CROP PROTECTION (1982) 1 (3), 289–297

Genetic analysis of resistance to whitebacked planthopper, *Sogatella furcifera* (Horvath), in some rice varieties

RAVINDER S. SAINI, G.S. KHUSH AND E.A. HEINRICHS

International Rice Research Institute, PO Box 933, Manila, Philippines

ABSTRACT. For genetic analysis of resistance to the whitebacked planthopper, *Sogatella furcifera* (Horvath) (Homoptera: Delphacidae), in 13 rice varieties, seedlings at the one-leaf stage were artificially infested in the greenhouse with second- and third-instar nymphs of this planthopper. Reactions of the seedlings were recorded 7–10 days after infestation when the susceptible check (control variety) TN1 was completely killed. The reactions of the F_1, F_2, and F_3 populations from the crosses of resistant varieties with TN1 revealed that single dominant genes condition resistance in the varieties Sinnanayam, ARC 13349, MGL 1, Sukhwel 20, Bam 3, Hornamawee, Senawee, A1, T1432, W128, and Chuvanna Kumbolum. The resistance in NP130 and CI-5662-2 was conditioned by two independent dominant genes. The allelic relationships of the latter genes for resistance in the test varieties to resistance genes *Wbph 1* and *Wbph 2* were determined. Reactions of the F_2 and F_3 progenies from the crosses of test varieties with IR13475-7-3-2 which is homozygous for *Wbph 1*, and with IR30659-2-165, which is homozygous for *Wbph 2*, showed that the resistance genes in Sukhwel 20, Senawee, T1432, and W128 are allelic to *Wbph 1*. The resistance genes in Sinnanayam, ARC 13349, MGL 1, Bam 3, A1, and Chuvanna Kumbolum are allelic to *Wbph 2*. The two independent dominant genes for resistance in NP130 and CI-5662-2 are *Wpbh 1* and *Wbph 2*. However, there is a single dominant gene for resistance in Hornamawee which is independent and non-allelic to *Wbph 1* and *Wpbh 2*.

Introduction

The whitebacked planthopper (WBPH), *Sogatella furcifera* (Horvath) (Homoptera: Delphacidae), is a serious rice pest. In recent years severe outbreaks of this insect have occurred in several rice-growing countries (Majid, Makdomi and Dar, 1979; Sidhu, 1979). The increased incidence of this insect is generally attributed to the reduced genetic variability of short-statured high-yielding varieties, use of high levels of nitrogenous fertilizers and continuous cropping with rice. These practices, which are intended to increase rice production, also favour the build-up of insect populations.

To combat the damage caused by WBPH, we are endeavouring to incorporate genetic resistance to this insect into improved rice varieties. We have screened more than 20 000 rice varieties from our germplasm collection for resistance to this insect; more than 200 were found to be resistant (IRRI, 1978). Forty-eight of these varieties were genetically analysed and four genes for resistance were identified. These genes were designated as *Wbph 1* (Sidhu, Khush and Medrano, 1979), *Wbph 2* (Angeles, Khush and Heinrichs, 1981), and *Wbph 3* and *wbph 4* (Hernandez and Khush, 1981; Nair, Masajo and Khush, 1981). These genes are being incorporated into improved germplasm to develop varieties with resistance to WBPH. The study reported here was undertaken to identify additional genes for resistance.

Materials and methods

Thirteen rice varieties that have shown a high level of resistance to the WPBH in tests at IRRI were used in the study (Table 1). The varieties were crossed with Taichung Native 1 (TN1), a high-yielding dwarf variety from Taiwan which is highly susceptible to WBPH. The F_1, F_2, and F_3 progenies of these crosses were tested for their reaction to the insect to determine the mode of inheritance.

The varieties were also crossed with IR13475-7-3-2 and IR30659-2-165, two breeding lines of improved plant type which are homozygous for resistance genes *Wbph 1* and *Wbph 2*, respectively. The F_1, F_2 and F_3 progenies of these crosses were studied to determine the allelic relationships of the resistance genes of the 13 test varieties.

All the crosses were made in the greenhouse. TN1, IR13475-7-3-2, and IR30659-2-165 were used as female parents and the test varieties were used as male parents. Ten plants of each cross were grown to maturity in a bed. A random sample of F_2 seeds from two or three F_1 plants was used to study reaction to WBPH. The remaining seeds from the F_1 plants were used to grow F_2 populations in the field. At least 150 plants were harvested at random from each F_2 population to determine the reaction of F_3 progenies.

TABLE 1. List of rice varieties used in the study, which are resistant to whitebacked planthopper.

Variety	IRRI acc. no.	Country of origin
Sinnanayam	15292	Sri Lanka
ARC 13349	22671	India
NP130	3702	India
MGL 1	6367	India
CI-5662-2	3520	Japan
Sukhwel 20	59	India
Bam 3	5893	India
Hornamawee	56980	Sri Lanka
Senawee	15281	Sri Lanka
A1	55051	India
T1432	55160	India
W128	56996	India
Chuvanna Kumbolum	56976	India

The *bulk seedling test* (Athwal, Pathak, Bacalangco and Pura, 1971) was used to test the hybrid progenies for resistance to WBPH. The method consists of planting the test materials in wooden 'flats' (seedboxes) measuring 60 × 45 × 10 cm filled with soil to a depth of 6 cm. Each 'flat' had 13 rows 45 cm long subdivided into 26 sub-rows about 20 cm long. Of these 26 sub-rows, 22 were planted with the test materials and the remaining four with the resistant and susceptible checks (control varieties). Seedlings (about 7 days old) were uniformly infested with second-instar or third-instar nymphs of WBPH that had been reared on TN1. The insects belonged to a colony that had been maintained in the greenhouse at IRRI for the past 11 years, having originated from insects collected from rice fields in the Philippines. Seedlings were infested by distributing the insects evenly throughout the seedbox at the rate of five to six insects per seedling.

Damage was rated when the susceptible check was completely killed, which usually occurred about 1 week after infestation. The seedling was rated as resistant if its reaction was similar to that of the resistant check. Seedlings which died or became severely stunted with signs of wilting were rated as susceptible. The F_1 and F_3 progenies were scored on a row basis. The F_2 seedlings were classified as resistant or susceptible on an individual seedling basis. The F_3 progeny rows were classified either as homozygous resistant, segregating, or homozygous susceptible.

Results

Inheritance of resistance

The F_1 seedlings from the crosses between the susceptible TN1 and resistant cultivars were resistant (Table 2), indicating that dominant resistance genes are present in these varieties. The F_2 populations from crosses between TN1 and Sinnanayam, ARC 13349, MGL 1, Sukhwel 20, Bam 3, Hornamawee, Senawee, A1, T1432, W128, and Chuvanna Kumbolum, segrated in a ratio of three resistant to one susceptible (Table 2), thereby indicating that resistance in these varieties is conditioned by single dominant genes. The F_2 segregation data from the crosses TN1 × NP130 and TN1 × CI-5662-2 fitted the ratio of 15 resistant:1 susceptible, indicating that the resistance of NP130 and CI-5662-2 is controlled by two independent dominant genes.

The data on the reactions of F_3 families of these crosses are also presented in Table 2. F_3 lines of the crosses involving Sinnanayam, ARC 13349, MGL 1, Sukhwel 20, Bam 3, Hornamawee, Senawee, A1, T1432, W128, and Chuvanna Kumbolum segregated in a ratio of 1 resistant:2 segregating:1 susceptible, thus confirming that a single dominant gene conditions resistance in these varieties. The F_3 segregation data from the crosses involving NP130 and CI-5662-2 showed a close fit to the ratio of 7 resistant:8 segregating:1 susceptible, thereby confirming that resistance in these varieties is governed by two independent dominant genes.

Allele tests

Crosses with IR13475-7-3-2. Information concerning the allelic relationships between resistance genes in the test varieties and *Wbph 1* was obtained from the reactions of F_1, F_2, and F_3 populations from crosses of test varieties with IR13475-7-3-2. As expected, all the F_1 progenies were resistant (Table 3). The F_2

TABLE 2. Reaction to whitebacked planthopper in F_1, F_2 and F_3 populations of the crosses between TN1 and resistant cultivars.

Cross	F_1	F_2 seedlings*			*P* value		F_3 families			*P* value	
		Res. (No.)	Susc. (No.)	Susc. (%)	3:1	15:1	Res. (No.)	Seg. (No.)	Susc. (No.)	1:2:1	7:8:1
TN1 × Sinnanayam	Res	691	211	23·39	0·2–0·3	—	38	79	37	0·9–0·95	—
TN1 × ARC 13349	Res	699	261	27·18	0·1–0·2	—	41	77	36	0·7–0·9	—
TN1 × NP130	Res	949	72	7·05	—	0·2–0·3	75	68	11	—	0·3–0·5
TN1 × MGL 1	Res	615	216	25·99	0·5–0·7	—	36	83	35	0·5–0·7	—
TN1 × CI-5662-2	Res	871	73	7·73	—	0·5–0·1	63	77	14	—	0·3–0·5
TN1 × Sukhwel 20	Res	506	198	28·12	0·05–0·1	—	34	84	40	0·7–0·9	—
TN1 × Bam 3	Res	675	242	26·39	0·3–0·5	—	43	77	34	0·7–0·9	—
TN1 × Hornamawee	Res	759	259	25·95	0·3–0·5	—	42	78	34	0·7–0·9	—
TN1 × Senawee	Res	678	245	26·94	0·2–0·3	—	34	86	34	0·5–0·7	—
TN1 × A1	Res	514	188	26·78	0·2–0·3	—	46	77	31	0·3–0·5	—
TN1 × T1432	Res	745	267	26·38	0·3–0·5	—	43	79	32	0·5–0·7	—
TN1 × W128	Res	572	179	23·83	0·3–0·5	—	42	79	32	0·5–0·7	—
TN1 × Chuvanna Kumbolum	Res	562	208	27·01	0·1–0·2	—	42	80	32	0·5–0·7	—

* Res = Resistant; Seg = Segregating; Susc = Susceptible.

TABLE 3. Reaction to whitebacked planthopper in F_1, F_2 and F_3 populations of the crosses between resistant cultivars and IR13475-7-3-2.

Cross	F_1	F_2 seedlings*				F_3 families			
		Res. (No.)	Susc. (No.)	Susc. (%)	*P* value 15:1	Res. (No.)	Seg. (No.)	Susc. (No.)	*P* value 7:8:1
IR13475-7-3-2 × Sinnanayam	Res	864	72	7·69	0·05–0·1	76	70	8	0·3–0·5
IR13475-7-3-2 × ARC 13349	Res	690	44	5·99	0·7–0·9	59	84	11	0·3–0·5
IR13475-7-3-2 × NP130	Res	908	4	0·44	—	154	0	0	—
IR13475-7-3-2 × MGL 1	Res	889	72	7·37	0·1–0·2	46	46	8	0·5–0·7
IR13475-7-3-2 × CI-5662-2	Res	984	3	0·30	—	154	0	0	—
IR13475-7-3-2 × Sukhwel 20	Res	878	2	0·23	—	154	0	0	—
IR13475-7-3-2 × Bam 3	Res	928	73	7·31	0·1–0·2	67	74	13	0·5–0·7
IR13475-7-3-2 × Hornamawee	Res	726	38	4·97	0·1–0·2	62	82	10	0·5–0·7
IR13475-7-3-2 × Senawee	Res	1011	6	0·58	—	154	0	0	—
IR13475-7-3-2 × A1	Res	932	74	7·35	0·1–0·2	70	72	12	0·5–0·7
IR13475-7-3-2 × T1432	Res	924	3	0·32	—	154	0	0	—
IR13475-7-3-2 × W128	Res	1003	5	0·49	—	78	0	0	—
IR13475-7-3-2 × Chuvanna Kumbolum	Res	796	60	7·01	0·3–0·5	75	67	12	0·2–0·3

* Res = Resistant; Seg = Segregating; Susc = Susceptible.

TABLE 4. Reaction to whitebacked planthopper in F_1, F_2 and F_3 populations of the crosses between resistant cultivars and IR30659-2-165.

Cross	F_1	F_2 seedlings*				F_3 families			
		Res. (No.)	Susc. (No.)	Susc. (%)	*P* value 15:1	Res. (No.)	Seg. (No.)	Susc. (No.)	*P* value 7:8:1
IR30659-2-165 × Sinnanayam	Res	956	1	0·10	—	147	0	0	—
IR30659-2-165 × ARC 13349	Res	999	4	0·39	—	154	0	0	—
IR30659-2-165 × NP130	Res	994	5	0·50	—	154	0	0	—
IR30659-2-165 × MGL 1	Res	922	4	0·43	—	154	0	0	—
IR30659-2-165 × CI-5662-2	Res	1079	3	0·27	—	154	0	0	—
IR30659-2-165 × Sukhwel 20	Res	863	69	7·40	0·1–0·2	77	70	7	0·2–0·3
IR30659-2-165 × Bam 3	Res	874	2	0·23	—	154	0	0	—
IR30659-2-165 × Hornamawee	Res	765	49	6·01	0·7–0·9	74	69	11	0·3–0·5
IR30659-2-165 × Senawee	Res	896	76	7·62	0·01–0·05	70	77	7	0·5–0·7
IR30659-2-165 × A1	Res	985	2	0·20	—	154	0	0	—
IR30659-2-165 × T1432	Res	951	76	7·40	0·1–0·2	75	67	12	0·2–0·3
IR30659-2-165 × W128	Res	915	74	7·48	0·1–0·2	59	86	9	0·3–0·5
IR30659-2-165 × Chuvanna Kumbolum	Res	826	0	0·00	—	154	0	0	—

* Res = Resistant; Seg = Segregating; Susc = Susceptible.

progenies from the crosses of IR13475-7-3-2 with NP130, CI-5662-2, Sukhwel 20, Senawee, T1432, and W128 showed little, if any, segregation for susceptibility. A few susceptible seedlings were observed in F_2 populations but the number was so small that genetic segregation for susceptibility was considered to be unlikely. The death of these seedlings in otherwise resistant populations may be attributed to attack by such pathogens as soil-borne fungi, or to an usually high insect population. A small number of seedlings of resistant checks were similarly killed in our tests. All the F_3 families of these crosses were resistant (Table 3). These data showed that one of the dominant resistance genes of NP130 and CI-5662-2 and the single dominant gene of Sukhwel 20, Senawee, T1432, and W128, are the same as *Wbph 1*. The F_2 populations from the crosses of IR13475-7-3-2 with Sinnanayam, ARC 13349, MGL 1, Bam 3, Hornamawee, A1 and Chuvanna Kumbolum showed segregation for susceptibility, resistant and susceptible seedlings occurring in a 15:1 ratio. These data indicate that the single dominant genes of Sinnanayam, ARC 13349, MGL 1, Bam 3, Hornamawee, A1 and Chuvanna Kumbolum are non-allelic to *Wbph 1*. The F_3 families from the crosses of IR13475-7-3-2 with the same seven varieties segregated in a ratio of 7 resistant:8 segregating:1 susceptible (Table 3). This confirms the conclusion drawn from F_2 populations that single dominant genes for resistance in these varieties are non-allelic to, and independent of, *Wbph 1*.

Crosses with IR30659-2-165. As expected, the F_1 progenies from crosses between the test varieties and IR30659-2-165 were resistant. The F_2 populations from crosses between IR30659-2-165 and Sukhwel 20, Hornamawee, Senawee, T1432, and W128 segregated in a ratio of 15 resistant:1 susceptible (Table 4), suggesting an independent segregation of two dominant genes. The F_3 families of these crosses showed a good fit to a segregation ratio of 7 resistant:8 segregating:1 susceptible (Table 4). This confirms the conclusion drawn from the F_2 data. These five varieties carry a single dominant resistance gene that is non-allelic to *Wbph 2*.

In F_2 populations from crosses between IR30659-2-165 and Sinnanayam, ARC 13349, NP130, MGL 1, CI-5662-2, Bam 3, A1, and Chuvanna Kumbolum, only a few seedlings were killed. As mentioned earlier, a similar number of seedlings were also killed in the resistant control varieties. The F_3 families of these crosses did not show any segregation for susceptibility. One of the two dominant genes for resistance in NP130 and CI-5662-2 is therefore allelic to *Wbph 2*. The single dominant genes for resistance in the other six varieties mentioned above are also allelic to *Wbph 2*.

Discussion

The results of this study show that in Sinnanayam, ARC 13349, MGL 1, Sukhwel 20, Bam 3, Hornamawee, Senawee, A1, T1432, W128, and Chuvanna Kumbolum, resistance to WBPH is conditioned by a single dominant gene. Tests for allelism with IR13475-7-3-2 and IR30659-2-165 revealed that single dominant genes in Sukhwel 20, Senawee, T1432, and W128 are allelic to *Wbph 1*. The single dominant genes for resistance in Sinnanayam, ARC 13349, MGL 1, Bam 3, A1, and Chuvanna Kumbolum are allelic to *Wbph 2*. However, the single dominant gene of Hornamawee differs from *Wbph 1* and *Wbph 2*. Further studies are needed to determine the allelic relationships with *Wbph 3* which has recently been reported by Hernandez and Khush (1981) in the rice variety ADR 52. As each of the two varieties

TABLE 5. Summary of genes for resistance to whitebacked planthopper in the test varieties.

Variety	Nature of resistance	Gene(s) for resistance
Sinnanayam	Monogenic, dominant	*Wbph 2*
ARC 13349	Monogenic, dominant	*Wbph 2*
NP130	Digenic, dominant	*Wbph 1*+*Wbph 2*
MGL 1	Monogenic, dominant	*Wbph 2*
CI-5662-2	Digenic, dominant	*Wbph 1*+*Wbph 2*
Sukhwel 20	Monogenic, dominant	*Wbph 1*
Bam 3	Monogenic, dominant	*Wbph 2*
Hornamawee	Monogenic, dominant	Not known
Senawee	Monogenic, dominant	*Wbph 1*
A1	Monogenic, dominant	*Wbph 2*
T1432	Monogenic, dominant	*Wbph 1*
W128	Monogenic, dominant	*Wbph 1*
Chuvanna Kumbolum	Monogenic, dominant	*Wbph 2*

NP130 and CI-5662-2 has two dominant genes for resistance and no segregation for susceptiblity was observed in their crosses with IR13475-7-3-2 and IR30659-2-165, the two genes in each of these varieties must be *Wbph 1* and *Wbph 2*. A summary of the allelic relationships of the resistance genes of the 13 varieties studied is presented in Table 5. Twelve of the thirteen varieties analysed have previously known resistance genes and only one variety was found to have a new gene.

Improved germplasm incorporating *Wbph 1* and *Wbph 2* has been developed at IRRI and this has been shared with scientists in national rice improvement programmes, where they are being used as sources of resistance to WBPH. Efforts are being made to incorporate *Wbph 3* and *wbph 4* into improved plant type background and the search for additional resistance genes is continuing. When more genes are available, several different breeding strategies can be considered.

Acknowledgements

The kind assistance of Mr Enrique Angeles and Miss Lita Marciano in various aspects of this study is greatly appreciated.

References

ANGELES, E.R., KHUSH, G.S. AND HEINRICHS, E.A. (1981). New genes for resistance to whitebacked planthopper in rice. *Crop Science* 21, 47–50.

ATHWAL, D.S., PATHAK, M.D., BACALANGCO, E.H. AND PURA, C.D. (1971). Genetics of resistance to brown planthoppers and green leafhoppers in *Oryza sativa* L. *Crop Science* 11, 747–750.

HERNANDEZ, J.E. AND KHUSH, G.S. (1981). Genetics of resistance to whitebacked planthopper in some rice (*Oryza sativa* L.) varieties. *Oryza* 18, 44–50.

IRRI (INTERNATIONAL RICE RESEARCH INSTITUTE) (1978). *Annual Report for 1977*. Los Baños, Laguna, Philippines: IRRI. 478 p.

MAJID, A., MAKDOMI, M.A. AND DAR, I.A. (1979). Occurrence and control of the whitebacked planthopper in the Punjab of Pakistan. *International Rice Research Newsletter* 4(1), 17.

NAIR, V.R., MASAJO T.M. AND KHUSH, G.S. (1981). Genetic analysis of resistance to whitebacked

planthopper in twenty-one varieties of rice, *Oryza sativa* L. *Theoretical and Applied Genetics* 60, (in press).

SIDHU, G.S. (1979). Need for varieties resistant to whitebacked planthopper in the Punjab. *International Rice Research Newsletter* 4(1), 6–7.

SIDHU, G.S., KHUSH, G.S. AND MEDRANO, F.G. (1979). A dominant gene in rice for resistance to whitebacked planthopper and its relationship to other plant characters. *Euphytica* 28, 227–232.

Received 18 January 1982

Citation:

RS Saini, GS Khush, EA Heinrichs. 1982. Genetic analysis of resistance to whitebacked planthopper, Sogatella furcifera (Horvath), in some rice varieties. Crop Protection 1(3): 289-297.

Keywords: rice, host plant resistance, genetic basis of resistance, inheritance of resistance, allele tests, rice breeding, resistant genes