decisions are difficult in a cropping season. Due to increased insecticide resistance in *S. furcifera,* host plant resistance and development of resistant varieties is imperative. In monogenic rice lines only limited available resistant genes are effective. Hence, thorough screening of resistance in rice germplasms is essential for the detection and utilization of resistance genes against planthoppers (Horgan *et al*., 2015). Screening of rice germplasm was made using variety of methods including standard seed box screening method. This test was performed to test the resistance level among 45 rice genotypes. Four varieties with damage rating 1 were found resistant (R) at 5 days after infestation. Ten genotypes were found moderately resistant (MR), 5 were found susceptible (S), one was highly susceptible (HS) and rest of 25 were found moderately susceptible (MS) to *S. furcifera*. TN1 was used as susceptible check while RPP49 genotype was used as resistant check. The genotype TN1 showed highest level of damage score 9 as reported by Heinrichs and Rapusas (1983) and Ramesh *et al*. (2014). RPP49 is a resistant variety to *S. furcifera* which is imported from IRRI, Philippines. N22 genotype with one resistant gene against *S. furcifera* also reported by Myint *et al*. (2009). Among the selected genotypes Basmati Pak (6129) was also documented as resistant cultivar to whitebacked planthopper (Heinrichs and Rapusas, 1983). From this test 14 topmost resistant genotypes were selected further for resistance mechanism studies in order to select most appropriate genotype with resistance against *S. furcifera*.

Plant resistance is classified as antixenosis, antibiosis and tolerance. Laboratory bioassays are necessary for the evaluation of resistant varieties for resistance. Several no choice tests were performed like nymphal survival, adult longevity, honey dew measurement, egg hatchability and growth index on selected genotypes. Tolerance is the ability of a plant to produce good quality and yield despite insect attack. Functional plant loss (FPLI) method was developed by Panda and Heinrichs (1983) and they identified rice varieties Kanchna, Utrirajapan and Triveni which were tolerant to *Nilaparvata lugens*. Alam and Cohen (1998) improve the tolerance parameter as they used plant dry weight loss (PDWL) as per unit dry weight of insect produced. *N. lugens* reduced plant dry weight loss (Chen and Cheng, 1978). Geethangali *et al*. (2009) suggested a test of days to wilt as tolerance parameter. Alagar and Suresh (2007) observed that 30 to 60 days older plants of varieties ARC6650, ARC 10550 and KAU 1661 took more days to wilt as compared to TN1. Ramesh *et al*. (2014) proposed a dominant gene wbph12 (t) to exert tolerance to Saina sivappu rice variety against *S. furcifera*. Rubia *et al*. (2003) in an experiment found that WBPH attack exerts strong influence on the plant height of varieties. It also reduced number of tillers, leaf area, photosynthetic rates and plant dry weight. WBPH reduced the development and growth of rice leaves, stems and also lessen the root dry weight of the cultivar. WBPH density was lower in resistant varieties as compared to TN1. These results support our findings that more functional plant loss index (FPLI) was recorded in TN1 rice variety, while on RPP49, N22, IR 64, IR74, Super Basmati, Basmati Pak and PKBB 8, FPLI was significantly lower than the susceptible one. Similar results of plant dry weight loss (PDWL), and days to wilt (D) were found and there was significant differences observed among resistant and susceptible rice varieties.

CONCLUSION

It is concluded from the above discussion that the rice germplasm has shown resistance to WBPH in standard seed box screening test. In further tolerance studies it is revealed that genotypes like RPP49 exhibited more tolerance than other varieties N22, Basmati Pak, IR 72 and PKBB 8. There are couple of new genotypes PK 10684 and PK 10436 which also exhibited significant tolerance to WBPH. These genotypes can be used in different breeding programs. As a result, the quantity of spray on the rice crop against WBPH will be reduced which will be more ecofriendly to the beneficial fauna and it will further reduce insecticide residues in the rice grains.

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Ethical statement

We ensure that all research is conducted in accordance with ethical principles. Neither human was the subject in this research nor such kind of animal, which required any administrative approval.

Statement of conflict of interest

The authors report no conflict of interest.

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