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LEVELS OF RESISTANCE OF RICE VARIETIES TO BIOTYPES OF THE BROWN PLANTHOPPER, NILAPARVATA LUGENS, IN SOUTH AND SOUTHEAST ASIA

REPORT OF THE
1979 INTERNATIONAL COLLABORATIVE
PROJECT ON BROWN PLANTHOPPER
RESISTANCE

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LEVELS OF RESISTANCE OF RICE VARIETIES TO BIOTYPES OF THE BROWN PLANTHOPPER, NILAPARVATA LUGENS, IN SOUTH AND SOUTHEAST ASIA.

Report of the 1979 International Collaborative Project on Brown Planthopper Resistance[1]

ABSTRACT

Reactions of differential varieties to feeding of the brown planthopper (BPH) in tests conducted throughout Asia indicated that the South Asian BPH population is distinct from that of Oceania, East Asia, and Southeast Asia. Within India there may be slight differences in the Hyderabad, Coimbatore, and Pantnagar populations. Four distinct BPH biotypes can be recognized in Asia from the reaction of differential varieties. The wild-type populations in East and Southeast Asia and Oceania belong to biotype 1. Biotype 2 became predominant in the Solomon Islands, Indonesia, Philippines, and Vietnam after IR26 was widely grown. Biotype 3 is being maintained in the laboratory in the Philippines. Biotype 4 occurs in India, Bangladesh, and Sri Lanka. However, at Pantnagar in India, all the BPH-resistant varieties have been classified as susceptible. Varieties with Bph 1 gene are resistant to biotypes 1 and 3, whereas varieties with bph 2 gene convey resistance to biotypes 1 and 2. Varieties with Bph 3 and bph 4 genes are resistant to all biotypes with the possible exception of Pantnagar (India) population.

The donor sources -- Babawee, Balamawee, and Sinna Sivappu -- and the advanced breeding lines IR13240 and IR17494 were resistant or moderately resistant at all sites except at Pantnagar.

Some varieties were susceptible in the greenhouse at the seeding stage but resistant as older plants in the field. Of the greenhouse methods tested to measure degree of field resistance, population buildup appeared most reliable.

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The brown planthopper (BPH), Nilaparvata lugens, has sporadically caused severe damage to rice crops in Japan and Korea for centuries but recently BPH outbreaks have occurred regularly in tropical Asia. In addition to damage caused by removing plant sap, the BPH transmits ragged and grassy stunt, (Ling et al 1978) and wilted stunt (Chen et al 1978) viruses.

Economic losses caused by BPH have been severe (Dyck and Thomas 1979). Although insecticides have been a primary method of BPH control, there is evidence that insecticides, by causing BPH resurgence, were at least partially responsible for many recent BPH outbreaks (Chelliah and Heinrichs 1980, Chelliah et al 1980, Heinrichs et al 1982). Insecticides that are biologically active against BPH and do not cause resurgence often provide poor control because little insecticide reaches the base of the plant where the BPH feed.

The growing of resistant varieties has been a successful means of controlling the BPH. Resistant varieties are now grown on milions of hectares in Indonesia, Vietnam, Philippines, China, Thailand, and the Solomon Islands and several other countries will release BPH-resistant varieties within the next few years. Breeding for resistance has, however, been complicated by the existence of BPH populations that differ in their ability to feed

on rice varieties. The term biotype has been used for these populations and herein refers to populations of N. lugens that differ in their ability to feed on and destroy rice varieties with specific major genes for resistance. Studies have shown that the biotype selection process occurs within a relatively short period (Pathak and Heinrichs 1982). In Indonesia and the Philippines, as a result of BPH biotype selection, IR26 carrying the Bph 1 gene for resistance became susceptible after being grown for about 3 years (Khush 1979). Variation in the reactions of biotypes throughout Asia, as based on the International Rice Brown Planthopper Nursery (IRBPHN), were reported by Seshu and Kauffman (1980).

In Indonesia, the Philippines, and Vietnam, IR36 with the bph 2 gene from CR94-13 (Ptb 18/Ptb 21) was released when the shift to BPH biotype 2 resulted in the susceptibility of IR26. IR36 has now been grown for more than 5 years without any evidence of the selection of a new virulent biotype. The reason for the greater stability of IR36 over IR26 is not known but there are indications that IR36 has minor genes besides bph 2.

Certain varieties have been observed to be susceptible in the seedling bulk screening test but moderately resistant as older plants in the field. Methods to identify these moderately resistant varieties and to determine their value as donor sources in the breeding of varieties with stable resistance must be determined. This collaborative project was developed to learn more about the role of varietal resistance as a component in the development of systems to manage BPH populations. Because of the occurrence of biotypes, it was evident that collaboration among scientists throughout Asia was necessary for fast production of relevant research results that can be used in a breeding program. Hence, a collaborative project was formulated in 1979 to:

- geographically characterize BPH biotypes as based on the reaction of differential varieties and to identify sources of resistance against each biotype;
- provide national programs with improved plant type materials that have major genes for resistance; and
- identify varieties or lines with moderate resistance (field or horizontal resistance) and to determine the nature of such resistance.

METHODS AND MATERIALS

Tests were conducted at the sites shown in Figure 1.

Determination of biotype reactions

Six varieties were used to determine the reactions of biotypes in Oceania, East Asia, Southeast Asia, and South Asia.

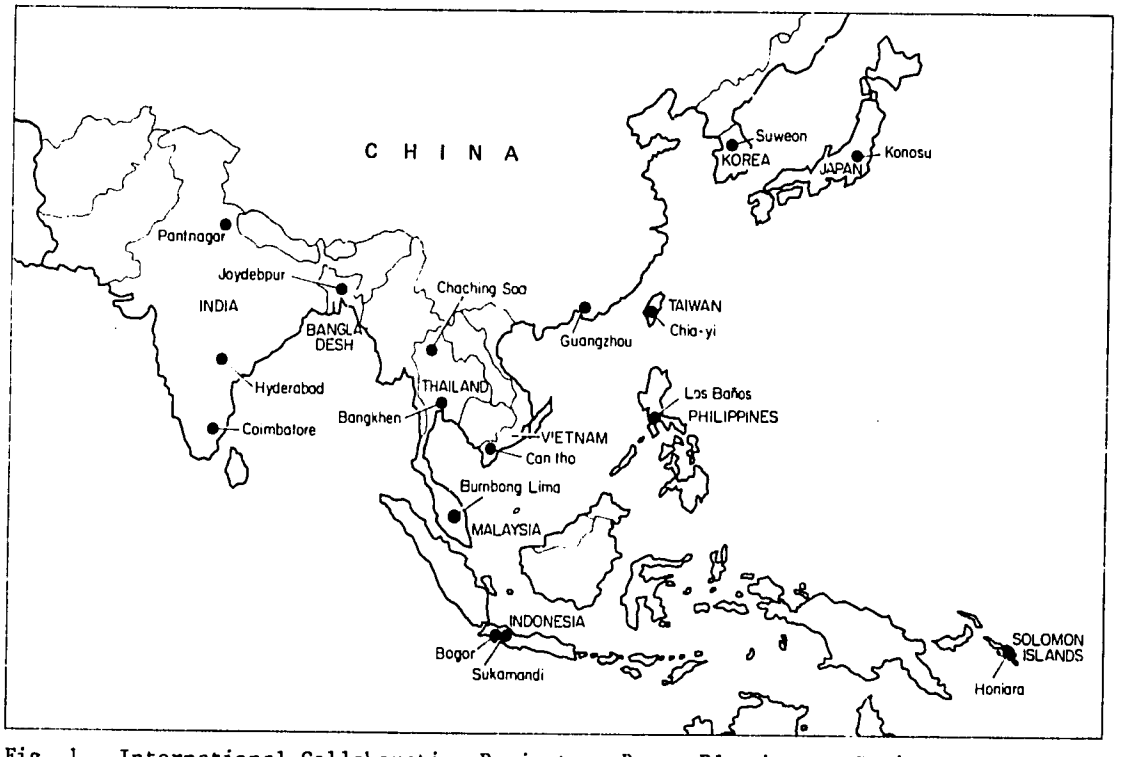

Fig. 1. International Collaborative Project on Brown Planthopper Resistance study sites, 1979.

Variety	Gene
IR26	Bph 1
ASD7	bph 2
Rathu Heenati	Bph 3
Babawee	bph 4
ARC 10550	Genes not identified
Ptb 33	2 Unidentified genes
TN1	None (Susceptible check)

Screening was in the greenhouse or field depending on the site.

Seedling bulk-screening test. For bulk screening, test varieties were sown in rows 5 cm apart in seed boxes 60 x 45 x 10 cm. Each variety was planted in 3 replications in a 20-cm row across the width of the seedbox.

About 5 days after seeding (DAS) seedlings were thinned to 20-30/row. Seedboxes were then placed in a galvanized iron tray (1.5 x 4.0 x 0.1 m) on a table inside a fine-mesh screened room. The tray contained about 5 cm standing water, which provided high humidity suitable for the insects and eliminated the need to water the plants. Separate screened rooms were used for different biotypes.

At 7 DAS, a large number of insects were uniformly scattered on the seedlings by gently tapping heavily infested plants from mass-rearing cages. An average of 5 insects/seedling constituted an optimum population to differentiate the resistant and the susceptible varieties. Second- and third-instar nymphs were generally used for infestation. The number of insects on 10 seedlings in each row at 48 hours after infestation indicated the preference or nonpreference of the insects for the different varieties. The final rating for resistance was based on a visual damage rating of 1-9 by the standard evaluation system (IRRI 1976):

1 = little or no damage (= to resistant check);
3 = first and second leaves partially yellow;
5 = pronounced yellowing and some stunting or wilting;
7 = more than half the plants wilting or dead and remaining plants severely stunted; and
9 = all plants dead (= to susceptible check).

Damage was rated when 95% of the plants in the susceptible check were killed and every 2 days after that for additional ratings.

Field screening. In field screening, 5 border rows were first planted with a BPH-susceptible variety resistant to the tungro virus. Depending on seed availability 1-4 rows (5 m) of the test entries were planted with 1-3 rows of the susceptible check between each test entry. To induce BPH populations, the susceptible rows at the end of the test entry rows were sprayed with an insecticide that caused BPH resurgence. The number of BPH/hill was counted on 5 hills/plot between 40 and 50 days after transplanting (DT) and every 20 days thereafter for another 2 countings. Damage ratings were by the standard evaluation system. Damage ratings were taken when 95% of the TN1 plants were killed and every 5 days thereafter for 3 additional ratings.

Identification of resistant sources with major (vertical) genes

The test varieties had the Bph 1 gene from Mudgo, bph 2 gene from CR94-13, Bph 3 gene from Rathu Heenati, bph 4 gene from Babawee, or unidentified gene(s) from Ptb 33. Sudu Hondarawala, Sinna Sivappu, and Suduru Samba have 2 unidentified genes.

Cultivars tested were:

Cultivar	Cross
TN1 (susceptible check)	
IR36	IR1561-228-1/IR1737//CR94-13
IR46	IR1461-131-5/IR1364-37//IR1366-120/IR1539-111
IR1154-243	IR8*2/Zenith
IR1539-823	IR24//Mudgo/IR8
IR4432-52-6-4	IR2061-125-37/CR94-13
IR13240-81-1	IR30S/Babawee//IR36
IR13240-83-1	IR30S/Babawee//IR36
IR13429-3-2	IR4432-43/Ptb 33//IR36
IR17494-32-3-4	Rathu Heenati/3*IR3403-267-1
IR17496-2-25-1	Ptb 33/3*IR3403-267-1
Ptb 33	
Sudu Hondarawala	
Sinna Sivappu	
Suduru Samba	
Mudgo	
Balamawee	
Babawee	

Entries were screened in the greenhouse and field using the techniques described in the previous sections.

Identification of field-resistant varieties

Greenhouse and field screening studies were used to identify varieties susceptible to BPH as a young plant in the seedling bulk test but resistant as an older plant in the field. To determine the nature of field resistance, survival and population buildup tests and feeding studies were conducted.

Greenhouse and field screening. The following varieties were screened in the greenhouse and field using the same techniques previously described.

Test variety	Resistance genes[a]	Origin	Observations[b]
Kencana	Minor?	Indonesia	MR to S in the greenhouse and MR to R in the field.
MRC603-303	Bph 1	Philippines	S to biotype 2 in the greenhouse and MR in the field.
Triveni	Minor?	India	MR to all biotypes.
Su-yai 20	Minor?	China	S to biotype 2 in the greenhouse but R in the field.
Manavari C022	Minor?	India	S to biotype 2 in the greenhouse but R in the field.
ARC 10520	Minor?	India	S to biotype 2 in the greenhouse but R in the field.
ARC 11354	Minor?	India	MR to biotype 2 in the greenhouse and R in the field.
H 105	Minor?	India	MR to biotype 2 in the greenhouse and in the field.
HR 100	Minor?	India	S to biotype 2 in the greenhouse and MR in the field.
Checks			
IR26	Bph 1	IRRI	R to biotypes 1 and 3, S to biotype 2 in the greenhouse and in the field.
IR42	bph 2	IRRI	R to biotypes 1 and 2, and S to biotype 3.
Mudgo	Bph 1 + minor genes	India	R to biotypes 1 and 3 in the greenhouse, S to biotype 2 in the greenhouse, but R in the field.
ASD7	bph 2	India	R to biotypes 1 and 2 in the greenhouse and in the field, S to biotype 3.
Ptb 33	2 unidentified	India	R to biotypes 1, 2, and 3.
TN1	None	Taiwan	S check.

[a] The presence of minor genes is speculative and is based on the fact that these varieties were susceptible in greenhouse screening at the seedling stage but with varying levels of resistance in field screening at IRRI. [b] Based on IRBPHN data from various sites and previous greenhouse and field screening at IRRI. S = susceptible, MR = moderately resistant, R = resistant.

Survival and population buildup. Three 10-day-old seedlings were transplanted in a 16-cm clay pot (5 replications/variety). At 30 DT, the plants were covered with a 13 cm x 90 cm mylar cage with fine-mesh-screened windows and 10 newly emerged nymphs were placed in each cage. Insects were counted at 20 days after infestation (DAI) to determine survival. At 40 DAI insects were again counted to determine population buildup. When a high population killed the susceptible check before 40 DAI, insects on all test varieties were counted and the test was terminated.

Feeding studies (honeydew excretion test). Seven-day-old seedlings were transplanted in clay pots (5 replications/variety). At 30, 45, and 60 DT, 5 pots of each variety were prepared for the collection of honeydew as shown in Figure 2. First, the outer leaf sheath that was loose from the stem was cut at its base to prevent it from coming in contact with the filter paper. The petri dish was fixed in place by guiding the plant through the center hole. Treatment and replication markings were written on the filter paper with a pencil. Forceps were used to avoid contact of the paper by moist hands. The plastic cup was then placed in an inverted position and the leaves were pulled through the center hole. The cup was held in place with tape.

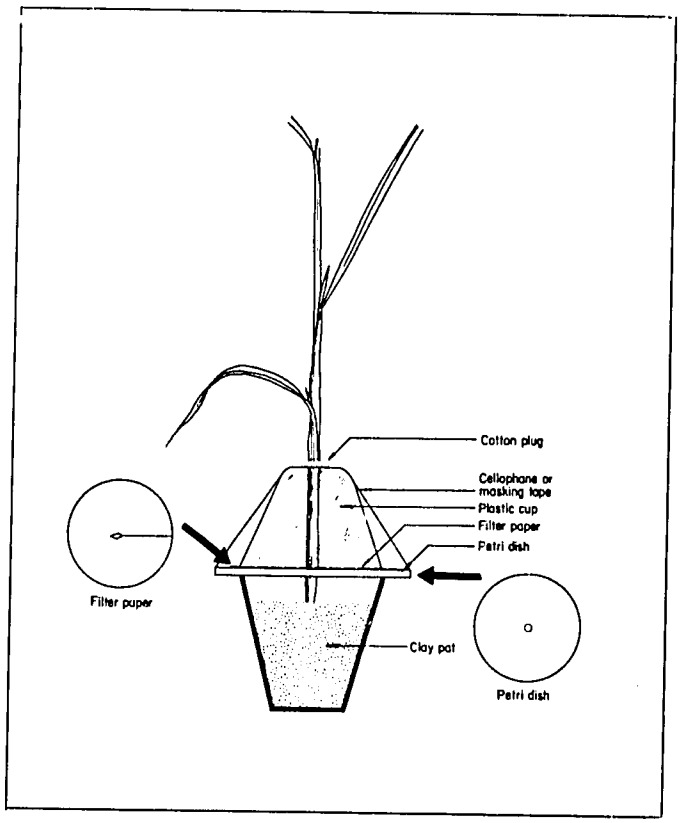

Fig. 2. Apparatus used for collecting honeydew in the feeding study.

Five-day-old adult females were starved for 5 hours in a container containing moist filter paper. Five adults were then introduced into each feeding chamber through the hole at the top of the cup and the hole plugged with cotton. After 24 hours, the filter papers were removed and sprayed with a ninhydrin solution (0.001% in acetone) and oven-dried at 100°C for 5 minutes. The purple spots produced by the reaction of ninhydrin with amino acids in the honeydew were immediately traced because the colors tended to fade rapidly. The area (mm^2) of the honeydew spots provided an indirect measure of the feeding activity. Tracing paper was placed over graph paper (mm^2) and the number of squares occupied by the spots counted.

RESULTS AND DISCUSSION

Results are discussed in the order that materials and methods are presented.

Determination of biotype reactions

There were distinct differences in the reactions of the differential varieties to BPH populations in the various countries. No variety was resistant at all sites. In general, the South Asian population was distinct from that of Oceania, East Asia, and Southeast Asia (Table 1). ARC 10550 was susceptible in Oceania, East Asia, and Southeast Asia, and resistant in South Asia, except in Pantnagar, India, where all varieties were susceptible. Rathu Heenati was resistant throughout Asia except in Coimbatore and Pantnagar. Babawee was resistant at all sites except at Pantnagar. ASD7 was resistant to the wild strain of BPH (biotype 1 in the Philippines and field strain in Taiwan) throughout Oceania, East Asia, and Southeast Asia, but susceptible in South Asia.

Based on the results in Table 1, at least six different BPH populations were evident (Table 2). In China, Japan, Korea, Malaysia, Taiwan (field biotype), and Thailand where BPH-resistant varieties have not been extensively grown, the biotype is still similar to biotype 1 in the Philippines, which was predominant before the growing of IR26.

Biotype 2 in the Philippines, Vietnam, Indonesia, and Solomon Islands are similar and were selected as the result of growing large areas of Bph 1 gene varieties such as IR26. The reaction of ASD7 in Taiwan where it was susceptible to biotypes 1 and 2 needs further investigation. In IRRI tests, ASD7 was sometimes moderately resistant to biotype 2 especially when insect pressure was high.

Identification of resistant sources with major (vertical) genes

Reactions of the test cultivars are given in Table 3. IR36, with the bph 2 gene, was resistant at all sites except in South Asia. Although IR1154-243 is a derivative of susceptible parents (IR8*2/Zenith) it was resistant or moderately resistant at six Southeast Asian sites. Selections of IR13240 and IR17494, with genes from Babawee and Rathu Heenati, respectively, were resistant or moderately resistant at all sites except at Pantnagar. IR17496-2-25-1, a derivative of Ptb 33, was resistant at all sites except at Bangladesh and Pantnagar where it was moderately resistant. However, IR13429-3-2, also a derivative of Ptb 33, was susceptible at Bangladesh, Coimbatore, and Pantnagar. Donor sources that were resistant or moderately resistant at all sites except at Pantnagar were Sinna Sivappu, Balamawee, and Babawee.

Identification of field-resistant varieties

Greenhouse screening to identify field-resistant varieties was done in China, India, Indonesia, Korea, Philippines (biotypes 1, 2, and 3), and Taiwan (Table 4); field screening was done in Korea, Philippines (biotype 2), Solomon Islands, and Taiwan (Table 5).

Several varieties were susceptible as seedlings in the greenhouse but resistant in the field as older plants, indicating field resistance. At IRRI, IR46 which has the Bph1 gene from Mudgo was susceptible to biotype 2 in the greenhouse but resistant to it in the field. The reaction was similar to Mudgo. IR26, on the other hand, which also has the Bph1 gene, but from TKM6, was susceptible in the greenhouse and field.

It was apparent that in addition to the Bph 1 gene, Mudgo and its derivative, IR46, have minor genes that impart field resistance, which is lacking in IR26. Repeated tests have consistently given the same results -- IR26 is hopperburned in the field where IR46 is undamaged. It is significant to note that IR46 and Mudgo were also resistant in the field in the Solomon Islands, where biotype 2 predominates, whereas IR26 was susceptible.

Triveni was consistently susceptible in the greenhouse but moderately resistant or resistant (depending on the level of insect infestation) in the field at IRRI. Although Triveni has no major gene for resistance, it was also moderately resistant in the field in the Solomon Islands.

In Korea, Kencana and ARC 10520 were susceptible in the greenhouse and resistant in the field.

Greenhouse studies of BPH preference for field-resistant varieties such as Triveni indicated different reactions at different sites and by various biotypes within a site (Table 6). In field screening in the Philippines, the number of BPH was higher on Triveni than on IR26, the susceptible check for biotype 2. IR26, however, was hopperburned (susceptible) but Triveni had a damage rating of 5 (moderately resistant) (Table 5).

Survival and population buildup

Survival and population buildup studies were conducted to gain a better understanding of the nature of resistance in field-resistant varieties. Only the variety Ptb 33, which has major genes im-

parting a high level of resistance, had distinctly lower survival than the susceptible (check) TN1 (Table 7). Although both ASD7 and IR42 have the same major gene (bph 2) differences in levels of resistance were detectable with the survival test. The moderate resistance of ASD7 to biotype 2 in the Philippines is indicated by the high survival in ASD7 compared to IR42.

The field-resistant varieties such as Triveni differed in their reaction from one site to another. Survival on Triveni was about equal to that on TN1 in the Philippines and the Solomon Islands. In China and Taiwan, BPH survival on Triveni was less than TN1. Survival of biotypes 2 and 3 in the Philippines was lower on Mudgo, which had field resistance to biotype 2, than on IR26 which was susceptible to biotype 2.

Table 1. Differential[a/] reactions of rice varieties to brown planthopper (BPH) biotypes at various sites, as based on greenhouse (GH) and field (F) screening. 1979.

Variety	Gene(s) for resistance	Oceania	East Asia	Southeast Asia						
		Solomon Is.	China	Japan	Korea	Malaysia	Philippines Biotype			
							1	2		3
		F	GH	GH	GH	GH	GH	GH	F	GH
IR26	Bph 1	S	R	R	R	MR	R	S	S	R
ASD7	bph 2	R	R	R	R	R	R	R	R	S
Rathu Heenati	Bph 3	R	R	R	R	R	R	R	R	R
Babawee	bph 4	R	R	R	R	R	R	R	R	R
ARC 10550	?	S	S	S	S	S	S	S	S	S
Ptb 33	2 unidentified	R	R	R	R	R	R	R	R	R
TN1	None	S	S	S	S	S	S	S	S	S

Variety	Gene(s) for resistance	Southeast Asia							South Asia			
		Taiwan Biotype				Thailand		Vietnam	Bangladesh	India		
		1	2	3		Bangkok	Chaching Soa			Coimbatore	Hyderabad	Pantnagar
		GH	GH	GH	F	GH	F	GH	GH	GH	GH	GH
IR26	Bph 1	R	S	R	R	R	R	--[b/]	S	S	S	S
ASD7	bph 2	S	S	S	R	R	MR	R	S	S	S	S
Rathu Heenati	Bph 3	R	R	R	R	R	R	R	R	S	R	S
Babawee	bph 4	R	R	R	R	R	R	R	R	R	R	S
ARC 10550	?	S	S	S	R[c/]	S	--[b/]	S	MR	R	R	S
Ptb 33	2 unidentified	R	R	R	R	R	R	R	R	R	R	S
TN1	None	S	S	S	S	S	S	S	S	S	S	S

[a/] Values are means of 3 replications. In a column, means followed by a common letter are not significantly different at the 5% level by DMRT. R = resistant, damage rating of 1-3; MR = moderately resistant, damage rating of 4-6; S = susceptible, damage rating of 7-9. [b/] A dash indicates no report for site. [c/] Variety resistant in field but may have been rated resistant because BPH population was low.

Table 2. Grouping of brown planthopper biotypes based on the response of different varieties.

Biotype	Response
Philippine biotype 1, China, Japan, Korea, Malaysia, Taiwan (field), and Thailand	• Resistant or moderately resistant: IR26, ASD7, Rathu Heenati, Babawee, Ptb 13 • Susceptible: ARC 10550, TN1
Philippine and Vietnam biotype 2, Solomon Islands	• Resistant: ASD7, Rathu Heenati, Babawee, Ptb 33 • Susceptible: IR26, ARC 10550, TN1
Philippine biotype 3 and Taiwan biotype 3	• Resistant: IR26, Rathu Heenati, Babawee, Ptb 33 • Susceptible: ASD7, ARC 10550, TN1
Bangladesh and Hyderabad, India	• Resistant or moderately resistant: Rathu Heenati, Babawee, Ptb 33, ARC 10550 • Susceptible: IR26, ASD7, TN1
Coimbatore, India	• Resistant: Babawee, Ptb 33, ARC 10550 • Susceptible: Rathu Heenati, IR26, ASD7, TN1
Pantnagar, India	• Susceptible: IR26, ASD7, Rathu Heenati, Babawee, Ptb 33, ARC 10550, TN1

Table 3. Identification of resistance sources with major (vertical) genes as based on plant damage rating. 1979.[a/]

Variety	Solomon Is.	China	Korea	Philippines Biotype 1	Philippines Biotype 2	Philippines Biotype 3	Taiwan		Thailand Bangkok	Bangladesh	India Coimbatore	India Pantnagar
	F	GH	GH	GH	GH	GH	GH	F	GH	GH	GH	GH
TN1	S	—[b/]	S	S	S	S	S	S	S	S	S	S
IR36	R	R	R	R	R	R	R	R	R	S	S	S
IR46	R	R	R	R	MR	R	R	R	R	S	S	S
IR1154-243	S	R	R	MR	MR	S	MR	R	R	S	-	S
IR1539-823	S	R	R	R	S	S	MR	R	MR	-	R	S
IR4432-52-6-4	R	R	R	R	R	R	R	R	R	MR	S	S
IR13240-81-1	R	R	R	R	R	R	R	R	R	MR	R	S
IR13240-83-1	R	R	R	R	R	R	R	R	R	MR	R	S
IR13429-3-2	R	R	R	R	R	R	R	R	R	S	S	S
IR17494-32-3-4	R	R	R	R	R	R	R	R	R	MR	R	S
IR17496-2-25-1	R	R	R	R	R	R	R	R	R	MR	R	MR
Ptb 33	R	R	R	R	R	R	R	R	R	R	R	S
Sudu Hondarawala	R	R	R	R	R	R	R	R	-	MR	R	S
Sinna Sivappu	R	R	R	R	R	R	R	R	R	R	R	S
Suduru Samba	R	-	R	R	R	R	R	R	R	R	S	S
Mudgo	R	R	R	R	S	R	R	R	-	S	S	S
Balamawee	R	R	R	R	R	R	R	R	R	MR	R	S
Babawee	R	R	R	R	R	R	R	R	R	MR	R	S

[a/] Values are means of 3 replications. R = resistant, damage rating of 1-3; MR = moderately resistant, damage rating of 4-6; S = susceptible, damage rating of 7-9. GH = greenhouse, F = field. [b/] A dash indicates no report for site.

Table 4. Greenhouse screening: seedling bulk test, Brown Planthopper (BPH) collaborative project, 1979.[a/]

Variety	China		India		Indonesia	Korea	
	BPH/ seedling	Damage rating	Damage rating Coimbatore[b/]	Pantnagar	Biotype 2 damage rating	BPH/ seedling	Damage rating
ARC 10520	9.7 ab	5 b	9	-[c/]	8 ab	4.4 cd	9 a
ARC 11354	4.0 cd	1 c	1	-	6 cd	6.4 bc	3 b
H 105	3.0 cdef	1 c	9	-	5 d	2.8 cde	1 c
HR 100	2.5 cdef	1 c	9	-	8 ab	1.2 e	2 bc
Kencana	11.7 a	8 a	5	-	9 a	21.2 a	9 a
Manavari CO 22	2.3 def	1 c	-	-	7 bc	1.5 e	1 c
MRC603-303	1.4 f	1 c	1	-	7 bc	2.4 cde	1 c
Su-yai 20	5.4 bc	5 b	9	-	8 ab	5.2 cd	8 a
Triveni	3.5 cde	1 c	5	-	8 ab	5.7 c	9 a
Mudgo	1.6 ef	1 c	9	8 a	9 a	5.5 cd	1 c
IR26	2.8 cdef	1 c	9	9 a	9 a	2.9 cde	1 c
ASD7	2.0 def	1 c	9	9 a	3 e	2.2 de	1 c
IR42	-	-	7	-	3 e	2.8 cde	1 c
Ptb 33	2.8 cdef	1 c	3	9 a	-	2.1 e	1 c
TN1	15.0 a	9 a	9	9 a	-	18.5 ab	9 a

Variety	Philippines						Taiwan			
	Biotype 1		Biotype 2		Biotype 3		Biotype 1	Damage rating[b/] Biotype		
	BPH/ seedling	Damage rating	BPH/ seedling	Damage rating	BPH/ seedling	Damage rating	BPH/seedling[b/]	1	2	3
ARC 10520	7.3 abc	9 a	15.7 bcde	9 a	5.2 cd	9 a	9.6	9	9	9
ARC 11354	4.3 abcde	6 c	18.3 abcd	6 b	6.8 bcd	7 ab	9.8	9	9	9
H 105	3.4 cde	2 e	10.3 fg	5 b	9.2 b	9 a	2.0	2	5	9
HR 100	5.2 abcde	4 d	13.8 cdef	9 e	4.8 cd	4 cd	7.8	3	9	7
Kencana	6.8 abcd	6 c	10.6 efg	6 b	5.8 cd	6 bc	9.6	9	9	7
Manavari CO 22	4.0 bcde	4 d	10.8 efg	9 a	7.1 bc	3 de	2.8	3	9	2
MRC603-303	3.2 de	4 d	18.3 abcd	9 a	5.8 cd	2 de	4.3	6	8	-
Su-yai 20	8.2 ab	8 ab	19.9 abc	8 a	5.8 cd	9 a	9.8	7	9	4
Triveni	4.6 abcde	7 bc	22.6 a	6 b	6.7 bcd	8 ab	11.2	9	9	9
Mudgo	5.8 abcde	2 e	18.2 abcd	6 b	4.8 cd	1 e	1.2	1	9	1
IR26	5.5 abcde	4 d	13.1 def	6 b	5.7 cd	3 de	4.2	3	9	1
ASD7	2.8 e	2 e	7.0 h	2 c	15.6 a	8 ab	6.1	7	9	9
IR42	5.0 abcde	1 e	9.0 gh	1 c	5.0 cd	7 ab	3.9	1	1	8
Ptb 33	3.0 e	1 e	4.8 i	2 c	4.2 d	2 de	1.6	1	1	1
TN1	8.6 a	8 ab	21.0 ab	9 a	16.8 a	9 a	15.6	9	9	9

[a/] Values are means of 3 replications. In a column, means followed by a common letter are not significantly different at the 5% level by DMRT. [b/] Damage rating by Standard Evaluation System (IRRI 1980).

Feeding studies (honeydew excretion test)

Feeding studies were made in China, India, Korea, Philippines, and Taiwan (Table 8). Feeding was low on the highly resistant variety Ptb 33 at all sites. Feeding on field-resistant varieties such as Triveni was generally less than on TN1, but not substantially so.

Effect of plant age on feeding activity varied from one site to another. Feeding on TN1 was generally similar at the 3 plant ages, except in Korea where feeding was least on 30-day-old plants. Feeding on Ptb 33 was low and equal at all plant ages. In India feeding on most varieties decreased with plant age as there was more feeding on 30- than on 45- and 60-day-old plants. At IRRI, feeding increased from 30 to 45 days and then decreased at 60 days for all 3 biotypes.

On the field-resistant variety Triveni, feeding activity changed with plant age. In China and India feeding on Triveni decreased with plant age whereas in the Philippines feeding on Triveni increased, similar to that on TN1. The change in feeding with plant age, however, may have been due to environmental conditions at the time each plant age was studied because the trend on Triveni was similar to that on TN1. It was evident that, at

least until 60 days of age, there is not a distinct type of mature plant resistance in Triveni. The level of resistance did not increase with plant age as had been previously suspected.

CONCLUSIONS AND RECOMMENDATIONS

The response of the differential varieties indicate distinct differences in BPH populations in Asia. Although the reactions of varieties to most of the populations are distinct, some responses need further investigation. For example, the susceptible reaction of ASD7 to biotypes 1 and 2 in Taiwan is different from that in the Philippines. However, it is significant to note that ASD7 is resistant to the Taiwan field population.

The susceptible reaction of Rathu Heenati in the seedling bulk test at Coimbatore, India, deserves further investigation considering that Rathu Heenati is resistant at Hyderabad.

ARC 10550 is MR in Bangladesh and resistant in South India. Possibly the BPH population in Bangladesh is more similar to that in Pantnagar, India, than to that in Hyderabad or Coimbatore in South India.

The BPH biotype screening study conducted annually by the All-India Coordinated Rice Improvement Project will provide additional evidence of the reactions within India. Also, the recently initiated program of screening populations from throughout Asia at Cardiff University, United Kingdom, will eliminate different environmental variables and may yield useful information.

The study on the identification of resistance in cultivars with major genes identified several breeding lines having Babawee, Rathu Heenati, and Ptb 33 parentage that were resistant to all biotypes throughout Asia, except in Pantnagar, India. IR13429-3-2, with Ptb 33 as a parent, however, was susceptible at Coimbatore although Ptb 33 was resistant. This indicates a lack of genetic transfer of the genes that impart resistance to the Coimbatore biotype. This points out the significance of national and international testing against various biotypes.

Table 5. Identification of field-resistant varieties based on plant damage ratings. 1979.

Variety	Korea		Philippines Biotype 2		Solomon Is.	Taiwan	
	GH	F	GH	F	F	GH	F
Kencana	S	R	MR	MR	MR	S	R
MRC603-303	R	R	S	MR	S	MR	R
IR46	- [a]	-	S	R	R	R	R
Triveni	S	S	S	MR	MR	S	R
Su-yai 20	S	MR	S	MR	S	MR	R
Manavari C022	R	R	S	MR	MR	MR	R
ARC 10520	S	R	R	MR	MR	S	R
ARC 11354	R	-	MR	R	MR	S	R
H 105	R	-	MR	MR	S	MR	R
HR 100	R	R	S	MR	S	MR	R
Mudgo	R	R	S	MR	R	MR	R
IR26	R	R	S	S	S	MR	R
ASD7	R	R	R	R	R	S	R
IR42	R	R	R	R	MR	R	R
Ptb 33	R	R	R	R	R	R	R
TN1	S	S	S	S	S	S	S

[a] A dash indicates no report for site. GH = greenhouse, F = field. S = susceptible, R = resistant, MR = moderately resistant.

Table 6. Number of brown planthoppers per hill in the field.[a]

Variety	Korea	Solomon Is.	Taiwan			Philippines (Biotype 2)		
	30 DT[b]	51 DT	60 DT	87 DT	100 DT	61 DT	66 DT	71 DT
ARC 10520	34	226	180	27	64	189	123	24
ARC 11354	-	68	7	14	31	187	252	36
H 105	-	248	2	12	39	185	100	20
HR 100	1	246	5	11	29	364	139	HB[c]
Kencana	29	179	44	34	53	411	344	HB
Manavari C022	0	168	6	13	37	429	242	81
MRC603-303	1	212	1	10	63	-	-	-
Su-yai 20	52	312	29	62	77	503	253	HB
Triveni	23	101	3	19	46	221	173	47
Mudgo	0	4	1	9	57	113	85	19
IR26	1	?	-	-	-	140	124	HB
ASD7	-	-	-	-	-	-	78	18
IR42	1	32	2	18	14	278	134	25
Ptb 33	0	2	0	15	19	139	72	10
TN1	88	316	46	70	107	-	-	-

[a] Values are means of 3 replications. A dash indicates no report for the site. [b] DT = days after transplanting. [c] Most of the plants hopperburned. No count was taken.

Table 7. Survival and population buildup of brown planthopper (BPH) in a BPH collaborative project, 1979.[a]

Variety	% survival at 20 DT and BPH/cage at 40 DT[b]											
	China		India[c]		Korea		Philippines					
							Biotype 1		Biotype 2			
	% surv.	BPH/cage	% surv.	BPH/cage	% surv.	BPH/cage	% surv.[d]	BPH/cage	% surv.[d]	BPH/cage		
ARC 10520	18 cd	61 bc	-	-	79 ab	33 ab	56 ab	903 a	64 ab	897 ab		
ARC 11354	20 cd	20 cd	-	-	-	-	66a	607 a	64 ab	539 ab		
H 105	24 cd	9 def	-	-	-	-	30 bcde	83 b	68 ab	494 bc		
HR 100	26 cd	8 def	-	-	10 d	1 d	46 ab	476 a	60 ab	829 ab		
Kencana	-	-	-	-	72 ab	34 ab	56 ab	817 a	50 ab	481 ab		
Manavari C022	2 e	3 def	-	-	22 d	0 d	42 ab	38 bc	66 ab	646 ab		
MRC603-303	20 cde	3 ef	-	-	16 d	7 c	36 abc	287 a	58 ab	1213 a		
Su-yai 20	58 ab	74 b	-	-	79 ab	39 ab	62 ab	836 a	72 ab	552 ab		
Triveni	36 bc	43 bc	-	-	56 bc	41 a	44 ab	814 a	76 ab	763 ab		
Mudgo	-	-	50		23 cd	2 d	48 ab	43 b	44 b	315 bc		
IR26	12 de	1 f	47		26 cd	10 c	50 abc	420 a	64 ab	379 bc		
ASD7	18 cde	5 def	57		-	-	16 cde	3 c	44 b	228 c		
IR42	22 cd	5 def	-	-	36 cd	11 bc	14 de	5 c	6 c	13 d		
Ptb 33	6 de	2 ef	10	13	8 d	0 d	6 de	6 c	10 c	0 d		
TN1	86 a	205 a	63	2934	90 a	65 a	62 a	1089 a	82 a	877 ab		
Mean	27	34	-	-	43	10	-	428	55	565		

Variety	% survival at 20 DT and BPH/cage at 40 DT[b]					
	Philippines Biotype 3		Solomon Is.		Taiwan	
	% surv.[e]	BPH/cage	% surv.	BPH/cage	% surv.	BPH/cage
ARC 10520	68 a	1292 ab	30 abcd	121 a	23 abc	83 cde
ARC 11354	78 a	1526 ab	37 abc	49 abc	32 ab	119 bcd
H 105	78 a	945 abc	50 ab	126 a	8 cdefg	73 cde
HR 100	72 a	651 abc	40 abcd	125 a	25 abc	103 ef
Kencana	68 ab	656 d	57 a	113 a	56 abc	460 ab
Manavari C022	60 ab	1108 abc	47 abc	75 a	4 fg	35 def
MRC603-303	56 ab	624 abcd	50 ab	76 a	4 fg	16 fg
Su-yai 20	84 a	806 abc	60 a	142 a	46 a	373 abc
Triveni	88 a	1550 ab	53 a	89 a	20 bcd	160 bcd
Mudgo	34 b	213 bcd	33 abcd	59 ab	5 efg	3 g
IR26	68 a	540 abcd	33 abcd	67 a	4 fg	7 fg
ASD7	82 a	1125 abcd	23 bcd	23 bc	17 bcdef	43 def
IR42	82 a	360 abcd	20 cd	12 c	2 g	2 g
Ptb33	32 b	347 cd	13 d	2 d	1 g	5 g
TN1	92 a	1903 a	53 a	103 a	43 abcde	797 a
Mean	69	910	40	79	17	152

[a] Values are means of 5 replications. In a column means followed by a common letter are not significantly different at the 5% level by DMRT. A dash indicates no report for the site. [b] DT = days after transplanting. [c] No analysis; data submitted were treatment means. [d] Newly hatched nymphs. [e] Fifth-instar nymphs.

Several field-resistant varieties were identified. Kencana, Triveni, ARC 10520, and Mudgo appeared most promising. It appears that actual field screening is the most accurate means of identifying field resistance of moderately resistant varieties. The use of BPH resurgence-inducing insecticides made field screening more reliable, especially in areas where natural hopperburn was not common, as at IRRI. However, field screening is laborious and expensive, and dictates the need to develop greenhouse techniques to measure survival, population buildup, and feeding.

The survival study proved to be the least useful and was not included in the 1980 project. The feeding study appeared useful in identifying field resistance in the greenhouse, but there was considerable variation among replications at some sites, indicating the difficulty of conducting the feeding test. For example, careful handling of the insects is crucial because if few insects are killed, results will be significantly altered.

Table 8. Amount (mm^2) of honeydew excreted, Brown Planthopper collaborative project, 1979.[a/]

Variety	China[b/]		India[c/]			Korea[b/]		
	Plant age (days)		Plant age (days)			Plant age (days)		
	30	60	30	45	60	30	45	60
ARC 10520	486 c	151 b	593 b	468 a	269 a	-	78 b	2028 a
ARC 11354	72 d	30 e	24 g	22 h	9 f	464 cd[d/]	-	-
H 105	32 d	39 e	620 b	359 b	91 cde	53 d[d/]	-	-
HR 100	63 d	20 e	198 b	191 efg	95 cde	759 c	17 b	70 c
Kencana	860 ab	112 bc	345 bc	159 fg	46 ef	758 bc[c/]	41 b[d/]	499 c
Manavari C022	22 d	44 e	869 a	494 a	291 a	-	36 b[d/]	46 c
MRC603-303	19 d	24 e	42 g	27 h	5 f	82 d	23 b	88 c[d/]
Su-yai 20	584 bc	97 cd	359 de	221 def	116 cd	1235 ab	264 a	1324 b
Triveni	142 d	60 de	235 f	126 g	56 def	369 cd[d/]	28 b	314 c
Mudgo	25 d	19 e	337 e	178 efg	126 c	38 d[c/]	80 b[d/]	-
IR26	-[e/]	-	488 c	250 cde	115 cd	137 d[c/]	16 b	189 c
ASD7	36 d	24 e	443 cde	280 cd	202 b	32 d[d/]	42 b	134 c
IR42	-	-	809 a	535 a	230 ab	55 d[d/]	30 b	142 c
Ptb 33	9 d	30 e	37 g	15 h	9 f	52 d[d/]	26 b	216 c
TN1	1027 a	361 a	450 cd	300 bc	271 a	1294 a[d/]	330 a[c/]	1435 b[d/]
Mean	260	78	390	242	129	432	71	479

Variety	Philippines[b/]								
	Biotype 1			Biotype 2			Biotype 3		
	Plant age (days)			Plant age (days)			Plant age (days)		
	30	45	60	30	45	60	30	45	60
ARC 10520	86 c	95 hi	205 de	81 b	157 i	74 ij	262 b	1481 a	259 e
ARC 11354	41 fg	242 e	219 d	25 g	259 f	137 g	76 i	126 gh	246 e
H 105	87 c	161 g	158 gh	54 de	203 gh	87 i	202 c	214 ef	266 e
HR 100	113 b	125 h	88 i	70 c	206 g	106 h	99 g	114 gh	219 f
Kencana	77 cd	427 c	173 fg	41 f	178 hi	63 j	125 f	266 e	138 g
Manavari C022	44 fg	354 d	80 i	47 ef	460 c	191 d	120 f	377 d	247 e
MRC603-303	47 ef	212 ef	77 i	25 g	352 d	117 h	43 j	109 gh	98 h
Su-yai 20	82 c	862 a	671 b	60 d	770 a	62 g	213 c	497 c	458 c
Triveni	86 c	410 c	334 c	56 d	311 e	250 c	150 e	359 d	457 c
Mudgo	40 fg	185 fg	53 g	39 f	126 g	155 f	46 j	60 h	303 d
IR26	72 d	90 i	76 i	60 d	276 f	333 b	95 gh	174 fg	247 e
ASD7	43 fg	56 g	189 ef	25 g	98 k	169 e	125 f	379 d	508 b
IR42	58 e	53 g	154 h	170 g	85 k	65 j	86 hi	161 fg	250 e
Ptb 33	37 g	35 g	84 i	61 d	54 l	45 k	172 d	40 h	119 gh
TN1	324 a	671 b	714 a	298 a	529 b	555 a	337 a	622 b	690 a
Mean	83	265	218	64	271	161	143	322	300

Variety	Taiwan[b/]								
	Biotype 1			Biotype 2			Biotype 3		
	Plant age (days)			Plant age (days)			Plant age (days)		
	30	45	60	30	45	60	30	45	60
ARC 10520	64 bcd	126 bc	92 bcd	84 c	81 c	124 bc[d/]	91 b	80 bcd	100 bc[d/]
ARC 11354	111 b	72 def	61 def	51 cde	64 c	76 def	66 bc	85 bcd	83 bcd
H 105	34 cd	77 cdef	90 bcd	51 cde	71 c	78 cdef	88 b	107 b	58 cde[d/]
HR 100	35 cd	43 ef	39 ef[d/]	73 cd	62 c	65 defg	64 bc	54 cde	54 cde[d/]
Kencana	94 b	107 bcd	114 bc	149 b	74 c	88 bcde	175 a	100 b	105 b
Manavari C022	19 d	44 ef	36 ef	89 c	44 cd	52 efg	84 b	48 de	54 cde
MRC603-303	18 d	46 ef	30 f	36 de	71 c	56 efg	85 b	47 de	40 de
Su-yai 20	85 bc	83 bcde	127 d	133 b	79 c	104 bcd	163 a	94 bc	48 b
Triveni	21 d	64 def	77 cde	45 de	46 cd	96 bcde	90 b	77 bcde	76 bcde
Mudgo	26 d	24 f	29 f	38 de	42 cd	74 def	27 c	33 e	53 de
IR26	32 d	41 ef	27 f	52 cde	63 c	54 efg	48 bc	55 cde	38 de
ASD7	39 cd	129 b	90 bcd	66 cd	118 b	173 a	92 b	77 bcde	58 cde[d/]
IR42	19 d	67 def	38 ef	36 de	57 c	42 fg	56 bc	66 bcde	39 de
Ptb 33	16 d	42 ef	27 f	25 e	16 d	28 g	20 c	45 de	31 e
TN1	340 a	250 a	185 a	237 a	185 a	129 b	192 a	171 a	179 a
Mean	64	81	71	78	72	82	89	76	73

[a/]Means followed by a common letter are not significantly different at the 5% level by DMRT. [b/]Mean of 5 replications. [c/]Mean of 3 replications. Conducted at TNAU, Coimbatore. [d/]Mean of 4 replications. [e/]A dash indicates no report for the site.

Overall, the population buildup technique appeared the most reliable. To increase the reliability of the method in the 1980 project, instead of combining a survival and population buildup in one test, only the population buildup test was conducted using equal numbers of male and female adults rather than newly emerged nymphs. This more closely approximates the field situation where adults immigrate and begin colonization.

Except for some possibility with the seedling bulk screening test, the greenhouse tests conducted do not measure tolerance, which may be an important component in field resistance of some varieties. Triveni, for example, was shown by Ho et al (1982) to be able to produce grain despite feeding by BPH populations equal to those on susceptible TN1, which produced no grain. Tolerance is readily evident in field testing but greenhouse methods must be developed to more easily identify the level of this component.

A modification of the seedling bulk test to identify tolerant varieties has been developed at IRRI and was included in the 1980 project. Also, several varieties, with higher levels of field resistance, were included in the 1980 collaborative project.

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