RESISTANCE OF RICE VARIETIES TO BROWN PLANTHOPPER (*Nilaparvata lugens* Stal)

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INTRODUCTION

The brown planthopper, (*Nilaparvata lugens* Stal), is a serious pest of rice in central and southern parts of Taiwan. Heavy infestation of this insect usually takes place in the warm and humid wet season crop when its population is high. Consequently, "hopper hurn" is more frequently observed in the second crop of rice. The damage caused by periodic extensive outbreaks of this insect during the period of 1962 to 1966 in Taiwan was estimated to reach as much as NT$ 800 or US$ 20 millions (Tao, 1967). In addition to this direct injury, the brown planthopper also causes damage to rice indirectly by acting as a vector of the grassy stunt virus disease of rice (Ling, 1968). The problem of effective control of this insect is, therefore, particularly important. The use of insecticides is not only expensive but provides only temporary control, although it remains the only practical method of controlling this insect at the present time. The development of brown plant hopper resistant varieties of rice offers a cheap and more permanent solution to this problem.

Breeding rice for brown planthopper resistance was initiated at the Chiayi Agricultural Experiment Station in 1968. Mudgo, an Indian variety found to possess high level of resistance to the brown planthopper (IRRI, 1968), was introduced in 1968 and this variety was crossed with local commercial varieties to furnish materials for both genetical studies (Chang, 1970; Chen and Chang, 1971) and breeding purpose. Also, from the screening of our varietal collection, an early introduction from the International Rice Research Institute (IRRI), IR 9-60 was identified to have a very high degree of resistance to the brown planthopper. Since most of agronomical characters of IR 9-60 are more desirable than those of Mudgo or other resistant varieties introduced from IRRI in 1969 and 1970, this strain was extensively used as the resistant parent in our breeding program. In addition to the regular testing of new introductions and breeding materials, efforts were also made to determine the mode of inheritance of brown planthopper resistance in resistant parents in order that our breeding program might advance more rapidly and effectively. This paper presents the reaction of several IRRI introductions and local commercial varieties to the infestation of the brown planthopper. Data obtained from the preliminary studies on the inheritance of brown planthopper resistance in rice strain, IR 9-60 are also reported.

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MATERIALS AND METHODS

Rice varieties evaluated for the resistance to the brown planthopper included 18 IRRI introductions and 4 local commercial varieties frequently used as parents in our breeding program. With the exception of IR 8, IR 9-50, and Zenith, all IRRI introductions were obtained in 1970. Among 1970 IRRI introductions, 12 varieties namely Mudgo, Pankhari 203, ASD 7, Kayama MGL 2, PTB 18, H 105, Muthumanikam, Vellanlangalayan, DK 1, DV 139, Bir-tsan No. 3, and AC 435 were specially selected for the testing at this station in order to find out if varietal reaction to the brown planthopper in Taiwan is similar to that in Philippines. Materials used for the inheritance studies were F_1 and F_2 plants of Taichung native 1 x IR 9-50; F_1, F_2 plants, and F_3 families of IR 8 x IR 9-50, and F_2 plants of IR 9-50 x IR 8. Both parents of each cross were also included in the testing. Taichung native 1 and IR 8 are susceptible and IR 9-50 is resistant to the brown planthopper.

Testing materials were sown in rows about 5 cm apart in 60 x 30 x 10 wooden flats. Each entry occupied one row except F_2 plants which were planted in several rows. Rice seeds were first germinated in petri dishes and 20 to 25 germinating seeds were spaced uniformly in a row. Each flat accommodated 10 rows of test plants and 1 row each of Mudgo, the resistant check, and Taichung native 1, the susceptible check. In the testing of hybrid plants, both parents were also included in the same flat in addition to check varieties.

About 10 days after sowing, the wooden flats were transferred to the insect rearing room covered with fine mesh screen and placed in a galvanized iron tray laid on a concrete bench. Water was maintained in the tray at a depth of 3 cm to provide suitable moisture for the plants. The seedlings were infested with third-instar to fourth-instar nymphs of the brown planthopper at the rate of 5 insects per plants or 1,200 per flat. The whole tray was covered with a nylon net after artificial infestation was made on all flats. The insects used in this test were obtained from cultures maintained in the insectary.

In the testing for varietal resistance, each plant was rated for its reaction to the brown planthopper damage once in every three days after the infestation. The final reaction of test plants was recorded when all susceptible check plants were either completely dead or wilting. The number of nymphs per plant was counted one and three days after the infestation. The average number of days the plants of each susceptible variety died was also recorded as the longevity of that variety. For the inheritance studies, each plant was rated for brown planthopper reaction when the seedlings of susceptible parents had been killed by the brown planthopper.

The 0 to 5 scale used by the International Rice Research Institute (IRRI, 1969) was also employed in this experiment for the recording of the seedling reaction. Grade 0 seedlings show no visible damage of the insect. Grade 1 seedlings show partial yellowing of the first leaf. Grade 2 seedlings show partial yellowing of the first and second leaves. Grade 3 seedlings show pronounced yellowing and slight stunting. Grade 4 seedlings show signs of wilting and severe stunting. Grade 5 seedlings are dead completely. In the testing for varietal resistance, rating of resistance for each test variety was based on the average

grade of its individual test plants. Rice varieties with average grade of 0 to 0.9, 1.0 to 1.9, 2.0 to 2.9, 3.0 to 3.9, 4.0 to 4.9, and 5.0 were rated as highly resistant (HR), resistant (R), moderately resistant (MR), moderately susceptible (MS), susceptible (S), and highly susceptible (HS), respectively. In the testing of hybrid plants, however, plants falling within the categories of grades 0, 1, and 2 were classified as resistant whereas grades 3, 4, and 5 plants were called susceptible. The number of plants in each grade was recorded and the chi-square analysis was made on each generation for the inheritance of resistance.

This experiment was conducted in the first and second crops of 1970 at the Chiayi Agricultural Experiment Station.

RESULTS AND DISCUSSION

Varietal Resistance

The reaction of rice varieties to the brown planthopper is presented in Table 1. It was observed that among 12 selected rice varieties from the International Rice Research Institute, H 105 and Muthumanikam were rated as highly resistant; Mudgo, ASD 7, Kayama MCL 2, and Vellanlangalayan as resistant; PTB 18 as moderately resistant; DV 139 and AC 435 as moderately susceptible; DK 1 and Bir-tsan No. 3 as susceptible, and Pankhari 203 as highly susceptible. From the varietal reaction of these varieties in IRRI (1969) which was also shown in Table 1, it became apparent that the pattern of varietal resistance to brown planthopper in rice was essentially alike in both stations. Although Mudgo, ASD 7, PTB 18 appeared less resistant; H 105 and Muthumanikam, more resistant; DV 139 and AC 435, less susceptible; and Pankhari, more susceptible in this testing in comparison with those of IRRI, there was no evidence to indicate that varietal reaction to brown planthopper in this station is different from that of IRRI. Since seeds of these 12 varieties also came from IRRI, the same reaction to brown planthopper recorded for these varieties at both stations seems to indicate that the brown planthopper used for the testing in this station is identical to that used in IRRI. Thus, the problem of physiological differentiation in *Nilaparvata lugens* Stal appears not important at the present moment.

Table 1. Reaction of rice varieties to the brown planthopper.

Variety or strain	Damage grading of rice seedlings				Reaction	Number of nymphs per plant			Longevity of rice seedlings (DAI)
	6 DAI*	12 DAI	18 DAI	Rating of resistance	in IRRI**	1 DAI	3 DAI	Average	
Mudgo	0	0.7	1.6	R	HR	3.3	3.1	3.2	—
Pankhari 203	0.1	5.0	5.0	HS	S	9.1	6.3	7.7	10.2
ASD 7	0.1	0.6	1.9	R	HR	3.7	3.8	3.8	—
Kayama MCL 2	0	0.8	1.9	R	R	3.3	6.3	4.8	—
PTB 18	0.1	0.8	2.0	MR	R	3.6	3.2	3.4	—
H 105	0	0	0.4	HR	R	2.8	2.7	2.7	—

Muthumanikam	0	0	0.4	HR	R	4.7	2.1	3.4	—
Vellanlangalayan	0	0.3	1.0	R	R	6.3	5.3	5.8	—
DK 1	0	0.8	4.8	S	S	7.7	8.5	8.1	13.1
DV 139	0.1	2.3	3.4	MS	S	8.1	7.0	7.5	17.7
Bir-tsan No. 3	0.6	3.9	4.9	S	S	7.1	7.3	7.6	12.9
AC 435	0	1.1	3.1	MS	S	7.6	8.6	8.1	18.7
IR 747 B_2-6-3	0	0.3	1.7	R	—	3.4	3.3	3.3	—
IR 1154-243	0.1	1.0	1.8	R	—	3.3	3.5	3.4	—
IR 9-60	0	0	0.4	HR	—	2.0	2.0	2.0	—
IR 8	0	1.9	4.2	S	—	5.6	6.3	5.9	17.6
IR 20	0	2.3	4.1	S	—	4.2	5.3	4.7	16.7
Zenith	0.8	5.0	5.0	HS	—	7.0	6.2	6.6	9.4
Chianan 8	0.2	4.5	5.0	HS	—	4.2	5.2	4.7	9.2
Tainan 5	0.2	5.0	5.0	HS	—	4.9	4.7	4.8	9.8
Kaohsiung shen 2	0.3	3.6	5.0	HS	—	4.9	5.4	5.1	12.2
Taichung native 1	0.4	2.9	5.0	HS	—	5.3	4.9	5.1	13.6

*DAI=Days after infestation.

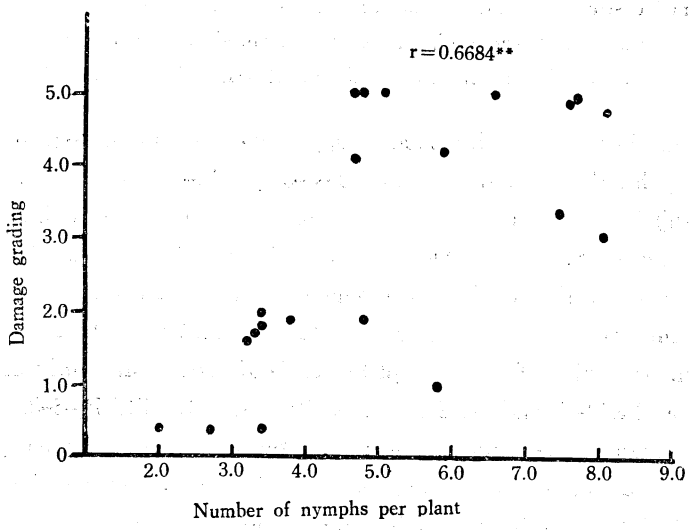
**Taken from "Testing rice varieties for brown planthopper and green leafhopper reaction", mimeograph printed on November 25, 1969 by the International Rice Research Institute.

Among remaining 6 IRRI introductions, IR 9-60 (Peta x I-geo-tze) fell into the category of being highly resistant, IR 747 B_2-6-3 (TKM-6/2 x TN 1) and IR 1154-243 (IR 8/2 x Zenith) into the resistant group, IR 8 and IR 20 into the susceptible group, and Zenith into the highly susceptible category. These three resistant lines thus constitute valuable breeding materials for the development of rice varieties resistant to the brown planthopper in our station. It was of interest to note that these three resistant lines were all selected from progenies of the susceptible varietal crosses and only one parent of each line namely Peta, TKM-6, and IR 8 for lines IR 9-60, IR 747 B_2-6-3, and IR 1154-243, respectively was found to be slightly tolerant to the brown planthopper (IRRI, 1968). This observation seems to indicate that sources of resistance to insect damage may not be necessarilly limited to varieties possessing high level of resistance and the possibility of recovering resistant recombinants in the progenies of the susceptible crosses should also be fully explored in the breeding program provided the parental varieties possess certain degree of tolerance to the brown planthopper. The two japonica rice varieties Chianan 8 and Tainan 5, and two indica rice varieties Kaohsiung shen 2 and Taichung native 1, were found to be highly susceptible.

The host preference of the brown planthopper expressed in the number of nymphs per plant is also given in Table 1. It was observed that the number of nymphs per plant differed considerably among test varieties, showing that the insects were able to locate

a host and stay on it. The number of nymphs per plant counted one day after infestation was generally similar to that counted 3 days after infestation for all test varieties, indicating that difference in varietal preference became evident within 24 hours after the release of the insects. A similar observation was also made by Sogawa and Pathak (1970). Rice varieties rated as susceptible were found to attract more insects than those rated as resistant, The average number of nymphs per plant was 6.3 for susceptible varieties whereas that for resistant varieties was 3.6. The results clearly demonstrated that susceptible varieties were more prefered by the brown planthopper and nearly twice as much insects were clustering on susceptible varieties. The average number of nymphs per plant is compared to the final damage grade of rice seedlings in Figure 1 ($r=0.6684^{**}$). The highly significant correlation coefficient seems to suggest that non-preference plays an important role in the resistance of the varieties to the brown planthopper in this experiment. However, considerably larger numbers of nymphs associated with certain resistant varieties such as Vellanlangalayan and Kayama MGL 2 may also be an indication of the involvement of factors other than non-preference in the varietal resistance to the insects.

Fig. 1. Relationship between damage grading of rice seedlings at 18 days after infestation and average number of nymphs per plant in 22 rice varieties.



The longevity of susceptible varieties expressed in the number of days the rice seedlings died is presented in Table 1. It was observed that rice seedlings died about 10.7, 15.1, and 18.2 days after infestation for the highly susceptible, susceptible, and moderately susceptible varieties respectively, showing that the longevity of rice seedlings was inversely associated with the level of varietal susceptibility. However, the longevity of rice seedlings was also found to differ substantially among rice vaerities of the same susceptible grade. For instance, Chianan 8 and Taichung native 1 were both rated as highly susceptible but

the latter outlived the former by more than 4 days, indicating that the ability to withstand the insect damage varied with varieties even though they fell in the same category of susceptibility. Thus, the longevity of rice seedlings appears useful in further differentiating susceptible varieties for their tolerance to insect damage. Susceptible varieties with better seedling survival in the insectary are likely to be more tolerant in the field than those with poor seedling survival. However, indica type variety, Taichung native 1 which showed better seedling surival than japonica type variety, Chianan 8 in this test was usually found to develop "hopper burn" earlier and severer than most of japonica type varieties in commercial rice field. It seems, therefore, doubtful if the length of seedling longevity really reflects the degree of field tolerance for susceptible varieties. Further investigation on the usefulness of seedling longevity for susceptible varieties appears worthwhile.

Inheritance of Resistance

The reactions of F_1, F_2 plants and F_3 families from the crosses of Taichung native 1 x IR 9-60, IR 8 x IR 9-60, and IR 9-60 x IR 8 are given in Table 2. It was observed that among 22 F_1 plants in the cross of Taichung native 1 x IR 9-60, there were three grade 3 plants, two grade 4 plants, and 17 grade 5 plants. Twenty plants of the susceptible parent, Taichung native 1 were classified to be all grade 5 whereas 8 plants of the resistant parent, IR 9-60 fell into grade 1 and 12 plants into grade 2. Among 20 F_1 plants of the cross IR 8 x 9-60, one was rated as grade 3, four as grade 4, and the remaining 15 as grade 5. Forty plants of the susceptible parent, IR 8 were all classified as grade 5 and 40 plants of the resistant parent, IR 9-60 all fell into grade 2. The wilting or complete kill of F_1 plants by the infestation of brown planthoppers indicated that resistance in rice strain IR 9-60 was recessive to susceptibility. It was also noted that F_1 plants of both crosses were not as susceptible as the susceptible parents. Although all classified as susceptible, few F_1 Plants were apparently less severely affected as susceptible parents. Kawano *et al.* (1969) reported that heterosis in plant weight at the early stage of growth was evident in F_1 hybrids of rice. Rice seedlings with more vigorous growth are likely to withstand insect damage for a relatively longer period of time than those with less vegetative vigor. Thus, small number of grades 3 and 4 F_1 plants may be to some extent due to the heterosis expressed in the growth of rice seedlings.

A total of 215 F_2 plants from Taichung native 1 x IR 9-60, 200 F_2 plants each from IR 8 x IR 9-60 and its reciprocal cross, IR 9-60 x IR 8 were tested for the resistance to the brown planthopper (Table 2). Observed frequencies of 52 resistant to 163 susceptible, 58 resistant to 142 susceptible, and 48 resistant to 152 susceptible plants were obtained in the F_2 populations of the crosses, Taichung native 1 x IR 9-60, IR 8×IR 9-60, and IR 9-60 x IR 8, respectively. The segregating ratios of the three F_2 populations agreed satisfactorily with the hypothesis that a single recessive gene controls resistance to brown planthopper in rice strain, IR 9-60. Chi-square values of 0.08, 1.71, and 0.11 for the three crosses indicated that an assumed monofactorial segregation for the inheritance of resistance is acceptable. A chi-square value of 3.84 is necessary to reject the theoretical ratio of 1:3 at the 0.05 probability level. A single recessive gene controlling the resistance to brown planthopper was also found in rice variety, ASD 7 (Kaneda, 1970). The data from the

reciprocal crosses made with IR 8 and IR 9-60 gave no evidence of cytoplasmic effect on the resistance to brown planthopper.

Table 2. Brown planthopper reaction of F_1, F_2 plants and F_3 families of susceptible x resistant crosses.

Variety or cross	Generation	Resistant	Segregating	Susceptible	Total	Expected ratio	Chi-square	P
Taichung native 1		—	—	20	20	—		
IR 9-60		20	—	—	20	—		
Taichung native 1	F_1	—	—	22	22	—		
x IR 9-60	F_2	52	—	163	215	1 : 3	0.08	0.70—0.80
IR 8		—	—	40	40	1 : 3		
IR 9-60		40	—	—	40	—		
IR 8 x	F_1	—	—	20	20	—		
IR 9-60	F_2	58	—	142	200	1 : 3	1.71	0.10—0.20
	F_3	11	22	12	45	1 : 2 : 1	0.07	0.95—0.98
IR 9-60 x	F_2	48	—	152	200	1 : 3	0.11	0.70—0.80
IR 8								

F_2 plants of the cross IR 8 x IR 9-60 were also grown in the uninfested field to produce F_3 seeds. A total of 45 F_3 lines were randomly selected to evaluate for the resistance to brown planthoppers. Among 45 F_3 lines tested, 11 lines were classified as homozygous resistant, 22 lines as segregating, and the remaining 12 lines as homozygous susceptible. The homozygous resistant F_3 lines were as resistant as resistant parent, IR 9-60 except one line which had one grade 5 plant. This grade 5 plant may be either killed by certain seedling diseases or a mixture of susceptible lines. Seedling diseases may also be responsible for an excess of suceptible plants in few segregating F_3 lines. Since ratings of F_3 lines are based on the performance of the whole line rather than on a single plant as the grading of F_2 plants, there may be less misreadings in the F_3 test, and therefore, more accurate data may be available. The segregating ratio of 11 homozygous resistant lines: 22 segregating lines: 12 homozygous susceptible lines gave a chi-square value of 0.07 for the expected 1:2:1 ratio. The data of F_3 lines were consistent with those of F_1 and F_2 plants in assuming that resistance to the brown planthopper in rice strain, IR 9-60 is conditioned by a recessive gene.

The preliminary data of this experiment and those reported by others seemed to indicate that the inheritance of resistance to brown planthoppers in rice is relatively simple. The resistance appears to be conditioned either by a dominant gene as in the variety Mudgo (IRRI, 1970; Chen and Chang, 1971) or by a recessive factor as in varieties ASD 7 (Kaneda, 1970) and IR 9-60, with possible involment of certain modifiers. Thus, a breeding program aimed at combining the high level of brown planthopper resistance in

resistant varieties with better agronomic traits of local commercial varieties could be carried out easily because the presence of resistance could always be determined in the seedling stage and resistant plants or lines could be moved out to the field for the selection of agronomic characters. It seems possible, therefore, that rice varieties with high yield potentials and resistance to the brown planthopper can be developed. Currently, several resistant selections with desirable plant types are already available for yield trials in this Station.

SUMMARY

Eighteen rice varieties introduced from the International Rice Research Institute (IRRI) and four local commercial varieties were evaluated for their resistance to the brown planthopper in the first and second crops of 1970 at the Chiayi Agricultural Experiment Station. Among IRRI introductions, H 105, Muthumanikam, and IR 9-60 were rated as highly resistant; Mudgo, ASD 7, Kayama MGL 2, Vellanlangalayan, IR 747 B_2-6-3, and IR 1154-243 as resistant; PTB 18 as moderately resistant; DV 139 and AC 435 as moderately susceptible; DK 1, Bir-tsan No. 3, IR 8, and IR 20 as susceptible, and Pankhari 203 and Zenith as highly susceptible. Four local commercial varieties Chianan 8, Tainan 5, Kaohsiung shen 2, and Taichung native 1 all fell in the category of being highly susceptible.

The evidence from F_1, F_2, and F_3 generations of the crosses between resistant strain IR 9-60 and susceptible varieties Taichung native 1 and IR 8 fitted the hypothesis that resistance to the brown planthopper in rice strain IR 9-60 is conditioned by a single recessive gene.

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水稻品種對褐飛蝨 (*Nilaparvata lugens* Stal) 之抵抗性研究

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摘　　要

嘉義農業試驗分所於民國59年第 1 、2 期作檢定水稻品種對褐飛蝨之抵抗性反應。初步結果顯示，由國際稻米研究所引進之18個品種系中，H 105, Muthumanikam,及IR 9–60 屬於極抗級；Mudgo, ASD 7, Kayama MGL 2, Vellanlangalayan, IR 747 B_2–6–3, 及 IR 1154–243 屬於抗級；PTB 18 屬於中抗級；DV 139 及 AC 435 屬於中感級；DK 1, Bir–tsan No. 3, IR 8 及 IR 20 屬於感級；而 Pankhari 203 及 Zenith 則屬極感級。本省推廣品種嘉南 8 號，臺南 5 號，高雄秈 2 號，及臺中在來 1 號均屬於極感級。

抗蟲品系 IR 9–60，感蟲品種臺中在來 1 號與 IR8 所得 F_1, F_2 及 F_3 雜交後裔對褐飛蝨之反應顯示水稻品系 IR 9–60 所具抗蟲性，符合於 1 對隱性因子所控制之假設。