Varietal resistance to the brown planthopper in Korea

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Since 1971, varietal screening for resistance to the brown planthopper has been conducted successfully using the mass-screening techniques developed by IRRI. Many varieties and lines from foreign collections have been identified as resistant, with resistance reactions identical to those of IRRI. Some factors of insect resistance were investigated. It was found that the resistant varieties are nonpreferred for feeding, but not always for oviposition. On resistant varieties, brown planthoppers suffered high mortality, had a slower rate of growth, and laid fewer eggs, from which fewer adults developed. Such effects might be attributed to less feeding on the resistant than on susceptible plants.

Study of the inheritance of resistance to the brown planthopper showed that the resistance in IR2061 seemed essentially the same as that in Mudgo, i.e. controlled by a single dominant gene.

No hopper-resistant varieties have been released, but many promising lines with hopper resistance are in advanced-generation trials. Their resistance-gene sources are mainly IR747B2-6 and Mudgo, with that of a few being H105. We are continually endeavoring to diversify resistance-gene sources.

THE BROWN PLANTHOPPER *Nilaparvata lugens* is now one of the key pests on rice in the countries of the Far East and Southeast Asia. In Korea, outbreaks have been sporadic and frequently severe. In 1975, we observed a severe outbreak in the southern part of the Republic of Korea. Severe losses of rice yield resulted : 24.1% in the Tongil variety, and 38.3% in Akibare (Park and Lee 1975).

In recent years, resistant varieties have received increasing attention because of growing awareness of the shortcomings of chemical pesticides. It has been well documented that varietal resistance can be a practical method for controlling insect pests. The control need is critical in Korea, because conventional rice varieties are all highly susceptible to the brown planthopper.

It is important that the available rice germplasm be screened for resistance to the pest and that resistance compatible with other desirable plant characters

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be incorporated into new varieties. Since 1971, Korean rice breeders and entomologists have paid great attention to discovering resistant sources, and to their use in Korea's breeding programs.

Fortunately, significant progress has been made in developing varietal resistance to the brown planthopper. Some lines showing high resistance will be commercialized in the near future.

SCREENING FOR RESISTANCE

In 1971, techniques of mass screening for varietal resistance to the brown planthopper were first introduced into Korea from the International Rice Research Institute (IRRI). Mass screening of seedlings was conducted in the greenhouse or laboratory, or sometimes in the screenhouse. Field screening is practically impossible in Korea because of fluctuations in annual migrations and the difficulty of obtaining sufficient insect populations for testing.

Mass rearing of test insects

The original colony of the test insects is started by one pair of adults. They are mass-reared on such susceptible rice varieties as Tongil, Yushin, and Jinheung, which provide the insects with food and sites for oviposition. Two methods are used in mass rearing; one uses 40- or 50-day-old potted plants inside a wooden cage covered by fine-mesh nylon cloth; the other uses rice seedlings placed in a transparent acrylic (plastic) cage. Details of both methods have been described by Choi (see Choi this volume). In the latter method, seedling-mats are prepared by placing the pregerminated seeds on gauze in enameled photographic trays. Two or three days later the seedlings are caged with adult insects. After 2 days, seedling-mats that contain eggs are taken out of the cages, after first removing the ovipositing insects. The plants or seedling-mats are transferred to another cage to await egg hatching. The method provides a continuous supply of test insects. The use of rice seedling-mats is feasible in the laboratory in the off-season, but rearing efficiency is inferior to that of potted plants in the field or greenhouse.

Screening procedures

Test varieties are seeded in rows spaced 4 cm apart in 40- × 51- × 10-cm polyethylene seedboxes. Each cultivar is planted in a 15-cm row across the width of the seedbox. A susceptible check variety (usually TNl, or Tongil, Yushin, or Jinheung) and a resistant check variety (always Mudgo) are planted at random in each seedbox.

The seeds are usually pregerminated by soaking in water at 30°C. For the first 10 hours the seeds are disinfected with fungicide phenyl mercuric acetate (PMA) in a water solution; then they are soaked again in water, which is replaced several times. Individual seeds are spaced uniformly within each row. The method, although laborious, gives a more uniform stand of seedlings than direct seeding. Twenty test varieties are accommodated in each seedbox. The seeded boxes are placed in a concrete or iron tray containing 5 cm of standing water. The bottom of each seedbox has several small holes to admit water freely. The water standing in the tray provides the high humidity required for survival of *N. lugens,* and eliminates the need for watering that might disturb feeding insects.

The seedboxes are usually covered by a bottomless wooden cage (30 × 40 × 30 cm) covered with fine-mesh nylon cloth. The cage keeps the insect population constant, preventing insects from escaping during the screening.

Seedlings at the one-leaf stage are infested by scattering a large number of second- and third-instar nymphs on them, an average of five insects per seedling. Final readings are made 10 to 14 days after infestation when all susceptible check plants have been killed. The scoring system of 0 to 9 is used.

Resistance response of source varieties

About 2,000 varieties or lines from Korean varietal collections and foreign introductions have been mass-screened for resistance to the brown planthopper. A large number from IRRI were reidentified in Korea as resistant, and at present their resistance has been identical to that of reactions at IRRI. All the japonica varieties tested so far from the Korean collection have been identified as highly susceptible.

CAUSES OF RESISTANCE

The resistance of varieties to insects could be due to one or more factors; nonpreference, antibiosis, or tolerance. Tolerance responses are generally more influenced by environmental conditions than are nonpreference and antibiosis (Painter 1951; Pathak 1970). Studies, therefore, have stressed evaluation of varietal resistance to the brown planthopper in terms of non-preference and antibiosis.

Preference for feeding and oviposition

Since 1971, investigations on the preference of brown planthopper for feeding and oviposition on different varieties of rice have been reported in Korea (Choi et al 1976; Song et al 1972). These results indicated that the brown planthopper exhibited distinctly different preferences for different varieties in respect to feeding and oviposition. With the resistant and susceptible varieties, feeding preferences of the brown planthopper nymphs did not always coincide with the ovipositional preference of adults.

Song et al (1972) carried out an experiment for evaluating the nature of resistance of rice varieties to the brown planthopper. The test varieties were sown in rows containing 10 seedlings per row, 4 cm apart, in 36- × 46- × 10-cm polyethylene seedboxes. At the one-leaf stage, about 800 third-instar nymphs were placed on the rice plants. In a separate experiment with the same method,

Table 1. Preference of brown planthoppers for feeding and oviposition on resistant and susceptible varieties of rice (Song et al 1972).

Variety	Feeding and ovipositional preference [a]		
	Nymphs (no./plant)	Eggs (no./plant)	Seedling reaction
Su-yai-20	6.5 a [b]	25.8 de [b]	S [c]
Suweon 213-1	5.3 ab	35.4 cd	S
Suweon 214	5.2 ab	22.9 de	S
Suweon 218	4.9 b	24.6 de	S
Suweon 215	4.8 bc	29.8 de	S
Jinheung	4.3 bcd	27.3 de	S
Suweon 217	4.1 bcde	26.3 de	S
H 105	3.4 cdef	56.3 bc	R
Vellailangalayan	3.2 defg	25.6 de	R
IR8	3.0 defgh	51.0 bc	S
Pankhari-203	2.8 efgh	24.0 de	S
DV-139	2.5 fgh	80.2 b	S
ASD-7	2.1 fgh	135.9 a	R
MGL-2	1.7 gh	58.5 bc	R
Mudgo	1.6 h	73.1 b	R

[a] 48 hours exposure. [b] In a column any two means followed by the same letter are not significantly different at the 5% level. [c] S = susceptible, R = resistant.

about 200 female adults were released on seedlings at the two-leaf stage. After 48 hours, the numbers of nymphs and of eggs on the seedlings of each variety were recorded.

As shown in Table 1, fewer nymphs were recorded on the resistant varieties Mudgo, MGL-2, and ASD-7, than on the susceptible varieties Su-yai-20, Suweon 213-1, etc. In contrast, the varieties Mudgo, MGL-2, and ASD-7 had a relatively large number of eggs despite a low feeding preference. Generally, there was low feeding preference for the resistant varieties. However, the insects caused no apparent damage to resistant varieties such as H105 and Vellailangalayan, which showed relatively high feeding preference. Song et al (1972) also conducted an experiment to ascertain the preferences of the brown planthopper for oviposition on resistant varieties. When female brown plant-hopper adults were placed individually in test tubes on the resistant variety ASD-7 and the susceptible variety Suweon 214, the numbers of eggs laid were significantly fewer on ASD-7 than on Suweon 214. When the two varieties were grown together in a test tube, brown planthoppers significantly preferred ASD-7 for oviposition (Table 2). When each test tube contained only ASD-7, the insects had to feed on it or starve, but the insects laid fewer eggs on it than on the susceptible variety Suweon 214. However, when each test tube contained both varieties, the insects frequently moved about from the resistant variety to the susceptible variety and vice-versa; presumably to one for feeding and to the other for oviposition.

There is additional strong evidence to account for differences in feeding and oviposition of the brown planthopper on resistant varieties. Choi et al (1976) conducted a laboratory experiment to evaluate the nature of resistance of the new rice varieties Milyang 21 and Milyang 23 to the brown planthopper.

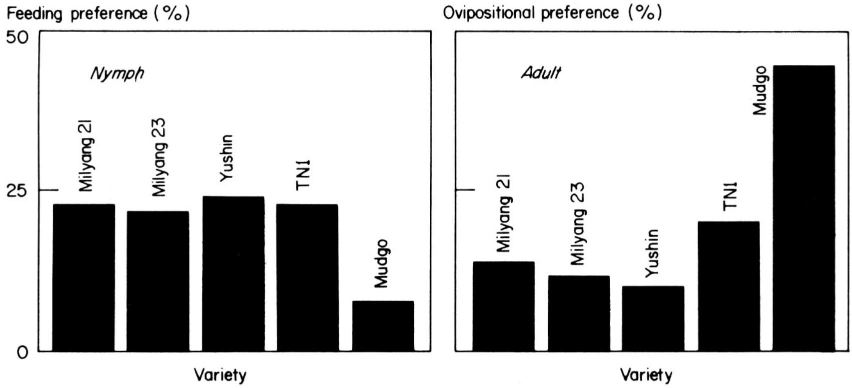
Table 2. Ovipositional preference of brown planthopper on rice varieties ASD-7 and Suweon 214 grown separately or together (Song et al 1972).

Variety	Eggs[a] (no./female)					Eggs (total no./female)
	1 Di	2Di	3Di	4Di	5Di	
			Grown separately			
ASD-7	5.5	2.3	10.3	0	0	17.8
Suweon 214	12.5	19.3	10.1	2.5	19.9	64.3
			Grown together			
ASD-7	18.1	12.4	5.4	14.2	12.3	62.4
plus						
Suweon 214	3.5	6.1	1.0	2.5	6.1	19.2

[a] Di = days after infestation.

According to our results (Fig. 1), nymphs preferred to feed on the susceptible varieties Milyang 21, Milyang 23, and Taichung Native 1 rather than on Mudgo. For oviposition, however, the adults preferred Mudgo rather than the susceptible varieties. Similar findings were also reported for small brown planthoppers (*Laodephax striatellus*) (Choi et al 1974, 1976), whitebacked planthoppers (*Sogatella furcifera*) (Choi et al 1973c), green rice leafhoppers (Choi et al 1973a) and zig-zag leafhoppers (Choi et al 1973b).

There is some evidence that contradicts the previous findings. Lee et al (1971) tested the preference of the brown planthopper for oviposition on varieties of rice in a paddy field screenhouse (39.6 m^2). The plants were exposed to about 10,000 brown planthopper adults 28 days after transplanting. After 7 days, eggs on 5 randomly selected plants of each variety were counted. A significantly higher number of eggs was found on the susceptible varieties than on the resistant variety Mudgo (Table 3).



1. Preference of brown planthopper nymphs and adults for feeding and oviposition on the seedlings of some varieties (Choi et al 1976).

Table 3. Ovipositional preference of brown planthopper on rice varieties or lines in a paddy field screenhouse (Lee et al 1971).

Source[a]	Varieties and lines tested (no.)	Egg-masses (no./15 hills)	Eggs (no./egg-mass)	Eggs (no./hill)
Tongil lines	12	82 2 ± 26.1	6 6 ± 0.6	36.3 ± 11.7
Japonica varieties	15	99 6 ± 30.1	6 3 ± 0.6	40.6 ± 11.2
IR1317 lines	8	97 5 ± 26.5	6.6 ± 0.7	44.0 ± 14.0
Other IR lines	11	108.8 ± 37.9	6.3 ± 0.5	44.7 ± 12.4
TN1 (check)		126	7	56
Mudgo (check)		8	6	3

[a]Varieties or lines susceptible to the brown planthopper.

Survival and development

When plants contain factors preventing insects from feeding on them, or are toxic to insects, the phenomenon is commonly known as antibiosis. At present, such a form of resistance appears to be desirable, and possibly has a more permanent basis for maximum effectiveness. Emphasis has, therefore, been placed on identifying varieties exhibiting antibiosis.

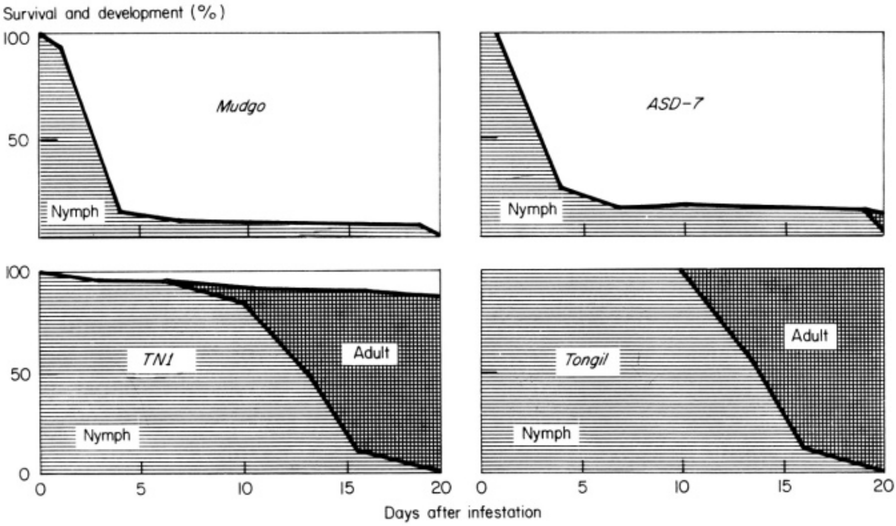
Lee and Park (1976) identified some lines that have been bred in Korea with promising resistance to the brown planthopper. First-instar nymphs caged on the new lines suffered high mortality, and fewer insects developed into adults than those that developed from nymphs on the susceptible varieties Tongil and Yushin (Table 4). Similar results were reported by Choi (1975) and Lee and Park (1976).

Song et al (1972) conducted a series of experiments to evaluate the nature of resistance of several varieties, studying several biological effects on the brown planthopper. The first-instar nymphs were caged on 10- to 14-day-old seedlings

Table 4. Rate of adult emergence of brown planthopper when first-instar nymphs were confined on seedlings of resistant and susceptible varieties or lines (Lee and Park 1976).

Variety or line	Insects infested (no.)	Adults emerged (no.)	Adult emergence (%)
Resistant lines[a]			
KR108-335-6	30	0	0
KR 87-56-4	20	1	5.0
KR 78-87-4	17	1	5.9
YR901-16-1	32	3	9.4
HR632-9-4	10	1	10.0
HR529-45-3	30	6	20.0
YR 92-91-3	38	12	31.6
HR529-42-5-2	19	6	31.6
Susceptible varieties[b]			
Yushin	14	12	85.7
Tongil	24	22	91.7

[a]Newly bred lines in Korea. [b]Leading varieties from indica japonica crosses.



2. Survival and development of' first-instar brown planthopper nymphs on 10- to 14-day-old seedlings of resistant (Mudgo and ASD-7) and susceptible (TN1 and Tongil) varieties (Song et al 1972, 1974).

of the resistant varieties Mudgo and ASD-7, and on the susceptible varieties TN1 and Tongil (Suweon 213-1). After caging on Mudgo. nymphs suffered high mortality. and few nymphs became adults; while on TN1 and Tongil, nymphal survival was high and all nymphs became adults (Fig. 2).

In additional, but separate, experiments some biological interactions between the insects and the varieties were studied (Table 5). The varieties did not in any way affect the egg period and hatchability. However, the nymphs caged on resistant plants had a longer nymphal life than those on susceptible lines. The nymphal span was extended by about I week on resistant varieties. The lowest adult emergence was recorded on Mudgo (5.3%); the next lowest (11.2%) on ASD-7. High numbers of adults emerged on TN1 (87.1%), on Suweon 214 (96.8%), and on Tongil (l00%). It is also apparent from the results that resistant

Table 5. Biological effects of resistant and susceptible rice varieties on the brown plant-hopper [a] (Song et al 1972).

Variety	Egg period (days)	Hatcha-bility (%)	Nymphal period (days)	Adult emergence (%)	Female adults life span (day)	Eggs (no./female)
Mudgo	8.3	92.0	20.0 a	5.3 a	0.5 a	0 a
ASD-7	7.2	94.2	20.0 a	11.2 b	0.8 a	0 a
TN1	8.5	90.4	13.7 b	87.1 c	13.4 b	46.6 b
Suweon 213-1	7.8	91.4	14.0 b	100 d	14.4 b	203.4 c
Suweon 214	8.2	92.6	13.4 b	96.8 cd	21.2 c	245.7 c

[a] In a column. any two means not followed by the same letter are significantly different at the 5% level.

varieties affect the longevity of adult insects. Large numbers of eggs were recorded in susceptible varieties, while no eggs were found on Mudgo or ASD-7, where the adults fed and died before egg-laying.

Feeding ability on resistant plants

It has been documented that insects sucking the plant sap excrete honeydew, and the amount of honeydew excretion is positively correlated with the amount of food ingested. The quantity of honeydew excreted can be used as a criterion for the quantitative assessment of insect feeding (IRRI 1968).

An estimate of the honeydew excreted by the brown planthopper on resistant and susceptible varieties was reported by Song et al (1974) and Lee and Park (1976). Five female adults were caged for 24 hours on individually potted plants. The honeydew dropped onto and was absorbed by filter paper in the bottom of the cage. A quantitative determination of relative honeydew excretion was obtained by treatment within ninhydrin. Results revealed that the relative amount of honeydew excreted by female adults of brown planthopper was much less after feeding on the resistant varieties Mudgo and Vellailangalayan than after feeding on the susceptible varieties TNl, Suweon 213-1, and Suweon 214.

Utilizing the ninhydrin method, Lee and Park (1976) investigated the relative amount of honeydew excreted by brown planthoppers fed on some selected Korean lines. It was also apparent from their results that brown planthoppers excreted less honeydew when feeding on resistant plants than on susceptible varieties (Table 6).

GENETICS OF RESISTANCE

Resistance derived from IR2061-214-2-3-6

Limited numbers of hybrid materials were checked for the inheritance of resistance to hoppers. As shown in Tables 7, 8, and 9, Mudgo and IR2061-214-

Table 6. The relative amounts of honeydew excreted by 5 female brown planthopper adults when caged on selected resistant lines (Lee and Park 1976).

Variety or line	Amt. of honeydew (cm^2)[a]
Resistant lines[b]	
KR108-335-15	0.09
KR 87-56-4	0.17
HR529-42-5-2	0.19
KR 78-87-4	0.39
HR529-45-3	1.00
Susceptible varieties[c]	
Yushin	5.3
Milyang 22	2.5
Tongil	4.4
Jinheung	5.8
TN1	5.1

[a]24-hour excretion. [b]The newly bred lines in Korea. [c]Leading Korean varieties.

Table 7. Reactions[a] to the brown planthopper of parent and hybrid materials (Kim and Heu, unpubl.).

Variety or cross	Rices (no.)[a]				X^2	P
	R	M	S	Total		
Parents						
Mudgo	302			302		
IR2061	146			146		
Co 22	190	6	3	199		
ASD-7	170	16	21	207		
IR4	186	52	24	262		
Ptb 18	190	2	10	202		
Muthumanikam	152	7	24	183		
Vellai-ilangalayan	99	11	38	148		
WX126			466	466		
F_2's						
Mudgo/WX126	602	18	203	823	0.059	0.75-0.90 (3:1)
WX126/Mudgo	429	7	153	589	0.326	0.50-0.75 (")
IR2061/WX126	742	16	248	1006	0.085	0.75–0.90 (")
Co 22/WX126	235	10	76	321	0.266	0.50–0.75 (")
WX126/Co 22	188	8	64	260	0.022	0.75–0.90 (")
ASD-7/WX126	124	15	425	564	2.734	0.05–0.10 (1:3)
WX126/ASD-7	61	13	214	288	2.242	0.10-0.25 (1:3)
IR4/WX126	1503	529	4187	6219	2.319	0.10-0.25 (")
Ptb 18/WX126	450	32	403	885		(")
WX126/Ptb18	323	23	318	664		(")
Muthumanikam/WX126	148	15	143	306		(")
Vellai/WX126	185	21	64	270	0.180	0.50-0.75 (3:1)

[a] R = resistant, M = moderately resistant, S = susceptible.

2-3-6 showed clear resistance responses while the others had a few susceptible individuals (Kim and Heu, unpubl.). Whether that was caused by impurity of the insect population or by incomplete penetrance of the resistant gene was not checked. Although the F_2 data of the crosses involving those resistant parents are presented in Table 7, the segregation ratios in their successive progenies were not studied except in the crosses involving IR2061.

Linkage relationship of the resistance from IR2061

Tests were conducted to find linkage relationships between the resistance to the brown planthopper of IR2061 and the marker genes of linkage-testers established by Takahashi (1964). As shown in Table 10. the resistance seems

Table 8. Reactions to the brown planthopper in BC_1 F_2 (Kim and Heu, unpubl.).

Cross	Reaction[a]			X^2	P
	Seg	S	Total		
Mudgo/WX126[2]	38	28	66	1.516	0.10-0.25
IR2061/WX126[2]	24	19	43	0.528	0.25-0.50
Co 22/WX126[2]	24	19	43	0.528	0.25-0.50

[a] Seg = segregating, S = susceptible.

Table 9. Reactions[a] to the brown planthopper in F_2's of R|R crosses (Kim and Heu, unpubl.).

Cross	Rices (no.)				Susceptible plants (%)
	R	M	S	Total	
Mudgo/ASD-7	176	5	13	294	4.5
ASD-7/Mudgo	201	2	6	209	29
Mudgo/Ptb 18	141	2	5	148	34
Mudgo/Co 22	277	1	8	286	2.8
Mudgo/IR2061	248	0	0	248	0

[a] R = reststant, M = moderately resistant, S = susceptible

to be associated with the purple-stigma (Ps) marker, which belongs to the linkage group V (Heu and Suh, unpubl.). Because the markers Ps and I-Bf are loosely associated (with 42 units of C.O. value) according to (Takahashi 1964) the resistance seems to be loosely associated with the I-Bf marker.

BREEDING FOR RESISTANCE

Breeding lines

Breeding for the brown planthopper resistance in Korea was started in 1971, when an IRRI trainee brought back some F_2 and BC_1F_1 seeds, mainly of crosses involving Mudgo, which were designated as KR lines. Some BC_1F_1 seedlings of the KR lines were distributed to Korea's three crop experiment stations during the summer of 1971 and were used as sources of resistance in hybridization work. In the same year, several hundred KC lines introduced from IRRI were grown, and some of them were utilized as resistance sources.

At the Suweon Crop Experiment Station, many KC lines were tested at first, but most were soon dropped because of unacceptable plant type. Many

Table 10. Linkage relationship of the resistance to brown planthopper in IR2061 and marker characters (Heu and Suh. unpubl.).

Character	Segregation				X^2	P
Purple stigma		Ps	t	Total		
(Ps)	CK	81	22	103		
Group V	Surv	25	17	42	9.051	0.005
	R	(33)	(9)			
	(3.1)	(31.5)	(10.5)		5.365	.01-025
Inhibitor for		I-Bf	Bf	Total		
brown fullow	CK	243	71	314		
(I-Bf)	Surv	140	59	199	5.628	.01-025
Group V	R	(154)	(45)			
	(3:1)	(149.25)	(49.75)		2.293	10–.25

[a] CK = segregation which did not screen for hoppers'. Surv = segregation of survived plants; R = ratio from the check

Table 11. Crosses and lines for the resistance to the brown planthopper Suweon Crop Exp. Stn., unpubl.).

Cross	F_1 crosses	F_2		F_3 and adv[a]		OYT[b]		YT[c]	
		Crosses	Families	Crosses	Lines	Crosses	Lines	Crosses	Lines
IR747B₂-6									
IR26	–	7	247	1	9	–		–	
IR29	–	5	84	–	–	–		–	
IR30	–	1	9	–	–	–		–	
IR747	1	2	10	1	127	–		–	
IR1541	–	2	76	–	–	–		–	
IR2061	18	24	637	1	212	–		–	
IR2071	6	11	253	–					
IR2151	3	5	94	1	24				
IR2153	2	1	10	–	–				
IR2181	2	2	21	2	119				
IR3255	–	1	2	–	–				
Mudgo									
KC45	–	–	–	1	67	–		–	
KC50	–			11	814	1	8	–	
KC59	–			2	76	–		–	
KR77	1								
KR36								1	2
Mudgo	1								

[a]Adv = advanced generations. [b]Observational yield trials. [c]Yield trials

crosses were made with those KC lines having a male desirable plant type; some were carried to advanced generations (Table 11; Suweon Crop Exp. Stn. 1976, unpubl.). Among the crosses with KR lines, only two progressed to the yield-trial stages. Many IRRI lines were utilized as parents in crossing for resistance, but as shown in Table 11, only limited numbers of resistant lines were selected.

At the Honam Crop Experiment Station, the KR lines were intensively screened and many of them progressed to the observational yield trial stage. Among them, only two lines advanced to yield trials (Table 12; Honam Crop Exp. 1976. unpubl.). In the Honam area, damage caused by brown planthopper and whitebacked planthopper is observed almost every year. Consequently, varieties to be released for the area must have resistance to hoppers.

At the Youngnam Crop Experiment Station, emphasis was placed more on the screening for the small brown planthopper and the green rice leafhopper (*Nephotettix cincticeps*), which respectively serve as vectors for the stripe virus and the dwarf virus. Since 1975, when the brown planthopper outbreak was widely observed, even in the Suweon area, screening for brown planthopper resistance was intensified (Table 13; Youngnam Crop Exp. Stn. 1976, unpubl.). Among many advanced lines. the most promising are Milyang 30. 34, and 36, which derive their resistance from IR946. Early hybrid generations of those lines were screened mainly for stripe virus and not for brown plant-hopper. Nevertheless, the hopper resistance was carried to the advanced genera-

Table 12. Crosses and lines for resistance to the brown planthopper (Honam Crop Exp. Stn., unpubl.).

Cross	F_1 crosses	F_2 crosses	F_3 and adv[a]		OYT[b]		YT[c]	
			Crosses	Lines	Crosses	Lines	Crosses	Lines
IR747B$_2$-6								
IR26	6	12						
IR28	12	4						
IR29	16	5						
IR34	3	–						
IR747	–	–			1	1		
IR2061	16	22						
IR2151	1	6						
IR2153	–	4						
Mudgo								
IR1857	–	1						
IR2034	–	1						
IR2035	2	2						
IR2562	–	2						
Mudgo	–	–	1	5				
KR 36	4							
KR 77	–	14						
KR 78	–	–	2	147				
KR108	1	15	16	674	1	37	1	2
KR109	–	–	7	149	1	5		
HR515			11	524	1	7		
HR517	–	–	1	44	–	–		
HR1225	–	–	–	–	1	1		
HR1271	–	1	–	–	–	–		
HR2131	36	26	–	–	1	7		
HR2132	3	–	–	–	1	1		
HR2138	3	–	–	–	1	2		
Iri 328	3	–	–	–	1	1		
Iri 329	6	–	–	–	1	1		
CR 94–13								
IR32	2							
IR36	3							
H *105*								
Mil. 30	5							

[a]Adv = advanced generations. [b]Observational yield trials. [c]Yield trials.

tion. Consequently the improved lines were used as parents in many crosses for resistance to both the brown planthopper and to viruses.

In 1976, for the first time, advanced yield trials were made with the following lines: Suweon 271 and 272 bred in Suweon; Iri 328 and 329 bred in Honam; and Milyang 30, 34, and 36 bred in the Youngnam Crop Experiment Station (Table 14). The resistance of the first four originate from Mudgo, and of the latter three from H105.

Resistance source

Although many varieties and lines from IRRI were used as sources of resistance, their ancestry can be traced back to the four varieties–IR747B$_2$-6, Mudgo, CR94-13, and H105. Because the resistance gene of IR747B$_2$-6 is the same as that of Mudgo (Martinez and Khush 1974), most of the lines bred in Korea

Table 13. Crosses and lines for resistance to brown planthopper (Youngnam Crop Exp. Stn. unpubl.).

Cross	F_1 crosses	F_2 crosses	F_3 and adv[a] crosses	OYT[b] crosses	YT[c]	
					Crosses	Lines
IR747B$_2$-6						
IR26	–	1	5			
IR28	8	7	–			
IR29	8	4	–			
IR30	5	12	–			
IR34	8	–	–			
IR747	–	–	3	19		
IR2061	26	8				
Mudgo						
IR1539	–	–	2	11		
IR2035	–	–	2	–		
WX 318	10	–	–	–		
KC 58	–	–	1	3		
CR 94-13						
IR32	3					
IR2071	7					
H 105						
IR4	–	–	1			
Mil. 30	47					
Mil. 34	10					
YR 983					1	3
BC34-8						
BC 34-8	10	–	1	3		

[a]Adv = advanced generations. [b]Observational yield trials. [c]Yield trials.

Table 14. Advanced lines tested for their performance and resistance to brown planthopper.

Designation	Pedigree	Cross
Suweon 271	Wx318-5A-4-4-1	IR1317/IR833//Tongil^2///KR36
Suweon 272	Wx318-5A-6-16	"
Iri 328	HR1231-117-1	Wx126-48/KR108-2
Iri 329	HR1231-258-2	"
Milyang 30	YR1010-17-5	YR983/YR675
Milyang 34	YR1010-42	"
Milyang 36	YR1010-17-5-2	"

have the resistance gene *Bph1* only. Anticipating the outbreak of new biotypes. crossing started very recently using Babawee and Rathuheenati, but screening against biotypes other than biotype 1 is not yet being conducted in Korea.

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