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GENETICS OF WHITEBACKED PLANTHOPPER, *Sogatella furcifera* (Horváth), RESISTANCE IN RICE

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SUMMARY

The genetics of resistance to whitebacked planthopper (WBPH) was investigated in six donors. Three donors were known to possess whitebacked planthopper resistance genes *viz.*, ADR 52 (*Wbph 3*), Podiwi A8 (*wbph 4*), and ARC 6650 (*wbph 4*). Three other donors *viz.*, ARC 5984, Velluthecherra, and MO 1 are suspected to possess unknown genes for resistance based on their reaction to WBPH. Each of the donors was crossed with a susceptible check (Taichung Native 1). Further, the crosses of ARC 6650 x ARC 5984, Podiwi A8 x MO 1, ADR 52 x Velluthecherra, Podiwi A8 x ARC 6650, and ARC 6650 x ADR 52 were made to investigate the allelic relationship of resistance genes. The parents, F_1s and F_2 progenies were screened in the greenhouse against a local population of the whitebacked planthopper. The inheritance pattern of resistance indicated a single dominant gene in ADR 52; a single recessive gene in ARC 6650, ARC 5984, and Podiwi A8; two dominant genes in Velluthecherra; and one dominant and one recessive gene in MO 1. Test of allelism revealed that the recessive gene present in ARC 5984 and ARC 6650 was allelic to that of Podiwi A8 (*wbph 4*). The recessive gene of MO 1 was non-allelic to that of Podiwi A8 (*wbph 4*). The dominant gene present in ADR 52 was different from that in Velluthecherra.

Key words: Rice, whitebacked planthopper, resistance genes, inheritance.

The whitebacked planthopper (WBPH), *Sogatella furcifera* (Horváth), causes considerable yield losses in rice (Khan and Saxena, 1985). It is distributed throughout South, Southeast, and East Asia (Nasu, 1967). Nymphs and adults suck phloem sap (Auclair and Baldos, 1982; Khan and Saxena, 1984) from leaves and leaf sheaths turning them yellow and reducing plant height, tillering, and filled grains. Severe infestation of the insect leads to hopper-burn resulting in complete drying and death of the crop (Pathak, 1968). In India, severe outbreaks of whitebacked planthopper incidence have been reported in the past across the states (Gunathilagaraj and Ganesh Kumar, 1997). During 1997 to 1998, the sudden outbreak in southern India caused total crop failure (Ambikadevi *et al.*, 1998). The main approach for the management of planthoppers in India and elsewhere involves the use of germplasm with diverse genes for resistance (Khush, 1980). A large number of donors, germplasm accessions, and breeding material have been screened in the greenhouse and various donors of resistance have been identified (Anonymous, 1998).

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Studies on the inheritance of WBPH resistance revealed eight major genes, *i.e.*, *Wbph 1* in N22 (Sidhu *et al.*, 1979), *Wbph 2* in ARC 10239 (Angeles *et al.*, 1981), *Wbph 3* in ADR 52 (Hernandez and Khush, 1981), *wbph 4* in Podiwi A8 (Hernandez and Khush, 1981), *Wbph 5* in N' Diang Marie (Wu and Khush, 1985), *Wbph 6(t)* in Giu-yi-gu (Brar and Khush, 1991), and *Wbph 7(t)* and *Wbph 8(t)* in B5 (Tan *et al.*, 2002). Among these genes, *wbph 4* is recessive, whereas, the other seven are dominant genes. These studies indicated that resistance to WBPH is simply inherited and is controlled by either a single dominant or by a single recessive gene (Angeles *et al.*, 1981; Nair *et al.*, 1982; Saini *et al.*, 1982; Krishna *et al.*, 1984; Singh *et al*, 1984; Gupta and Shukla, 1986; Gunathilagaraj and Ganesh Kumar, 1997) or two independent genes, either both dominant or one dominant and one recessive (Angeles *et al.*, 1981 and 1986; Hernandez and Khush, 1981). In addition to these genes, involvement of minor genes conferring resistance has also been reported (Yamasaki *et al.*, 1999; Kadirvel *et al.*, 1999; Geethanjali, 2001; Sogawa *et al.*, 2001). The genetics of resistance in several donors still remain unelucidated. Therefore, an investigation was made to identify novel genes for resistance to WBPH in donors that are frequently used in breeding for resistance to this insect pest.

MATERIALS AND METHODS

The seeds of six genotypes that have consistently shown a high level of resistant reaction to WBPH in the greenhouse at DRR were obtained from the DRR germplasm centre and used as parents in this study (Table 1). The cultivar TN1 was also included as susceptible check in the tests. The three donors with known resistance genes (ADR 52, Podiwi A8, and ARC 6650) were crossed with three other donors with unknown resistance genes (ARC 5984, Velluthecherra, and MO 1). In the free-choice seedling test, the crossed seeds (F_1) and the F_2 progenies along with parents and checks were sown in trays. A basal dose of di-ammonium phosphate (40N:40P Kg/ha) was given at the time of soil mixing, filling trays up to a depth of 5 cm. Seeds were sown in lines in plastic trays (60 x 40 cm) at a spacing of 5 cm between lines. In each tray, the middle row was sown with resistant MO 1 and two border rows on either side with susceptible TN1. In addition to parents and F_1s (each comprised of 25-30 seedlings), all the seedlings in the F_2 progenies of all crosses were also evaluated for their reaction to WBPH. A local virulent population of WBPH, obtained from fields and maintained at DRR, was used in the tests. The rice seedlings (10-15 days old) were exposed to WBPH by releasing nymphs (2nd and 3rd instar) at a rate of 8-10/seedling. Care was exercised by using separate cubicles to prevent insects from flying away from the trays. All the plants were provided with irrigation as and when required. After inoculation, the plants were kept under high humid conditions in a greenhouse equipped with a water cooling system. Observations were recorded 14 days after infestation on the severity of WBPH reaction based on a 0-9 scale (IRRI, 1996) with 0= no damage; 1= very slight damage; 3= 1st and 2nd leaves of most seedlings with partial yellowing; 5= pronounced yellowing and stunting or 10-25% of the seedlings wilting; 7= >50% seedlings wilting or dead and the remaining plants severely stunted and dying; and 9= all seedlings dead. The data on reaction to WBPH were rearranged by treating the mean damage scores < 3 as resistant and scores >5 as susceptible to be able to draw inference on seedling performance. Based on the reaction of the seedlings, the progeny was grouped as susceptible or resistant to arrive at the segregation ratio. These ratios were further tested for their goodness of fit using the chi-square test. Statistical analyses were done as per Gomez and Gomez (1984).

Table 1. Reaction to whitebacked planthopper of rice used as parents in repeat tests.

Cultivar	Origin	Damage score (0-9 scale)*
Donors with known genes		
ADR 52 (*Wbph 3*)	India	3.0
Podiwi A8 *(wbph 4)*	Sri Lanka	2.5
ARC 6650 (*wbph 4*)	India	2.8
Donors with unknown genes		
ARC 5984	India	3.0
Velluthecherra	India	2.0
MO 1 (Resistant check)	India	1.5
Taichung Native 1 (Susceptible check)	Taiwan	9.0

*IRRI, (1996).

RESULTS AND DISCUSSION

Mode of inheritance of resistance

The resistant donors *i.e.*, ADR 52, Podiwi A8, ARC 6650, ARC 5984, Velluthecherra, and MO 1 used in the present study recorded resistance and TN1, a susceptible reaction (Table 1). Hernandez and Khush (1981) reported that Podiwi A8 was effective against a WBPH population of the Philippines where it was rated as moderately resistant (score of 4.2) in the free choice test and susceptible (score of 4.6 to 7.8) in a no choice test. In the present study, however, Podiwi A8 was highly resistant with a damage score of 2.5 in the free choice test while also showing a resistant reaction (score of 3.0) in the no choice test. This may indicate the possible occurrence of biotype variation and Podiwi A8 can be used as a potential donor for WBPH resistance in India. The F_1s derived from the cross of TN1 with ADR 52 (*Wbph3*) was resistant, indicating dominance of resistance over susceptibility. In the F_2 population, the ratio of resistant and susceptible seedlings in the cross TN1 x ADR 52 showed goodness of fit to the expected ratio of 3R:1S ($\chi 2 = 1.90$, p= 0.20-0.10) (Table 2). This finding confirmed the earlier report of Hernandez and Khush (1981) about the monogenic and dominant gene control of WBPH resistance in ADR 52 against the WBPH population of the Philippines. Since the *Wbph3* gene has been effective over the years against both the Philippine and Indian WBPH populations, transferring this gene into high yielding varieties would help in obtaining long-lasting WBPH resistance.

The F_1 seedlings of the crosses TN1 x ARC 6650, TN1 x ARC 5984, and TN1 x Podiwi A8 were found to be susceptible. The F_2 segregation showed a good fit to the ratio of 3S:1R (χ^2= 1.86, 0.01, and 0.94, respectively) indicating that resistance in the donors ARC 6650, ARC 5984, and Podiwi A8 is governed by a single recessive gene (Table 2). Hernandez and Khush (1981) reported that Podiwi A8 possessed a single recessive gene effective against the WBPH population of the Philippines. A similar type of recessive gene control of WBPH resistance was reported by Gupta and Shukla (1986) in the entries IET 4695, IET 6288, and NCS 212, and by Krishna *et al.* (1984) in ARC 6650. The present findings also indicated that the WBPH resistant genes, *Wbph 3* and *wbph 4*, are effective against the Philippines' WBPH population.

Table 2. Reaction to WBPH of F_1 and segregating F_2 populations from crosses between rice cultivars.

Name of cross	F_1 seedlings	F_2 population R	F_2 population S	Ratio (R:S)	χ^2	P value
Susceptible x Resistant						
TN 1 x ADR 52	R	112	48	3:1	1.90	0.20-0.10
TN 1 x ARC 6650	S	28	92	1:3	1.86	0.20-0.10
TN 1 x ARC 5984	S	42	122	1:3	0.01	0.95-0.90
TN 1 x Podiwi A8	S	99	265	1:3	0.94	0.50-0.30
TN1 x Velluthecherra	R	164	14	15:1	0.79	0.50-0.30
TN 1 x MO 1	R	281	59	13:3	0.34	0.70-0.50
Resistant x Resistant						
Podiwi A8 x ARC 6650	R	501	7	-		-
ARC 6650 x ARC 5984	R	210	0	All resis -tant	-	
Podiwi A8 x MO 1	R	85	28	45:19	1.29	0.30-0.20
ADR52 x Velluthecherra	R	186	14	57:7	2.79	0.10-0.05
ARC 6650 x ADR 52	R	205	45	13:3	0.03	0.90-0.80

R-Resistant.
S-Susceptible.

The cross of TN 1 x Velluthecherra recorded a resistance reaction in the F_1 that segregated into 15R:1S in the F_2 generation (χ^2= 0.79, p= 0.50-0.30), indicating the presence of two dominant genes conferring resistance.

The F_1 seedlings of the cross between TN1 and MO 1, the most frequently used susceptible and resistant checks, respectively, in WBPH screening programs was resistant and the F_2 progeny showed a good fit to a segregation ratio of 13R:3S ratio (χ^2= 0.34, p= 0.70-0.50) revealing the presence of one dominant and one recessive gene. Angeles *et al.* (1981) reported that the resistance in the cultivars WC 1240 and Colombo against the Philippine population of WBPH was governed by one dominant and one recessive gene.

Studies on allelic relationship

The information on allelic relationships of the resistance genes was obtained from the reactions of F_1 and F_2 populations from five crosses involving six donors. The F_1 plants of the crosses ARC 6650 x ARC 5984, ARC 6650 x ADR 52, ADR 52 x Velluthecherra, Podiwi A8 x MO 1, and Podiwi A8 x ARC 6650 were all found resistant (Table 2).

The F_2 seedlings of the cross ARC 6650 x ARC 5984 did not show any segregation for susceptibility. This indicated that the gene conferring resistance in ARC 5984 is allelic to that of ARC 6650 (*wbph4*). The F_2 segregation ratio of 45R:19S in the cross Podiwi A8 x MO 1 with a non significant χ^2 value (1.29) demonstrated a good fit indicating the involvement of three genes. The recessive gene of MO 1 appears to be non-allelic to that of Podiwi A8. Since the F_2 population of Podiwi A8 and MO 1 was small, the three-gene ratio analysis may lead to a biased estimate; hence, this result needs to be confirmed.

When Velluthecherrra was crossed with ADR 52 (*Wbph 3*), resistant and susceptible segregants were obtained in the ratio of 57R:7S (χ^2 = 2.79, p= 0.10-0.05), indicating the involvement of three dominant genes.

The F_2 seedlings derived from the cross Podiwi A8 x ARC 6650 showed no segregation. Although seven F_2s from a total of 508 F_2s died due to chlorotic leaves, this possibly was not due to insect damage. This further indicated that the recessive gene present in Podiwi A8 and ARC 6650 were allelic (*wbph 4*). In the cross ARC 6650 x ADR 52, one dominant and one recessive gene, as expected, were observed as revealed by the F_2 segregation ratio of 13R:3S and a non significant χ^2 value (0.03).

CONCLUSIONS

The present study provided insights on the spread of diverse WBPH resistance genes across geographic boundaries and on the simple nature of their inheritance in rice cultivars. The donor ARC 5984 possessed a single recessive gene *(wbph 4)*. Velluthecherra harbored *Wbph 3* gene, with a second dominant gene yet to be identified. Similarly, MO 1 contained a recessive gene (*wbph4*), with another dominant gene still unidentified. The present results confirm earlier findings indicating that the resistance genes *Wbph 3* and *wbph 4* are effective against the WBPH populations of India and the Philippines. These WBPH resistance genes can, therefore, be incorporated into improved high yielding cultivars to obtain stable resistance to this important insect pest.

REFERENCES

Ambikadevi, D., B. Haseena, G. Thomas, and H. Bhaskar. 1998. Whitebacked planthopper, *Sogatella furcifera* (Horvath) (Homoptera: Delphacidae), a major pest of rice in Kuttanad, Kerala. *Insect-Environ.* 4:36.

Angeles, E.R., G.S. Khush, and E.A. Heinrichs. 1981. New genes for resistance to whitebacked planthopper in rice. *Crop Sci.* 27: 47-50.

Angeles, E.R., G.S. Khush, and E.A. Heinrichs. 1986. Inheritance of resistance to planthoppers and leafhoppers in rice. In: *Rice Genetics*, IRRI, Manila, Philippines, pp. 537-549.

Anonymous, 1998. *Evaluation of Rice Germplasm for Biotic Stresses*. ICAR Adhoc Research Network Program 1993-1998, Directorate of Rice Research, Hyderabad, A.P., India.

Auclair, J.L., and E. Baldos. 1982 Feeding by the whitebacked planthopper, *Sogatella furcifera,* within susceptible and resistant rice varieties. *Entomologia Exp. Appl.* 32:200-203.

Brar, D.S., and G.S. Khush. 1991. Genetics of resistance to insects in crop plants. *Adv. Agron.* 45:223-274.

Geethanjali, S. 2001. *Molecular marker analysis for resistance to planthoppers(Sogatella furcifera Horvath and Nilaparvata lugens Stal) in rice (Oryza sativa L). using simple sequence repeats.* M.Sc. Thesis. Tamil Nadu Agricultural University, Coimbatore, India.

Gomez, K.A., and A.A. Gomez. 1984. *Statistical Procedures for Agricultural Research.* IRRI, Los Baños, Philippines.

Gunathilagaraj, K., and M. Ganesh Kumar. 1997. Rice insect outbreaks: an analysis. *Madras Agric. J.* 84:298-311.

Gupta, A.K., and K.K. Shukla. 1986. Sources and inheritance of resistance to whitebacked planthopper (*Sogatella furcifera*) in rice. In: *Rice Genetics*, IRRI, Philippines, pp. 529-535.

Hernandez, J.E., and G.S. Khush. 1981. Genetics of resistance to whitebacked planthopper in some rice (*Oryza sativa* L.) varieties. *Oryza* 18:44-50.

IRRI. 1996. *Standard Evaluation System for Rice.* IRRI, Manila, Philippines. 30 p.

Kadirvel, P., M. Maheswaran, and K. Gunathilagaraj. 1999. Molecular mapping of quantitative locus (QTLs) associated with resistance to whitebacked planthopper in rice. *Int. Rice. Res. Notes.* 24:12-14.

Khan, Z.R. and Saxena, R.C. 1984. Electronically recorded waveforms associated with the feeding behavior of *Sogatella furcifera* (Homoptera: Delphacidae) on susceptible and resistant rice varieties. *J. Econ. Entomol.* 77:1479-1482.

Khan, Z.R. and Saxena, R.C. 1985. A selected bibliography of the whitebacked planthopper, *Sogatella furcifera* (Horvàth) (Homoptera: Delphacidae). *Insect Sci. Appl.* 6:115-134.

Khush, G.S. 1980. Breeding rice for multiple disease and insect resistance. In: *Rice Improvement in China and Other Asian countries.* International Rice Research Institute and Chinese Academy of Agricultural Sciences, IRRI, Los Baños, Philippines, pp. 219-238.

Krishna, T.S., D.V. Seshu, and M.B. Kalode. 1984. Inheritance of resistance to white backed planthopper in rice. *Indian. J. Genet. Plant Breed.* 44:329-335.

Nair, V.R., T.M. Masajo, and G.S. Khush. 1982. Genetic analysis of resistance to white backed planthopper in twenty one varieties of rice, *Oryza sativa* L. *Theor. Appl. Genet.* 61:19-22.

Nasu, S. 1967. Rice leafhoppers. In: *The Major Insect Pests of the Rice Plant.* Johns Hopkins Press, Baltimore, MD, USA, pp. 493-523.

Pathak, M.D. 1968. Ecology of common pests of rice. *Ann. Rev. Entomol.* 13:257-296

Saini, R.S., G.S. Khush, and E.A. Heinrichs. 1982. Genetic analysis of resistance to whitebacked planthopper, *Sogatella furcifera* (Horvath), in some varieties. *Crop Prot.* 1:289-297.

Sidhu, G.S., G.S. Khush, and F.G. Medrano. 1979. A dominant gene in rice for resistance to whitebacked planthopper and its relationship to other plant characteristics. *Euphytica* 28:227-232.

Singh, J.P., J.S. Nanda, and H. Singh. 1984. Genetics of resistance to whitebacked planthopper (WBPH) in two rices. *Int. Rice. Res. Newsl.* 9:7.

Sogawa, K., H. Fujimoto, Q. Qian, S. Teng, G. Liu, and L. Zhu. 2001. QTLs for ovicidal response to whitebacked planthopper in rice. *Chinese Rice Res Newsl.* 9:5.

Tan, G., X. Ren, Q. Weng, L. Zhu, and G. He. 2002. Two whitebacked planthopper resistance genes shared the same loci with brown planthopper resistance genes. *Abtr. Intl. Rice Congr.*, CAAS, Beijing, China.

Wu, C.F., and G.S. Khush. 1985 A new dominant gene for resistance to whitebacked planthopper in rice. *Crop Sci.* 25:505-509.

Yamasaki, M., H. Tsunematsu, A. Yoshimura, N. Iwata, and H. Yasui. 1999. Quantitative trait locus mapping of ovicidal response in rice *Oryza sativa* L. against the whitebacked planthopper, *Sogatella furcifera* (Horvath) *Crop Sci.* 39:1178-1183.