Effects of Adult-Plant Resistance on Blast Severity and Yield of Rice

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ABSTRACT

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Adult-plant resistance is defined as resistance that is expressed as the plant matures. Field studies were performed in flooded plots in 1984 and 1985 to evaluate various degrees of adult-plant resistance to leaf and panicle blast and to determine the relationship of such resistance to rice yield. The rice cultivars showing adult-plant resistance to leaf blast were effectively protected from leaf blast under flooded conditions. Cultivars with high quantitative levels of adult-plant resistance to leaf blast showed higher resistance to both leaf and panicle blast. Reduction of yield by blast was less in the adult-plant-resistant cultivars than in susceptible cultivars. The cultivar Dobong, which was highly resistant to both leaf and panicle blast, showed as stable a yield potential as Nongbaek, which has a hypersensitive type of resistance to blast.

Additonal key words: *Pyricularia oryzae*

Infection of rice by *Pyricularia oryzae* Cav. results in different symptoms depending on the plant parts infected. The symptoms are especially conspicuous on leaves and peduncles (necks) or panicle branches (6). Reactions of rice leaves to blast have generally been considered to be similar to those of necks or panicles (6); however, resistance of rice cultivars to neck or panicle blast did not always correlate with that of leaf blast in the paddy field (1,2,10). Heavy blast infections on either the rice plants at the tillering stage or on the panicles are often detrimental to rice yields, but there are few reliable estimates of yield losses caused by blast disease.

In earlier studies, we reported that less blast developed on adult than seedling rice plants (4,5). The resistance of rice cultivars with adult-plant resistance was race-specific at early growth stages (3). Blast infection became increasingly reduced on either leaves of adult plants or older leaves when rice plants at different growth stages were infected by different races (3). Evaluation of yield potential of cultivars with adult-plant resistance under rice blast epidemics in flooded fields may contribute to the precise characterization of adult-plant resistance to blast. In addition, it would be of interest to know the relationship of adult-plant resistance to development of leaf and panicle blast to better understand how adult-plant resistance influences blast epidemics and yield. Knowing the contribution of adult-plant resistance to the variation among rice cultivars in yield reduction caused by blast would be of value to rice breeders attempting to incorporate these attributes into commercial cultivars. It has not been known how adult-plant resistance to rice blast is inherited.

The objectives of this study were to investigate how adult-plant resistance is expressed under field conditions and to determine the relationship of adult-blast resistance to epidemic development of leaf and panicle blast and the effect on rice yield.

MATERIALS AND METHODS

Eight rice (*Oryza sativa* L.) cultivars were selected from the blast nursery during the 1983 rice growing season and evaluated for leaf and panicle blast resistance and yield potential. Tests were conducted in the field at the experimental farm of the College of Agriculture, Seoul National University, Suweon, Korea, during 1984–1985. The cultivars Akibare, Palkeum, and Jinheung were selected as having moderate adult-plant resistance; the cultivars Olchal and Dobong had high adult-plant resistance to leaf blast in the blast nursery; Nakdong and Jinju were used as susceptible checks; and Nongbaek was included as a resistant check (4,5).

Rice seeds of eight cultivars were sown on 27 April 1984 and 26 April 1985 in nursery beds. Fertilizer was applied at the rate of 150, 100, and 150 kg of actual NPK per hectare in the forms of $(NH_4)_2SO_4$, P_2O_5, and K_2O before sowing. The nursery was hand-weeded and no fungicide was applied. Seedlings were transplanted in the flooded paddy field on 5 June 1984 and 31 May 1985, respectively. Basal fertilizer was scattered by hand at the rate of 75, 100, and 150 kg a.i. of NPK per hectare before transplanting. Additional N fertilizer was applied at 150 kg/ha at 25 and 50 days after transplanting in 1984 and 1985, respectively.

The 1984 experimental plots consisted of the healthy control (fungicide-sprayed) and the blast-infected (unsprayed) plots arranged in a split-plot design with four replicates. The 1985 experimental plots consisted of the healthy control, the panicle blast-controlled plots, and the blast-infected plots with three replicates. Inoculation with *P. oryzae* was unnecessary because natural infection occurred in the experimental plots. The healthy control plots were completely protected from blast infection by spraying the systemic fungicide tricyclazole (Beam 75WP) every 10 days from 10 days after transplanting to 10 days before harvest. The panicle blast-controlled plots were infected by leaf blast but protected from panicle infection by spraying the tricyclazole every 10 days from just before heading to harvest.

Leaf blast severity, recorded as the percentage of the leaf area diseased, was evaluated every 5 days from 13 July to 27 August 1984 and from 10 July to 24 August 1985, respectively. Twenty hills per plot were randomly examined for disease severity.

For assessment of panicle blast, including rotten neck, disease severity was rated in terms of the percentage of rotten necks (decayed culm tissue below the panicle) and rotten panicles (decayed axis of the panicle, particularly more than one-third of the panicle affected) from 20 randomly selected hills in each plot. Disease ratings were made every 7 days from 31 August to 12 October 1984 and from 29 August to 10 October 1985, respectively.

To compare relative levels of resistance of rice cultivars to blast in the paddy field, leaf and panicle blast severity data were converted to areas under disease progress curves (AUDPC) according to the modified formula described by Shaner and Finney (9):

$$AUDPC = \sum_{i=1}^{k} [(X_{i+1} + X_i)/20][t_{i+1} - t_i],$$

in which X_i = blast severity at the ith observation, t_i = time (days) at the ith observation, and k = total number of observations.

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Grain yields were measured from 20 hills that were harvested in each plot on 15 October 1984 and 12 October 1985, respectively.

RESULTS

Leaf blast progress curves for eight rice cultivars in the paddy field in 1984 are plotted in Figure 1. Leaf blast progressed differently with different rice cultivars. All cultivars tested showed maximum leaf blast infection about 63 days after transplanting, and thereafter, leaf blast severity decreased with maturity. The susceptible cultivars Nakdong and Jinju were severely infected, but no susceptible lesions occurred on the resistant cultivar Nongbaek. The cultivars Akibare, Palkeum, and Jinheung had less infection than the susceptible Nakdong and Jinju. The cultivars Olchal and Dobong showed only traces of leaf blast. Similar leaf blast progress was observed in the 1985 experiment (Fig. 2). The tested cultivars showed somewhat higher leaf blast infection in 1985 than in 1984, but the relative levels of leaf blast severity among rice cultivars were similar in both years.

AUDPC values of leaf blast in the paddy field in 1984 and 1985 are shown in Table 1. Significant differences in the AUDPC values were found among rice cultivars in the 2 yr. The highest AUDPC values were obtained from Nakdong and Jinju, whereas smaller AUDPC values were obtained for Olchal, Dobong, and Nongbaek. Based on the differences in AUDPC, the cultivars tested were divided into three groups: 1) Nakdong and Jinju, highly susceptible; 2) Akibare, Palkeum, and Jinheung, moderately susceptible; and 3) Olchal, Dobong, and Nongbaek, resistant.

Panicle blast progress curves for eight rice cultivars in the paddy field in 1984 are presented in Figure 1. Panicle blast progress varied among rice cultivars, particularly being quite different from leaf blast progress in the cultivars Nakdong and Jinheung. Jinju, Jinheung, and Akibare were severely infected by panicle blast, whereas Nakdong, Palkeum, and Olchal were moderately infected. Panicle blast on Dobong was similar to the resistant cultivar Nongbaek. The panicle blast progress patterns and the relative levels of panicle blast severity among rice cultivars were similar in the 2 yr, although Jinju, Jinheung, and Akibare showed higher infections of panicle blast in 1985 than in 1984 (Fig. 2).

AUDPC values of panicle blast in the paddy field during 1984–1985 are presented in Table 1. There were significant differences in the AUDPC values among rice cultivars for the 2 yr. AUDPC values for panicle blast were not correlated with those for leaf blast of the cultivars tested. In contrast to AUDPC values for leaf blast, the highest AUDPC values were obtained from Jinju and Jinheung, followed by Akibare, Nakdong, and Olchal. Based on the differences in AUDPC of panicle blast, the cultivars tested could be divided into three groups: 1) Jinju, Jinheung, and Akibare, highly susceptible; 2) Nakdong, Palkeum, and Olchal, moderately susceptible; and 3) Dobong and Nongbaek, resistant.

The reduction in grain yield of the

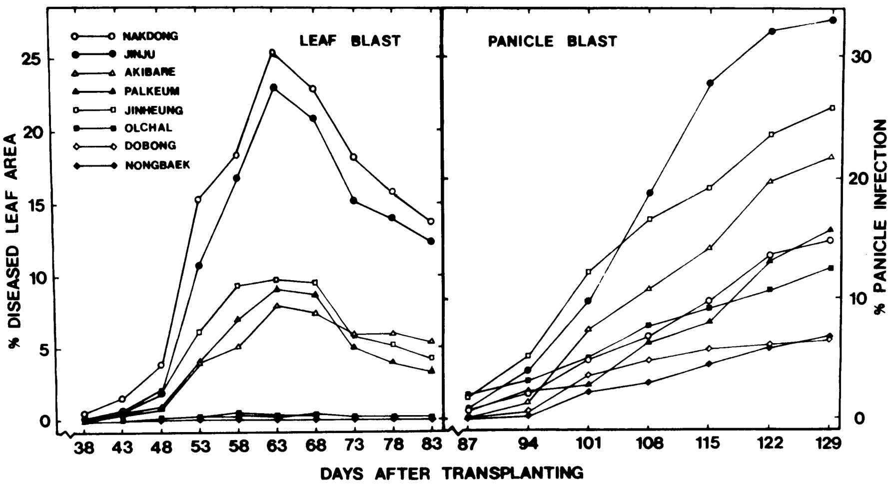

Fig. 1. Leaf and panicle blast disease progress curves for eight rice cultivars representing different levels of resistance to *Pyricularia oryzae* in the field (transplanted 5 June 1984 at Suweon, Korea).

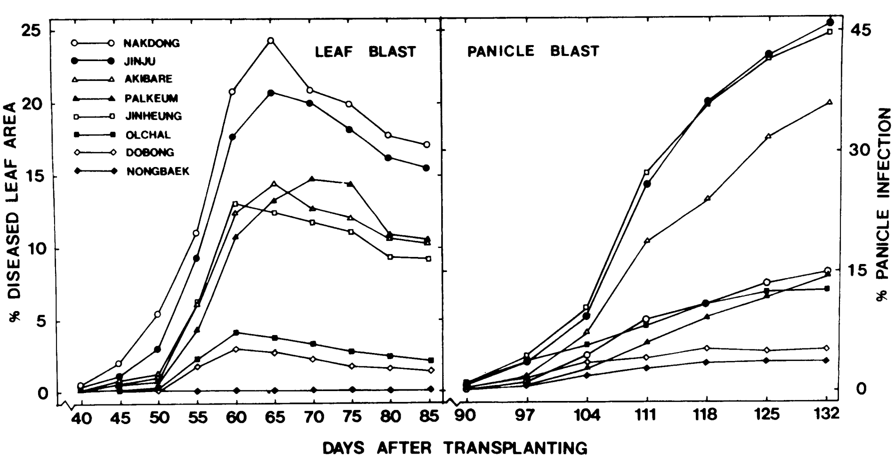

Fig. 2. Leaf and panicle blast disease progress curves for eight rice cultivars representing different levels of resistance to *Pyricularia oryzae* in the field (transplanted 31 May 1985 at Suweon, Korea).

Table 1. Areas under disease progress curves (AUDPC) of leaf and panicle blast for eight rice cultivars in the paddy field in 1984 and 1985 at Suweon, Korea

	AUDPC			
	1984[t]		1985[u]	
Cultivar	**Leaf[v]**	**Panicle[w]**	**Leaf[x]**	**Panicle[y]**
Nakdong	63.6 a[z]	31.7 bc	65.7 a	32.8 c
Jinju	54.5 a	76.6 a	57.3 a	98.5 a
Akibare	20.5 b	45.4 b	38.8 b	71.2 b
Palkeum	20.7 b	26.9 cd	37.8 b	27.1 cd
Jinheung	25.8 b	63.6 a	35.4 b	99.8 a
Olchal	1.1 c	30.3 bc	13.6 c	33.9 c
Dobong	1.2 c	17.5 cd	7.3 c	15.6 de
Nongbaek	0.1 c	14.1 cd	0.5 d	10.6 e

[t] Sown on 27 April and transplanted on 5 June 1984.
[u] Sown on 26 April and transplanted on 31 May 1985.
[v] Rated from 13 July to 27 August 1984.
[w] Rated from 31 August to 12 October 1984.
[x] Rated from 10 July to 24 August 1985.
[y] Rated from 29 August to 10 October 1985.
[z] Values in the same column followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

eight rice cultivars by blast infection in 1984 and 1985 is shown in Table 2. The rice yields in naturally blast-infected plots in the 1984 experiment decreased by about 4–42% depending on the level of resistance of each cultivar when compared with the grain yields of fungicide-sprayed plots. The cultivar Jinju had the highest yield reduction, followed by Jinheung, Akibare, Nakdong, Palkeum, and Olchal. The yield reduction in Dobong was similar to that of the resistant cultivar Nongbaek. Yield reductions in the 1985 experiment ranged from 6 to 48%. Grain yields were reduced by leaf blast in 1985 about 1–17% compared with those of healthy plots. The levels of yield loss in leaf blast-affected plots (panicle blast-controlled) were in the order Nakdong > Jinju > Jinheung > Palkeum > Akibare > Olchal > Dobong > Nongbaek.

AUDPC values of leaf blast were significantly correlated with yield loss in naturally blast-infected plots ($r = 0.76$ in 1984 and $r = 0.82$ in 1985, $P = 0.05$). Panicle blast was also highly correlated with yield loss ($r = 0.93$ in 1984 and $r = 0.90$ in 1985, $P = 0.01$). There was highly significant correlation ($r = 0.99$, $P = 0.01$) between leaf blast and yield loss in leaf blast-affected plots in 1985.

DISCUSSION

The relative levels of resistance of eight rice cultivars to leaf blast in the field were very similar to the results of earlier blast nursery tests (4,5). The susceptible Nakdong and Jinju were highly susceptible to leaf blast, and the resistant Nongbaek showed hypersensitive resistance in the field. The cultivars Akibare, Palkeum, and Jinheung, which were moderately adult-plant resistant to leaf blast in the blast nursery (4,5), were moderately susceptible to leaf blast in the field. The cultivars Olchal and Dobong, which were fully susceptible at the seedling stage but resistant at the adult-plant stage in the blast nursery, were highly resistant to leaf blast in the field. These results suggest that the rice cultivars showing adult-plant resistance to leaf blast may be effectively protected from leaf blast after transplanting to the field.

The quantitative levels of panicle blast resistance of the tested rice cultivars in the field were different from those of leaf blast resistance (Figs. 1 and 2). The cultivar Nakdong, which was highly susceptible to leaf blast, showed moderate susceptibility to panicle blast. In contrast, Jinheung, which was moderately susceptible to leaf blast, was highly susceptible to panicle blast. However, the highly adult-plant resistant cultivar Dobong also showed a high level of resistance to panicle blast that was comparable to that of the resistant Nongbaek. Similar phenomena were reported by Asaga and Yoshimure (1) and Chung and Koh (2). This indicates that resistance to panicle blast may be expressed in some genotypes of rice independently of that to leaf blast (7). Also, the quantitative levels of resistance to rice blast in the field did not always coincide with those to leaf blast in the seedling nursery. However, the cultivars in which the quantitative level of adult-plant resistance to leaf blast was higher, showed higher resistance to rice blast in the field, and their resistance was more stable to leaf and panicle blast. Dobong was highly resistant to leaf and panicle blast in both the upland nursery and the field.

Although there is no universal agreement on the extent of the correlation between leaf blast and panicle blast, it seems reasonable to speculate that the dramatic reduction in leaf blast on rice plants at later growth stages may affect the severity of panicle blast. Rice blast typically begins on the lower leaves at early growth stage, then moves progressively to the upper leaves at later growth stages. Neck or panicle infections may be initiated more frequently by the inoculum derived from lesions on the upper leaves (8). These suggestions could support our results that highly adult-plant resistant cultivars permitted panicle blast infection as low as that of resistant cultivars. However, further histological and physiological studies on rice plants at different development stages are needed to elucidate the nature of adult-plant resistance to leaf and panicle blast.

Severe yield reduction has been known to be caused by severe leaf and panicle blast including neck rot, resulting in the loss of entire panicles (6). Our data indicate that differences in yield reduction among rice cultivars were dependent on leaf and panicle blast development. The highest yield reduction occurred in the cultivar Jinju, which is highly susceptible to both leaf and panicle blast. Higher yield reductions were obtained in the cultivars Jinheung and Akibare, both highly susceptible to panicle blast, than in the cultivar Nakdong, which was only susceptible to leaf blast. This also indicates that yield reduction by panicle blast infection is twice as severe as that by leaf blast. However, differences in yield reduction were also great in response to leaf blast development on rice cultivars in the panicle blast-controlled plots.

Markedly less reduction in rice yield by blast occurred in the highly adult-plant resistant cultivars than in the susceptible ones. Particularly, Dobong, which was highly resistant to both leaf and panicle blast in the paddy field, showed as stable a yield potential as Nongbaek, which had a hypersensitive type of resistance to

Table 2. Grain yield and percent losses of eight rice cultivars following leaf and panicle blast infection in the field in 1984 and 1985 at Suweon, Korea

	Grain yield (kg/ha)							
	1984[s]			1985[t]				
Cultivar	Sprayed[u]	Unsprayed[v]	Loss (%)[w]	Sprayed[u]	Unsprayed[v]	Loss (%)[w]	Panicle blast controlled[x]	Loss (%)[y]
Nakdong	7,226	5,489	24.0 bc[z]	5,851	4,161	28.9 d	4,845	17.2 a
Jinju	7,204	4,225	41.3 a	5,601	2,933	47.6 a	4,709	15.9 a
Akibare	6,510	4,712	27.6 bc	5,567	3,729	33.0 c	5,014	9.7 b
Palkeum	6,861	5,390	21.5 c	6,153	4,484	27.1 d	5,530	10.1 b
Jinheung	6,521	4,501	30.7 b	5,964	3,580	40.0 b	5,341	10.5 b
Olchal	6,866	5,936	13.5 d	6,234	5,173	17.1 e	5,873	5.8 c
Dobong	7,166	6,853	4.4 e	6,102	5,671	7.1 f	5,907	3.2 cd
Nongbaek	6,688	6,305	5.6 e	6,007	5,617	6.5 f	5,959	0.8 d

[s] Sown on 27 April and transplanted on 5 June 1984.
[t] Sown on 26 April and transplanted on 31 May 1985.
[u] Leaf and panicle blast was completely controlled by spraying the fungicide tricyclazole every 10 days from 10 days after transplanting to 10 days before harvest.
[v] Leaf and panicle blast was naturally infected.
[w] Yield losses by infection of leaf and panicle blast.
[x] Leaf blast was naturally infected but panicle blast was completely controlled by spraying tricyclazole every 10 days from just before headings to 10 days before harvest.
[y] Yield losses by leaf blast infection.
[z] Values in the same column followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

blast. Therefore, cultivation of adult-plant resistant cultivars may be practical as a form of rice blast management in the temperate areas such as Korea, because the cultivars are resistant to leaf and panicle blast in the paddy field and thereby less damaged in yield by rice blast epidemics.

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LITERATURE CITED

1. Asaga, K., and Yoshimure, S. 1970. Field resistance of sister line crosses to leaf and panicle blast. (Abstr.) Proc. Kanto-Tosan Plant Prot. Soc. 17:7.
2. Chung, H. S., and Koh, Y. J. 1981. Epidemiological studies on slow blasting of rice cultivars to leaf blast and neck blast in the paddy field. ORD, AIC 81-23, Off. Rural Dev., Suweon, Korea.
3. Kim, K. D., Hwang, B. K., Koh, Y. J., and Chung, H. S. 1987. Evaluation of rice cultivars under greenhouse conditions for adult-plant resistance to *Pyricularia oryzae*. J. Phytopathol. In press.
4. Koh, Y. J., Hwang, B. K., and Chung, H. S. 1986. Screening of rice cultivars for adult-plant resistance to *Pyricularia oryzae*. Kor. J. Plant Pathol. 2(2):69-81.
5. Koh, Y. J., Hwang, B. K., and Chung, H. S. 1987. Adult-plant resistance of rice to leaf blast. Phytopathology 77:232-236.
6. Ou, S. H. 1985. Rice Diseases. Commonwealth Mycological Institute, Kew, Surrey, England. 380 pp.
7. Padmanabhan, S. Y. 1965. Recent advances in the study of blast disease of rice. Madras Agric. J. (Golden Jubilee Number):564-583.
8. Park, J. S., Yu, S. H., and Kim, H. G. 1980. Epidemiological studies of blast disease of rice plant. I. Infection of panicle blast in leaf sheaths during booting stage. Kor. J. Plant Prot. 19(4):203-211.
9. Shaner, G., and Finney, R. E. 1977. The effect of nitrogen fertilization on the expression of slow-mildewing resistance in Knox wheat. Phytopathology 67:1051-1056.
10. Shinto, K. 1980. Resistance to leaf blast and to panicle blast. Pages 303-321 in: Rice Blast Disease and Breeding for Resistance. T. Kosaka and Y. Yamasaki, eds. Hakuyu-sha, Tokyo. 607 pp.