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DIFFERENTIAL RESPONSE OF RICE VARIETIES TO THE BROWN PLANTHOPPER IN INTERNATIONAL SCREENING TESTS

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DIFFERENTIAL RESPONSE OF RICE VARIETIES TO THE BROWN PLANTHOPPER IN INTERNATIONAL SCREENING TESTS[1]

ABSTRACT

The results from International Rice Brown Planthopper Nursery screening in several Asian countries over a 5-year period (1975-79) provide significant information on biotype variation in brown planthopper and sources of genetic resistance to the different biotypes in the various countries. A major distinction between the insect populations in South Asia (Bangladesh, India, and Sri Lanka) and those in the rest of Asia is evident. Biotype differences of lower order within the common insect populations in East and Southeast Asian countries are also evident. Differential reactions within areas in India are also noted. Within each of the group of varieties of Bph 1, bph 2, Bph 3, and bph 4 genes identified at IRRI, certain differences are evident from the reactions in other countries and, based on those, a set of differential varieties has been proposed. PTB33, Suduru Samba, and Sinna Sivappu were resistant at almost all test sites. Several improved breeding lines derived from PTB33 were promising in all the regions of Asia and Solomon Islands. Genes conveying resistance to brown planthopper in PTB33 seem to be different in South Asia from those in the rest of Asia as evident from the differential reactions of the semidwarf selections derived from that variety. International collaboration in breeding and genetic studies has been emphasized for an effective follow-up on the extremely useful findings from the International Rice Brown Planthopper Nursery screening tests.

[1]By D. V. Seshu, plant breeder, and H. E. Kauffman, plant pathologist, International Rice Testing Program, International Rice Research Institute, Los Baños, Laguna, Philippines. Submitted to the IRRI Research Paper Series Committee May 1980.

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DIFFERENTIAL RESPONSE OF RICE VARIETIES TO THE BROWN PLANTHOPPER IN INTERNATIONAL SCREENING TESTS

The rice brown planthopper *Nilaparvata lugens* (Stål) has become a serious threat to rice production in several South, Southeast, and East Asian countries. The biotypic specialization of the insect and its role as a vector of the rice virus diseases, grassy stunt, ragged stunt, and wilted stunt have aggravated the challenge posed by the insect. Distribution of the brown planthopper (BPH) is seen in Figure 1. A comprehensive coverage of the problems posed by the BPH for rice production is provided by *Brown planthopper: threat to rice production in Asia* (IRRI 1979).

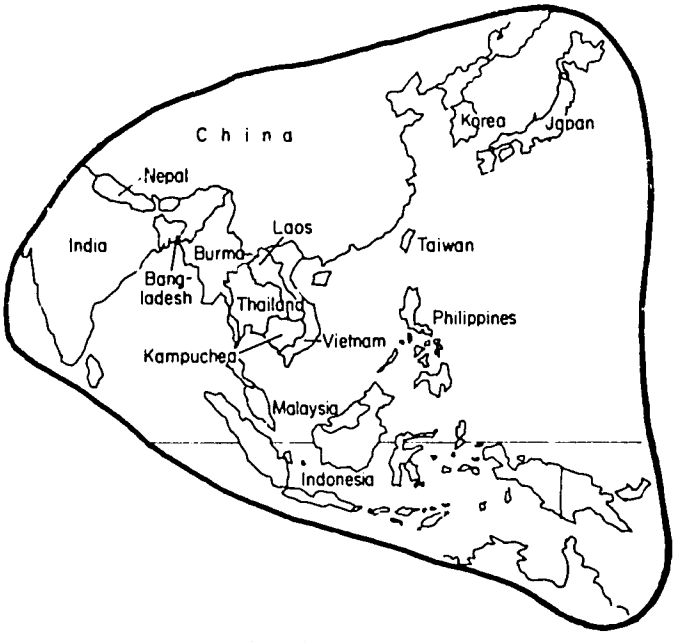

Fig. 1. Reported distribution of the brown planthopper.

The existence of biotype variation in BPH has become increasingly evident across time and space. For example, IR26, a BPH-resistant variety named by IRRI in 1973, was resistant in the Philippines but susceptible in India during the same period because of differences in the biotypes of the insect. Three years after its release IR26 also became susceptible in the Philippines because of a change in biotype. The same sequence of biotype development occurred in Indonesia and Vietnam.

An International Rice Brown Planthopper Nursery (IRBPHN) to monitor the biotypes of BPH was created in 1975. IRBPHN screening tests for 1975-79 in several Asian countries are discussed in this paper with special reference to:

- the understanding of biotype variation in BPH as evident from those results, and
- identification of traditional and improved varieties resistant to the insect at various sites.

THE INTERNATIONAL RICE BROWN PLANTHOPPER NURSERY

The objectives of the IRBPHN are to:

1. Disseminate traditional and improved varieties and breeding lines resistant to brown planthoppers and encourage the utilization of resistant germplasm in the rice improvement programs in different countries where the insect is a problem.
2. Determine the distribution of biotypes of the insect in various regions of the world.
3. Evaluate genetic resistance of selected varieties and breeding lines against diverse biotypes of the insect.

Screening and scoring procedures of IRBPHN

IRBPHN screening is done in the greenhouse and in the field.

Greenhouse. The test lines are seeded in rows 5 cm apart in 60 x 45 x 10-cm seedboxes. Each line is planted in a 20-cm row demarcated along the width of the seedbox. A susceptible and 3 resistant check varieties are planted in each seedbox. The outer rows in each seedbox are planted with TN1 to prevent escapes.

At 7 days after seeding the test varieties are thinned to contain about 20 to 30 seedlings per row. The seedboxes containing these lines are then placed in a 1.5 x 4.0 x 0.1 m galvanized iron tray on a table inside a fine mesh screening cage. The tray which contains about 5 cm standing water provides high humidity suitable for survival of the insects and also eliminates the need for watering the plants which may disturb the insects feeding on them.

The seedlings are then infested by gently tapping the pots with the insect colonies to uniformly scatter a large number of insects on the test plants. An average of 5-10 (depending on the biotype) second- and third-instar nymphs per seedling constitutes an optimum population to differentiate the resistant and susceptible lines. This infestation is adequate to kill the susceptible check lines in about 7-10 days.

The final rating for resistance is based on the extent of damage to the different test varieties. Reaction

scores are taken when 90% of the plants of the susceptible check variety (TN1) get killed. Scoring is based on a visual grading of 0-9, which is as follows:

Score	*Rating*	*Symptoms*
0	Highly resistant	No visible damage (= to resistant check)
1	Resistant	Partial yellowing of first leaf
3	Moderately resistant	First and second leaves partially yellow
5	Moderately susceptible	Pronounced yellowing and some stunting or wilting
7	Susceptible	More than half of the plants are wilting or dead and remaining plants severely stunted
9	Highly susceptible	All plants dead (= to susceptible check)

Field. Several border rows of the susceptible TN1 are planted 1 month earlier than the test varieties. High levels of nitrogen are applied to induce more rapid insect buildup. When the plants (TN1) are 30-40 days old, brown planthoppers are released. The susceptible border rows are sprayed with sublethal rates of an insecticide which induces the BPH population to increase. When the border TN1 plants show the initiation of hopperburn, the rows are cut on alternate days so that the BPH population moves to the test varieties.

Test entries are scored prior to harvest as per scale suggested for greenhouse and the number of BPH on 5 hills at random in each entry at peak period of infestation is recorded.

IRBPHN screening sites

The test sites and cooperating scientists for the IRBPHN screening for 1975-79 are listed in Table 1. The screening sites are in East Asia, Southeast Asia, South Asia, and Oceania (Fig. 2).

Test materials

The nursery included 41 entries in the first IRBPHN (1975), 97 in the second IRBPHN (1976), 128 in the third, 134 in the fourth (1978), and 162 in the fifth (1979). The test materials included several traditional tall varieties and improved semidwarf breeding lines. The entries tested over the 5-year period originated from the collections and breeding programs of Bangladesh, India, Indonesia, Japan, Korea, Sri Lanka, Taiwan, Thailand, and IRRI. The traditional tall varieties included were predominantly from South India and Sri Lanka, whereas the improved semidwarf lines were mostly from IRRI.

The check varieties were:

- *Mudgo.* It has a single dominant gene for resistance which was designated as Bph 1 (Athwal et al 1971). It is resistant to biotypes 1 and 3 at IRRI and susceptible to biotype 2.
- *ASD7.* Resistance in this variety is controlled by a single recessive gene bph 2. No recombination between Bph 1 and bph 2 was observed. The two genes reacted differentially to different biotypes and hence they were considered different but closely linked (Athwal and Pathak 1972). This variety is resistant to biotypes 1 and 2 of IRRI and susceptible to biotype 3.
- *ITB33.* Studies at IRRI indicated the presence of two genes for resistance, one dominant and one recessive, but their allelic relationships were not determined (Khush 1979). Duplicate dominant genes are reported from the studies in India (Krishna and Seshu 1978). This variety is resistant to biotypes 1, 2, and 3 at IRRI.
- *TN1.* Susceptible check. Susceptible to all 3 biotypes at IRRI.

The test entries also included other known sources of resistance, namely, the dominant gene Bph 3 as in the variety Rathu Heenati and the recessive gene bph 4 as in the variety Babawee (Lakshminarayana and Khush 1977).

Results reported here reflect at least 2 years of tests in a given site.

SCREENING RESULTS AND THEIR IMPLICATIONS

The nursery was screened against 3 biotypes at IRRI and at Chiayi, Taiwan, and against 2 biotypes at Bogor and Maros, Indonesia. The biotypes were designated as 1, 2, and 3 at Chiayi and IRRI and as 1 and 2 at Muara and Maros. In all other tests screening was against a single non-designated local biotype.

The proportion of susceptible entries at different test sites in the 1977-79 nurseries are summarized in Table 2. The information specific to 1978 nursery is also shown in Figure 3. The proportion of susceptible entries varied among locations but was quite high at all sites in South Asia compared to other regions. This is suggestive of the general distinctiveness of the insect populations in South Asia from the rest of Asia. In the Philippines, Taiwan, and Indonesia where screening was done with more than 1 biotype of the insect, the entries susceptible to biotype 1 in each case were relatively low.

Within South Asia the frequency of susceptible entries was extremely high at Gannoruwa, Sri Lanka; Pantnagar, India; and Joydebpur, Bangladesh. For example, the frequency of entries for different scores in 1978 IRBPHN at those 3 sites compared to those for IRRI biotype 2 were as follows:

Site	1978 IRBPHN entries (no.) with scores of									
	1	2	3	4	5	6	7	8	9	Total
Gannoruwa	0	0	2	0	4	0	29	0	98	133
Pantnagar	0	0	0	2	4	5	13	40	67	131
Joydebpur	6	0	7	0	19	0	26	0	76	134
IRRI biotype 2	28	0	33	0	13	0	11	0	49	134

The reactions of the check varieties in the greenhouse tests at different sites are summarized in Table 3. Mudgo was resistant at all sites in East and Southeast Asia but not to biotype 2 in Taiwan, Indonesia, and the Philippines. It was susceptible at all sites in South Asia and Solomon Islands. ASD7 was resistant at all sites in East and Southeast Asia and Solomon Islands but not to biotype 3 in the Philippines and to biotypes 2 and 3 in Taiwan. It was reported to be susceptible to biotype 1 in Taiwan in 1978 and 1979 IRBPHN but moderately resistant in earlier years. It was susceptible at all South Asian sites. PTB33 exhibited resistant reactions at all sites (inclusive of all biotypes where there are more than one) except at Pantnagar, India, and Gannoruwa, Sri Lanka. The reactions at Gannoruwa, however, were not consistent from year to year. TN1 is susceptible at all sites. Thus, based on the reactions of the check varieties, two types of reaction patterns are evident as follows:

Region	Reaction[a]			
	PTB33	ASD7	Mudgo	TN1
East and Southeast Asia	R	R[b]	R	S
South Asia	R[c]	S	S	S

[a]Refers to biotype 1 in the Philippines, Taiwan, and Indonesia. [b]Reaction to biotype 1 not consistent in Taiwan. [c]Except at Pantnagar, India. R = resistant, S = susceptible.

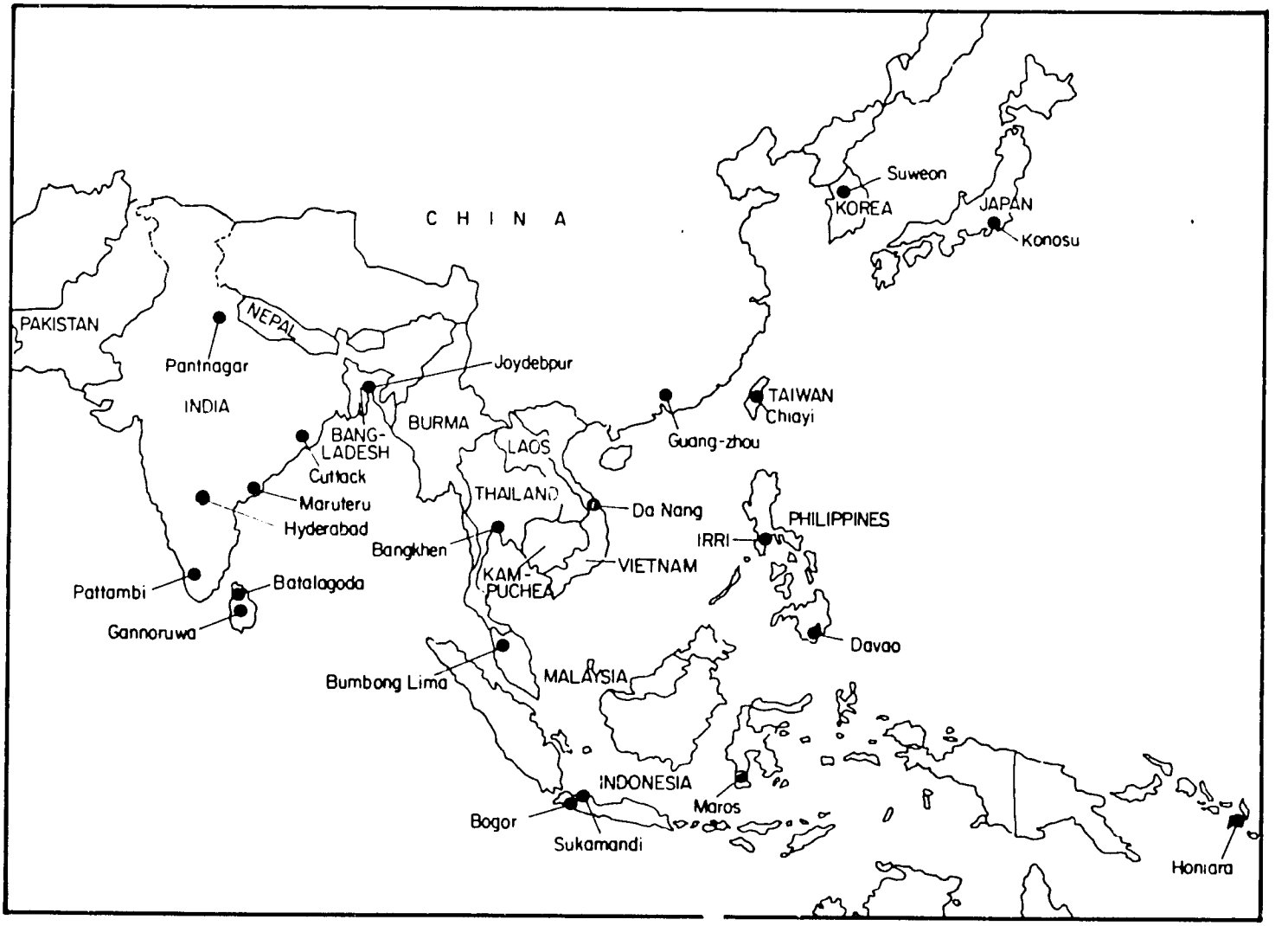

Fig. 2. Screening sites for the International Rice Brown Planthopper Nursery.

Table 1. International Rice Brown Planthopper Nursery (IRBPHN) test sites and cooperators, 1975-79.

Region	Site	Cooperator(s)	Year
East Asia	Konosu, Japan	C. Kaneda	1976-78
	Seoul, Korea	S. Y. Choi	1975-77
	Chiayi, Taiwan	R. J. Chiu, Wao	1975
		C. C. Huan	1976
		C. H. Cheng	1977-79
Southeast Asia	Bogor, Indonesia	Suartini	1975, 1977, 1979
		I. Oka, Suartini, W. Dela	1978
	Sukamandi, Indonesia	O. Mochida, S. Hendarsih	1976-77
		O. Mochida, S. Tatang	1978
		O. Mochida, T. Suryana	1979
	Maros, Indonesia	P. V. Halteren, S. Sama, Slamet	1975
		I. Manwan, S. Sama	1976
		I. Manwan, S. Sama, Wafiali	1977, 1979
		I. Manwan, S. Sama, N. Akib	1978
	Bumbong Lima, Malaysia	J. Varughese, G. V. Vreden	1979
	Los Baños, Philippines	Entomology Department, IRRI	1975-77
		-do-	1977
		-do-	1978
		-do-	1978
		-do-	1979
		E. A. Heinrichs, F. Medrano, V. Viajante	1979
	Davao, Philippines	R. Reyes	1975
	Bangkhen, Thailand	P. Weerapat, S. Pongprasert, T. Jaturonrungsi	1975
		P. Weerapat, T. Jaturonrungsi	1976
		S. Pongprasert, Thayapatchra	1977-78
		P. Weerapat, W. Sirikant, V. Kamboonruang	1979
	Hoa Chan, Vietnam	D. T. Tuan, N. O. Thuat	1977
South Asia	Joydebpur, Bangladesh	S. Alam, R. Karim, M. B. Alam	1977
		S. Alam, M. S. Alam	1978-79
	Hyderabad, India	M. B. Kalode	1975, 1977
		M. B. Kalode, A. Laxminarayana	1976
		M. B. Kalode, N. V. Krishnaiah	1978
		M. B. Kalode, Y. Kondala Rao	1979
	Cuttack, India	B. C. Misra	1975, 1977, 1978, 1979
	Pattambi, India	B. Thomas	1975, 1977
	Maruteru, India	Rice Breeder	1977
		D. V. Siva Rao	1978
	Pantnagar, India	P. K. Pathak, S. K. Verma	1977
		S. K. Verma, M. N. Lal	1978-79
	Batalagoda, Sri Lanka	C. Kudagamage	1975
		L. Nugaliyadde	1978
	Gannoruwa, Sri Lanka	Y. Elikawela, J. S. Devadas	1976-78
Oceania	Honiara, Solomon Is.	J. Howell	1975
		Y. Y. Jackson	1978-79

Test entries that showed reactions at IRRI similar to Mudgo (resistant to biotypes 1 and 3 and susceptible to biotype 2), ASD7 (resistant to biotypes 1 and 2 and susceptible to biotype 3), and PTB33 (resistant to biotypes 1, 2, and 3) are listed in Tables 4, 5, and 6. The reactions within each group at other sites were not similar, particularly in East and Southeast Asia. For example, Mudgo (Bph 1 gene) was resistant to biotypes 1 and 3 but susceptible to biotype 2 at IRRI and was susceptible at all the South Asian sites. BKMBRI088-84, on the other hand, had similar reactions as Mudgo at IRRI but was resistant at several South Asian sites. Likewise, ASD7 (bph 2 gene) and

Table 2. Proportion of susceptible entries in the International Rice Brown Planthopper Nursery (IRBPHN) greenhouse screening tests at different sites, 1977-79.

Site	Susceptible entries (%)					
	1977		1978		1979	
	Scores 5-9	Scores 7-9	Scores 5-9	Scores 7-9	Scores 5-9	Scores 7-9
East Asia						
Konosu, Japan	16	13	27	25	-	-
Suweon, Korea	23	17	-	-	-	-
Chiayi, Taiwan						
Biotype 1	5	5	38	30	25	17
Biotype 2	67	62	52	47	41	38
Biotype 3	25	22	43	38	27	18
Guang-zhou, China	-	-	36	30	-	-
Southeast Asia						
Bogor, Indonesia						
Biotype 1	15	7	23	23	38	25
Biotype 2	-	-	79	57	58	44
Sukamandi, Indonesia	44	16	32	20	24	16
Maros, Indonesia						
Biotype 1	21	11	19	9	24	15
Biotype 2	-	-	59	51	-	-
Bumbong Lima, Malaysia	-	-	-	-	38	26
IRRI, Philippines						
Biotype 1	8	5	57	30	21	19
Biotype 2	68	62	54	45	38	33
Biotype 3	34	23	69	51	26	23
Bangkhen, Thailand	59	44	30	25	32	20
Da Nang, Vietnam	36	9	-	-	-	-
South Asia						
Joydebpur, Bangladesh	85	79	90	76	83	73
Hyderabad, India	57	38	89	77	80	64
Cuttack, India	70	57	82	71	70	60
Pantnagar, India	98	82	98	92	99	94
Gannoruwa, Sri Lanka	92	85	98	95	-	-
Oceania						
Solomon Islands						
Greenhouse	-	-	40	22	57	34

CR94-13 showed similar reactions to the three biotypes at IRRI (resistant to biotypes 1 and 2 and susceptible to biotype 3) but ASD7 was susceptible to biotypes 2 and 3 and CR94-13 resistant to all 3 biotypes in Taiwan (reaction of ASD7 to biotype 1 in Taiwan was not consistent). Some differences with regard to genes for resistance of varieties within each reaction group based on IRRI biotypes are thus evident. Also evident is the fact that although there is a major distinction between insect populations in East and Southeast Asia and those in South Asia, biotypic differences of a lower order exist among the common insect populations at different countries within East and Southeast Asia.

Among the varieties resistant to all three biotypes at IRRI, three different types of reactions were observed at sites in different countries:

Group	Reactions[a] to BPH at sites in	
	East and Southeast Asia and Solomon Islands	South Asia
PTB33	R[b]	R[c]
Varieties with Bph 3 gene	R[b]	R, MR
Varieties with bph 4 gene	R[d] (except in Indonesia, where they are susceptible particularly to biotype 2)	MR, S

[a]R = resistant, MR = moderately resistant, S = susceptible. [b]Includes all 3 biotypes in the Philippines and Taiwan and 2 biotypes in Indonesia. [c]Except at Pantnagar, India. [d]Includes all 3 biotypes in the Philippines and Taiwan.

Table 3. Reactions to BPH of check varieties in the International Rice Brown Planthopper Nursery (IRBPHN) at different test sites.[a]

Site		Mudgo	ASD7	PTB33	TN1
Konosu, Japan		R	R	R	S
Chiayi, Taiwan	B_1	R	MR/S[b]	R	S
	B_2	S	S	R	S
	B_3	R	S	R	S
Guang-zhou, China		R	R	R	S
Muara, Indonesia	B_1	R	R	R	S
	B_2	S	R	R	S
Sukamandi, Indonesia		R	R	R	S
Maros, Indonesia	B_1	R	R	R	S
	B_2	S	R	R	S
IRRI, Philippines	B_1	R	R	R	S
	B_2	S	R	R	S
	B_3	R	S	R	S
Bangkhen, Thailand		R	R	R	S
Joydebpur, Bangladesh		S	S	R	S
Hyderabad, India		S	S	R	S
Cuttack, India		S	S	R	S
Pantnagar, India		S	S	S	S
Pattambi, India		S	S	R	S
Gannoruwa, Sri Lanka		S	S	R[b]	S
Solomon Islands		S	R	R	S

[a] B_1 = biotype 1, B_2 = biotype 2, B_3 = biotype 3. R = resistant, MR = moderately resistant, S = susceptible.
[b] Reaction not consistent.

Table 4. Entries showing Mudgo-type reactions to the 3 biotypes at IRRI but some with differential reactions at other sites.

Designation	Cross	Deviations from Mudgo-type reactions
Mudgo	-	Refer to Table 3 for Mudgo reactions at different sites.
B2360-11-3-2-1	IR2180-2/IR2178-1	Reactions similar to those of Mudgo at all sites
IR26	IR24/TKM6	-do-
RD9	LY*2/TN1//W1256///RD2	-do-
Milyang 44	YR675-153/IR26	-do-
OB 678	-	-do-
HR1231-258-2	WX126-48-12/RR108-2	-do-
BKNBR1088-84	IR2030-203-3-1/RD1	Resistant in South Asian sites
BKNBR1030-28-1-3	Muey Nawng 62M/IR262//RD9	Susceptible in Thailand
WX324-20-6-8	WX206/IR206-214-2-3-6	Resistant in Sri Lanka
H5 (Acc 156)	-	Susceptible to biotypes 2 and 3 in Taiwan; resistant in Sri Lanka
BKNBR1094-78-1	IR2031-352-3-2/BKN6805-2-7	Resistant at Indian sites

The traditional varieties PTB33, Suduru Samba (Acc36851), and Sinna Sivappu (Acc15547) and the improved variety IR13427-60-1 were resistant at almost all test sites.

Some of the Assam Rice Collection (ARC) lines from Northeast India reported to be resistant to BPH in India (Krishna et al 1976) were included in the IRBPHN. ARC lines in general showed good level of resistance in South Asia and some, such as ARC6650, showed resistance at several sites in East and Southeast Asia. At Joydebpur, Bangladesh, where generally there has been a high proportion of susceptible entries, ARC6650 and ARC14529 each

scored 1 in 1978 and 1979. ARC10550 showed distinct differential reactions in the 1977 IRBPHN where it was resistant at all South Asian site and susceptible at all East and Southeast Asian sites. Entries resistant in South Asia but susceptible in the rest of Asia were not common among the IRBPHN entries.

Improved breeding lines rated resistant or moderately resistant to BPH at different sites are in Table 7. Those listed under East and Southeast Asia and Solomon Islands were from divergent sources, whereas most of the entries found promising at the South Asian sites owe their origin to PTB33 or PTB21.

Table 5. Entries showing ASD7-type reactions to the 3 biotypes at IRRI but differential reactions at other sites.

Designation	Cross	Deviations from ASD7-type reactions
ASD7	-	Refer to Table 3 for ASD7 reactions at different sites.
CR94-13	PTB21/PTB18//IR8	Resistant to all 3 biotypes in Taiwan
B2850b-Si-2-3	B541b-Kn-91-3-1/IR2011-15-4-1-2	-do-
ARC6650	-	Resistant to all 3 biotypes in Taiwan; susceptible to biotype 2 in Indonesia; resistant in South Asia
IR44	IR1529-680-3/CR94-13//IR480-5-9-3	Resistant to all 3 biotypes in Taiwan; susceptible to biotype 2 in Indonesia
Murungakayan 3	-	Resistant (moderately resistant) to biotypes 1 and 2 in Taiwan and susceptible to biotype 3

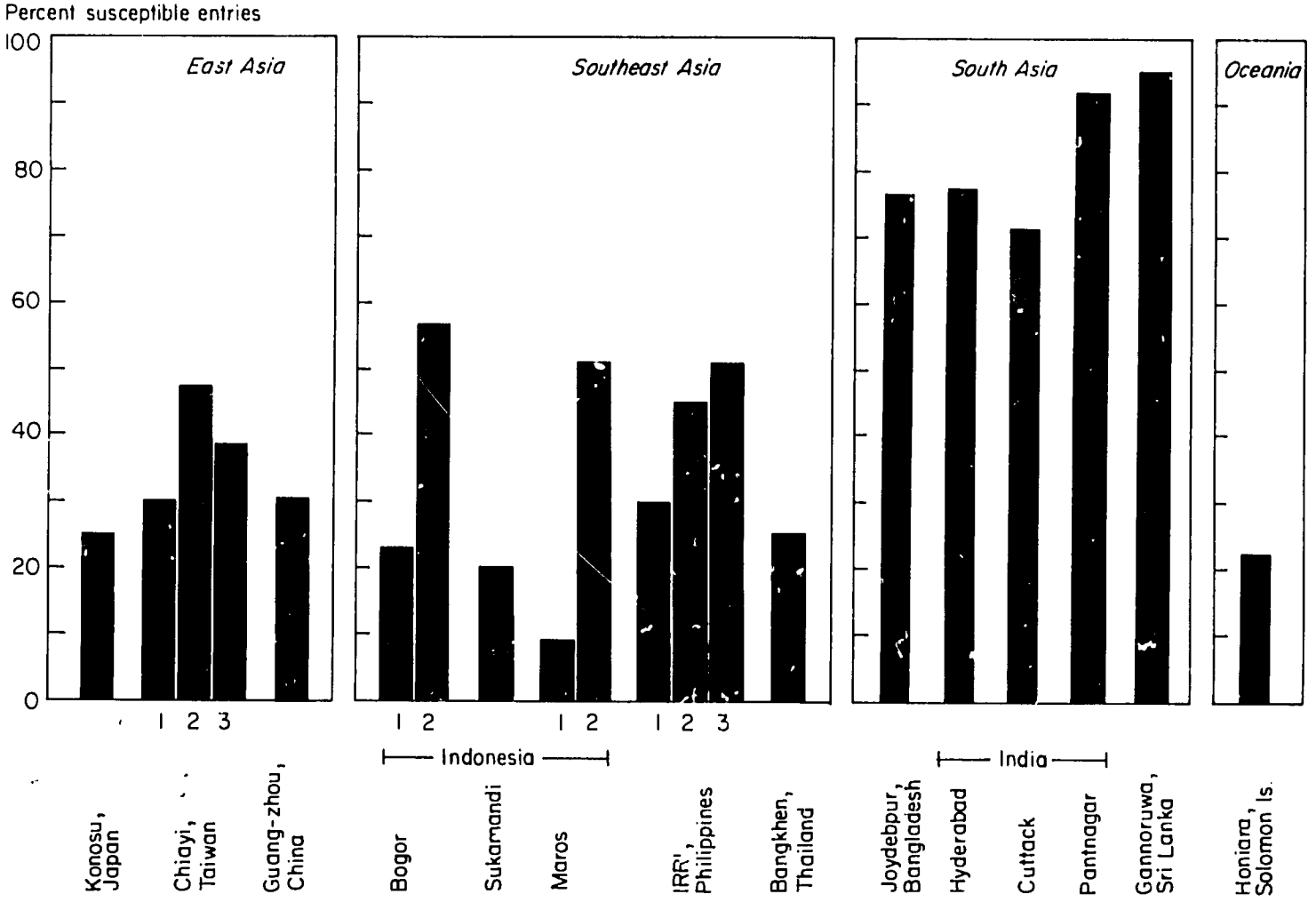

Fig. 3. Percent susceptible entries at different test sites of the 1978 International Rice Brown Planthopper Nursery. (1, 2, and 3 refer to biotypes 1, 2, and 3)

Table 6. Entries showing PTB33-type reactions to the 3 biotypes at IRRI but some with differential reactions at other sites.

Designation	Deviations from PTB-33 type reactions
PTB33	Refer to Table 3 for PTB33 reactions at different sites
Suduru Samba	Reactions similar to those of PTB33 at all sites
Sinna Sivappu	-do-
Rathu Heenati (Bph 3)	Resistant, moderately resistant, and moderately susceptible in Bangladesh and India
Kuru Hondarawala (Bph 3)	Resistant to moderately resistant in Bangladesh and India
PTB19 (Bph 3)	-do-
Gangala (Bph 3)	Susceptible to biotype 2 in Indonesia; moderately susceptible to susceptible in South Asia
Heendoramawee (bph 4)	Susceptible to biotype 2 in Indonesia; susceptible in South Asia
Kahata Samba (bph 4)	-do-
Gambada Samba (bph 4)	Susceptible in Japan; susceptible to biotype 2 in Indonesia; susceptible in South Asia
Kalu Kuruwee (bph 4)	-do-
Lekam Samba (bph 4)	-do-
Senawee (bph 4)	-do-
Babawee (bph 4)	Susceptible in Thailand; resistant and susceptible at different sites in India

Although PTB33 was resistant at all South (except in Pantnagar), East, and Southeast Asian sites, the improved derivatives from PTB33 selected for BPH resistance at IRRI were not all resistant in South Asia. For example:

- IR13429-196-1, IR13429-3-2, and IR13429-47-3 were resistant in East and Southeast Asia but susceptible in South Asia.
- IR13427-60-1 and IR13427-45-2 were resistant in East, Southeast, and South Asia.

It would thus be apparent that different genes in PTB33 convey resistance in South Asia and in the rest of Asia. Genetic studies at IRRI indicated that PTB33 possesses one dominant and one recessive gene (Khush 1979). In India duplicate genes were reported (Krishna and Seshu 1978).

At IRRI greenhouse tests, materials resistant to either biotype 2 or 3 were also resistant to biotype 1 and those susceptible to both biotypes 2 and 3 were also susceptible to biotype 1. Exceptions, where an entry was resistant only to biotype 1, were Chianung sen yu 11, Chianung sen yu 20, and HP191-9-B-B-11-2. If these reactions are confirmed, the varieties mentioned may prove to be alternate gene sources.

Biotype differences were evident within sites in India, where reactions at Pantnagar were distinct from those at other sites. Almost all entries in the IRBPHN were susceptible at Pantnagar. Some differences in reactions were observed at Cuttack and Hyderabad.

The 1979 IRBPHN included some selections from crosses involving Triveni, a semidwarf variety from Kerala, India. KAU10666, KAU10658, KAU10661-1, and KAU10667 were all selections from the cross Triveni/IR36; KAU1722-2 and KAU1734-2 were selected from the cross Triveni/IR1539. Triveni is susceptible to the 3 biotypes in IRRI greenhouse tests, IR1539 has the Bph 1 gene, and IR36 the bph 2 gene. All the selections from the above crosses were, however, resistant to the 3 biotypes at IRRI and at all sites in East and Southeast Asia. The Triveni/IR1539 derivatives, in addition, were resistant or moderately resistant in South Asia.

Differences between field and greenhouse reactions of several entries were observed in sites where both tests were carried out. More detailed studies are needed to provide genetic interpretation for such differences.

Table 7. Improved breeding lines in the International Rice Brown Planthopper Nursery (IRBPHN) rated resistant or moderately resistant in greenhouse tests at different test sites.

Region/Site	Entries	
	Designation	Cross
East and Southeast Asia and Solomon Islands[a]		
	IR4432-52-6-4	IR2061-125-37/CR94-13
	IR9115-40-1-3	C021/IR2153-14-1-6-2/IR36
	IR32	IR20*2/O.N.//CR94-13
	IR44	IR1529-680-3/CR94-13//IR480-5-9-3
	IR46	IR1416/IR1364//IR1366/IR1539
	IR48	IR1702-74-3-2/IR1721-11-6-8-3//IR2055-481-2
	B2850b-Si-2-2	B541B-KN-91-3-1/IR2011-15-4-1-2
	B2360-11-3-2-1	IR2180-2/IR2178-1
	CR95-13-3	IR8/Leuang 152
	KAU10667	Triveni/IR2071
	BKNBR1030-28-1-5	Muey Nawng 62M/IR262//RD9
	BG379-1	BG96-3*2/Ptb33
	IR3518-96-2-2-2	BKN6806-18/IR1529//CR94-13/IR1416
	IR13429-47-3	IR4432-53-33/PTB33//IR36
	IR13240-82-2	IR30S/Babawee//IR36
	IR15315-42-2	Babawee/IR4432-53//IR4432-84-3-1
	IR17494-32-2-4	R. Heenati/IR3403-267-1*3
	IR13543-66	R. Heenati/IR3403-267-1//IR34
	IR8608-82-3-2	IR2061-465-1-5-5/IR2071-625-1
	IR13427-45-2	IR3403-267/PTB33//IR36
	IR13427-60-1	-do-
	IR17496-2-25-1	PTB33/IR3403-267-1*3
South Asia		
Joydebpur, Bangladesh	BKNBR1088-81	IR2039-203-3/RD1
	RP825-24-7-5	Vijaya/Ptb21
	B2850b-Si-2-2	B541b-KN-91-3-1/IR2011-15-4-1-2
	IR13543-66	R. Heenati/IR3403-267-1//IR34
	KAU1722-2	Triveni/IR1539
	KAU1734-2	-do-
	IR13429-198-2	IR4432-53-33/PTB33//IR36
	IR13427-60-1	IR3403-267/PTB33//IR36
	IR13240-6-3	IR30S/Babawee//IR36
	BG12-1	OB678/BG11-11*2
Cuttack, India	CR57-11-2	IR8/PTB21
	B2360-8-5-9-5	IR2180-2/IR2178-1
	RP825-24-7	Vijaya/Ptb21
	IR13543-66	R. Heenati/IR3403-267-1//IR34
	KAU1734-2	Triveni/IR1539
	IR13427-60-1	IR3403-267/PTB33//IR36
	IR13429-198-2	IR4432-53-33/PTB33//IR36
	IR17496-2-25-1	PTB33/IR3403-267-1*3
	IR17494-32-2-4	R. Heenati/IR3403-267-1*3
	IR13240-6-3	IR30S/Babawee//IR36
	IR13427-45-2	IR3403-267/PTB33//IR36
	IR13427-60-1	-do-
	BG12-1	OB678/BG11-11*2
Hyderabad, India	RP825-24-7	Vijaya/Ptb21
	KAU1734-2	Triveni/IR1539
	IR13427-45-2	IR3403-267/PTB33//IR36
	IR17494-32-2-4	R. Heenati/IR3403-267-1*3
	IR17496-2-25-1	PTB33/IR3403-267-1*3
Pantnagar, India[b]	KAU10667	Triveni/IR2071
	IR17496-2-25-1	PTB33/IR3403-267-1*3
	CR178-22-527	MR1550/Ratna
	B1991-Pn-43-4-1	Pelita I-1/CPA6805-7
	RP825-24-7	Vijaya/Ptb21
Gannoruwa, Sri Lanka[b]	RP825-24-7	Vijaya/Ptb21
	CR57-11-2	IR8/PTB21
	CR95-13-3	IR8/Leuang 152
	WX324-20-6-8	WX206/IR2061-214-2

[a]Includes the Philippines, China, Taiwan, Japan, Indonesia, Malaysia, and Thailand. [b]All listed entries are moderately resistant.

At IRRI, Triveni, a variety selected from the cross PTB10/TN1/PTB15, was susceptible to all 3 biotypes in the greenhouse but moderately resistant in the field. The variety apparently has an interesting genetic background relative to BPH resistance. Triveni, although susceptible in most other countries, has shown resistant to moderately resistant reactions in several greenhouse tests in Indonesia (Table 8).

Monitoring varietal differences for field resistance through more systematic studies and international collaboration may help in identifying sources of moderate resistance that may likely have extended effectiveness in combating the insect problem. Among the IRBPHN entries, Utri Rajapan, a variety from Thailand, holds some promise as it has demonstrated field resistance in two seasons' tests at IRRI and has a high level of resistance to tungro virus. IR46 possibly represents a combination of major gene resistance for biotypes 1 and 3 and field resistance to biotype 2. These varieties may have special significance in future breeding programs. Efforts toward identification and utilization of field resistance should go hand in hand with continued attempts to monitor alternate sources of major genes for resistance and incorporation of those in agronomically superior genotypes either singly or in effective combinations.

Table 8. Reactions of the variety Triveni to brown planthopper in Indonesia and the Philippines, 1975-79, International Rice Brown Planthopper Nursery (IRBPHN).

Year	Reaction scores at						
	Indonesia (Greenhouse)			IRRI, Philippines			
	Bogor	Sukamandi	Maros	Greenhouse			Field
	B_1			B_1	B_2	B_3	
1975	5	-	2	8	8	8	-
1976	5	1	2	8	8	9	-
1977	4	6	1	[illegible]	9	7	-
1978	7	9	5	9	9	9	1
1979	9	5	3	5	5	5	7

B_1, B_2, and B_3 refer to biotypes 1, 2, and 3.

CONCLUSIONS AND SUGGESTIONS

IRBPHN is a valuable medium for an international collaborative effort in understanding host-insect relationships and the genetic variation in the insect biotypes, a knowledge that ultimately helps in developing effective breeding strategies. Excellent sources of resistance have been identified. The differential varieties identified in the discussion may serve as a potential gene pool for providing appropriate gene combinations toward achieving more stable genetic resistance to BPH in different countries that are concerned with the pest. Future collaborative genetic studies based on IRBPHN findings may help in more clearly establishing the diagnostic attributes of the different biotypes and providing them valid designations.

We have several suggestions relative to breeding for BPH resistance.

1. Resistant segregants from early filial generations from crosses involving certain BPH-resistant varieties should be tested at different sites and resistant selections interchanged after each generation. This procedure should be followed until fixed lines are developed. One underlying philosophy is that when a variety has resistance to several biotypes, it may be because of a specific gene(s) conveying resistance to several biotypes or because of the presence of several independent genes each conferring resistance to a specific biotype(s). In the latter case selection for resistance at a single site will not be effective in developing genotypes with broader resistance. *Mobile breeding*, meaning thereby mutual exchange and testing of early generation resistant selections at various sites concerned with the insect, will have an obvious advantage under those circumstances.

2. The procedure in item 1 is also true for crosses between two resistant parents with different genes for resistance.

3. Varieties listed in Tables 4 to 6, when used appropriately in breeding programs, may produce additive or interactive effects that may broaden the host resistance. For example, the genotypes receiving genes from both ASD7 and CR94-13 (which have similar reactions at IRRI but differential reactions in Taiwan) may prove

resistant in regions where both ASD7 and CR94-13 are susceptible.

4. Resistance genes from several ARC lines should be combined with PTB33 and Bph 3 genes.

5. PTB21 derivatives such as CR57-11-2 and RP825-24-7 should be crossed with improved PTB33 and Rathu Heenati derivatives and selections combining genes from these sources identified. These selections could be screened for other pests such as gall midge to which PTB21 is resistant. Gall midge and BPH occur together in several regions in India, Indonesia, China, and Sri Lanka.

6. Chianung sen yu 11 and Chianung sen yu 20, if proved deviant from the reaction patterns at IRRI (resistant to biotype 1 and susceptible to biotypes 2 and 3), may be utilized as new sources of resistance and combined with other known sources.

7. The field tolerance of Utri Rajapan can be utilized either singly or in combination with major genes for resistance to specific biotypes.

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