Resistance

Adult-Plant Resistance of Rice to Leaf Blast

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ABSTRACT

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Eight rice cultivars with different degrees of resistance or susceptibility to *Pyricularia oryzae* were evaluated for adult-plant resistance at different plant growth stages under natural infection. Blast infection gradually decreased with aging of plants in all cultivars tested, indicating that both resistant and susceptible cultivars became increasingly resistant to leaf blast at later growth stages, although the levels of cultivar resistance varied. Lower leaves of rice plants were more severely infected than upper leaves. The cultivars Olchal and Dobong, which were highly susceptible at the seedling stage but resistant at later growth stages, were determined to be adult-plant resistant to leaf blast in the field. It is suggested that adult-plant resistance may be estimated by monitoring blast infection on a particular leaf of rice plants at later growth stages.

Strategies for controlling plant diseases have changed in recent years in response to economic and environmental constraints on chemical measures, and breeding for disease resistance has been increasingly emphasized. Hypersensitive resistance was one of the first types of resistance employed by rice breeders to control blast (4). Protection of rice by the hypersensitive type of resistance has been ephemeral because of the appearance and rapid spread of new races of *Pyricularia oryzae* Cav. capable of overcoming effects of genes for this resistance (3). To cope with this problem, rice breeders have searched constantly for a stable, durable type of resistance to blast to use in breeding programs.

Usually, screenings for blast resistance have been made by assessing reactions of rice cultivars to *P. oryzae* at seedling stages in nurseries or greenhouses. Rice cultivars or lines with adult-plant resistance may be evaluated as highly susceptible to leaf blast at the seedling stages. However, rice cultivars that may be susceptible at seedling stages but reduce blast progress to negligible levels at later growth stages are valuable in temperate countries such as Korea, where *P. oryzae* appears late in the growing season.

Adult-plant resistance to plant disease has been found in various crops. Recently, adult-plant resistance of rice to bacterial blight was reported (12), but there is little information about this phenomenon in the rice leaf blast system. Until now, rate-reducing resistance to rice blast, described as quantitative resistance (1,2,11), dilatory resistance (8,9), and slow-blasting resistance (15,16), has been studied intensively only at a particular plant growth stage in the field.

In an attempt to find rice cultivars with adult-plant resistance for use in our breeding program, we selected cultivars from the 1983 and 1984 blast nursery that had a low severity of leaf blast at later growth stages but a compatible infection type. We report here the degree of adult-plant resistance to leaf blast of selected rice cultivars at different growth stages in the field.

MATERIALS AND METHODS

The eight rice (*Oryza sativa* L.) cultivars used in this study were selected from a large number of cultivars, based on our epidemiological data from preliminary field tests at Suweon (7). Nakdong and Jinju were used as susceptible checks, and Nongbaek, identified earlier in Korea as field resistant (3), was included as a resistant check. Akibare, Palkeum, Jinheung, Olchal, and Dobong, which at Suweon showed different levels of resistance to blast at later stages of development, were intensively studied.

To evaluate disease reactions on individual leaves or whole plants of rice at different stages of growth, the eight cultivars were sown in hill plots of 20 seeds per hill in the upland blast nursery on 11 May 1983 and 11 May, 25 June, and 16 July 1984. The hill plots, spaced 30 cm apart, were arranged in a randomized complete block design with five replicates. Mixed seeds of the rice cultivars tested were planted around the blast nursery to increase the natural occurrence of blast. Basal fertilizer was scattered by hand at the rate of 300-100-150 kg of actual NPK per hectare before planting. Additional nitrogen fertilizers (150 kg/ha) were applied later for all sowings. The nursery was hand-weeded and kept wet by periodic flood-irrigation. Positions of leaves on the main culms of five plants randomly selected within each hill plot were marked by small plastic clips with different colors to permit disease assessments on the same leaves each time.

Disease development on the marked leaves was rated daily Monday through Friday each week after the first appearance of blast lesions. The hill plot mean for each leaf position was the basic datum used in all subsequent analysis. The data for each experiment were analyzed separately. Disease ratings were also simultaneously done at different plantings of rice for 30 days (15 July to 14 August 1983 and 30 July to 29 August 1984). Because different types of lesions appeared on a leaf, the percentage of diseased leaf area (DLA) and the proportion of DLA based on lesion types were recorded to permit more accurate evaluation of the reactions of rice cultivars to blast. Disease severity on different leaves or whole plants was determined using the following equation (10): Disease severity (%) = $\Sigma_{i=1}^{3}$ [DLA (%) × DLA proportion based on lesion type (%) × lesion type (i)]/(100 × 3), in which a resistant type lesion = 1 (pinpoint or larger pinhead), an intermediate type lesion = 2 (round to slightly elongated, necrotic grey spots with a brown margin), and a susceptible type lesion = 3 (elliptical lesion with a greyish center and brown margin). The disease severity of whole plants was calculated from the blast severity data of individual leaves. Blast severity data obtained in whole plants were converted to areas under disease progress curves (AUDPC) to compare relative levels of resistance of rice cultivars to blast at different stages. The AUDPC was calculated as

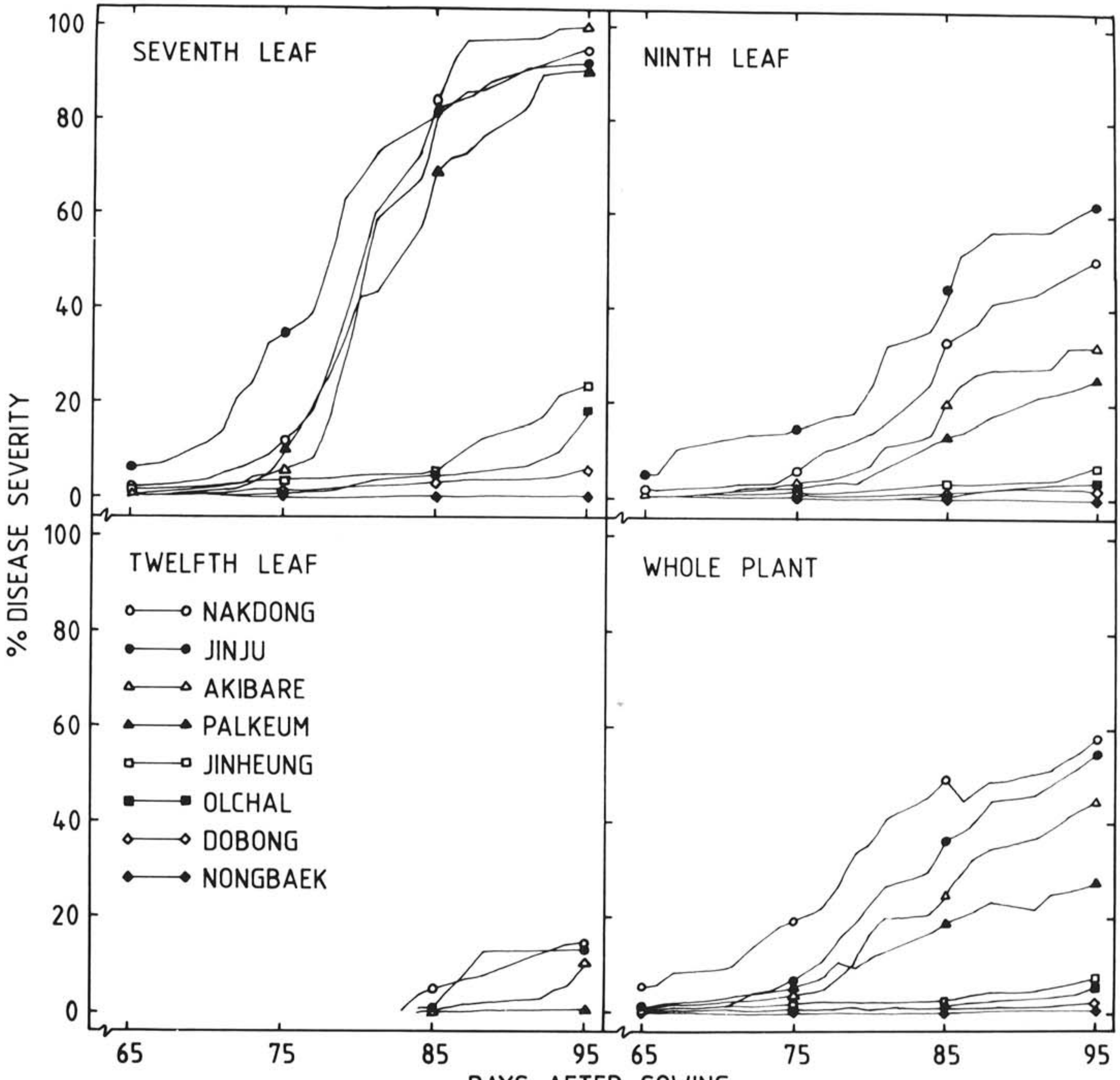

Fig. 1. Rice blast disease progress curves for various leaves and whole plants of eight rice cultivars representing different levels of resistance to *Pyricularia oryzae* in blast nursery hill plots sown on 11 May 1983 at Suweon, Korea. Day 65 = 15 July. Each value is the mean of five replicates. Each replicate consists of five leaves or plants.

described by Shaner and Finney (13): AUDPC = $\Sigma_{i=1}^{n}[(X_{i+1} + X_i)/20](t_{i+1} - t_i)$, where X_i = blast severity at i^{th} observation, t = time (days) at the i^{th} observation, and n = total number of observations.

RESULTS

Blast disease progress on various leaves and whole plants of eight rice cultivars sown on 11 May 1983 are shown in Figure 1. Percent disease severities on seventh leaves of 95-day-old mature plants were similarly high on the cultivars Nakdong, Jinju, Akibare, and Palkeum. The cultivars Jinheung, Olchal, and Dobong were relatively resistant, but Nongbaek was highly resistant throughout the observation period. On the ninth leaves, the cultivars Nakdong, Jinju, Akibare, and Palkeum, showing similar susceptibility to leaf blast on the seventh leaves, were quite distinguishable from each other in levels of blast severity. Twelfth leaves were highly resistant on all cultivars tested. Based on differences in blast severity of whole plants, the relative ranks of cultivars in levels of resistance were Nongbaek > Dobong > Olchal > Jinheung > Palkeum > Akibare > Jinju > Nakdong.

Blast progress curves on individual leaves of eight rice cultivars at the early seedling stage in the third sowing in 1984 are plotted in

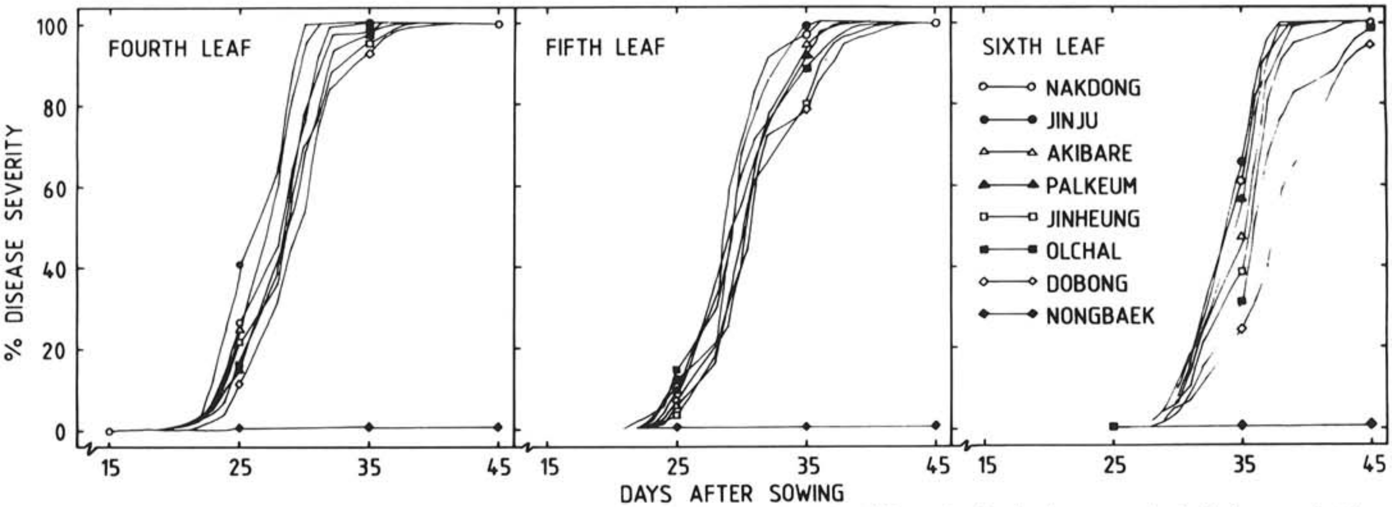

Fig. 2. Rice blast disease progress curves for various leaves of eight rice cultivars representing different levels of resistance to *Pyricularia oryzae* in blast nursery hill plots sown on 16 July 1984 at Suweon, Korea. Day 15 = 30 July. Each value is the mean of five replicates. Each replicate consists of five leaves.

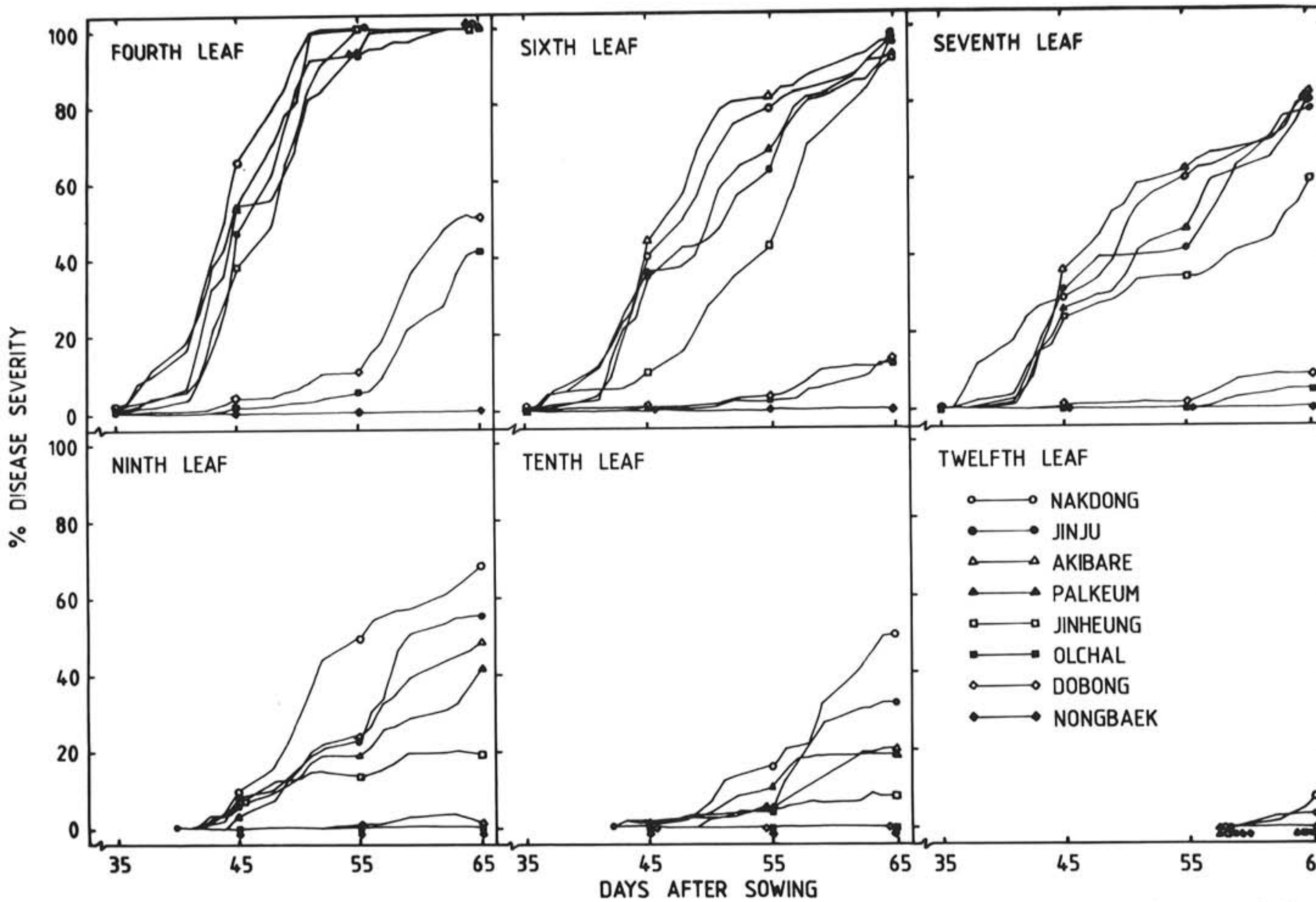

Fig. 3. Rice blast disease progress curves for various leaves of eight rice cultivars representing different levels of resistance to *Pyricularia oryzae* in blast nursery hill plots sown on 25 June 1984 at Suweon, Korea. Day 35 = 30 July. Each value is the mean of five replicates. Each replicate consists of five leaves.

Figure 2. All cultivars but Nongbaek were highly susceptible to leaf blast, being practically killed by blast 45 days after sowing. Nongbaek showed only resistant type lesions at all growth stages. Differences between cultivars in percent disease severity were more marked on the sixth than the fourth or fifth leaves.

Figure 3 shows blast progress curves for the second sowing in 1984. In general, lower leaves were more severely infected than upper leaves. Differences in disease severities among the cultivars were more distinguishable on the ninth leaves than on any other leaves. The most conspicuous change in susceptibility to blast was observed on the cultivars Olchal and Dobong, whose ninth leaves were as resistant as those of the resistant cultivar Nongbaek. Level of resistance to leaf blast could be differentiated quantitatively on the basis of rates of blast infection on the seventh leaves of mature plants at the first sowing in 1984 (Fig. 4). Twelfth leaves of all cultivars, whether susceptible or resistant at the seedling stage, were highly resistant to blast. With aging of leaves, i.e., fourth, sixth, and ninth leaves, blast infection decreased on all cultivars, especially Olchal and Dobong (Figs. 2–4).

Rice blast progress curves for whole plants of eight rice cultivars evaluated for adult-plant resistance in hill plots in each of three sowings in 1984 are shown in Figure 5. The cultivar Nongbaek was highly resistant at all stages of plant development. With aging of plants, the quantitative level of resistance to blast gradually increased in the other seedling susceptible cultivars. In particular, the cultivars Olchal and Dobong, which were highly susceptible at the early seedling stage, became resistant to leaf blast at later stages of development. There were also significant differences among cultivars in AUDPC at later growth stages of rice plants (Table 1). Based on AUDPC values, relative levels of resistance to leaf blast were Nongbaek > Dobong > Olchal > Jinheung > Palkeum > Akibare > Jinju > Nakdong. Similar trends in levels of resistance of rice cultivars were found in all the growing seasons of both experiment years. Among the cultivars tested, Olchal and Dobong had AUDPCs as high as those of other susceptible cultivars at the early seedling stage but much lower AUDPCs at later growth stages. Therefore, they were considered to be adult-plant-resistant in the field.

DISCUSSION

During the 45-day nursery period (April through May) in temperate countries such as Korea, temperatures under 20 C are unfavorable for seedling blast. Blast epidemics usually occur in July after transplanting into the paddy field. Durable resistant cultivars that, even though susceptible at the seedling stage in the nursery, can resist severe blast epidemics in the paddy field are needed in temperate areas. In particular, "Tongil" type cultivars that have been bred by crossing japonica and indica cultivars and cultivated intensively in Korea have been replaced by other japonica cultivars, because the extreme hypersensitive type of resistance of the Tongil type cultivars to blast was broken down by

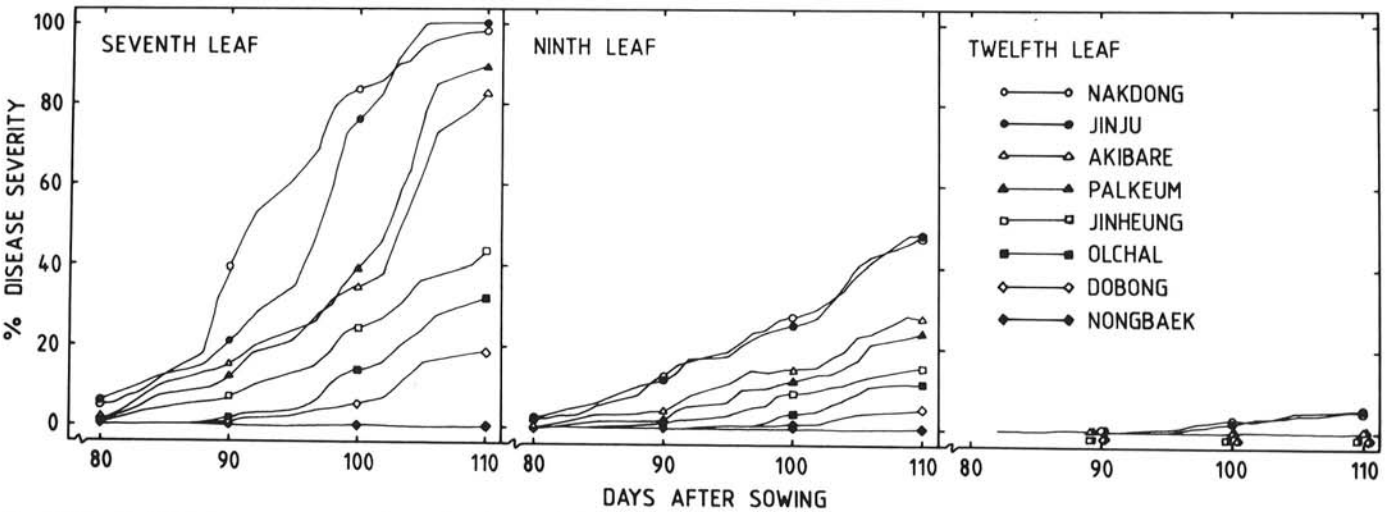

Fig. 4. Rice blast disease progress curves for various leaves of eight rice cultivars representing different levels of resistance to *Pyricularia oryzae* in blast nursery hill plots sown on 11 May 1984 at Suweon, Korea. Day 80 = 30 July. Each value is the mean of five replicates. Each replicate consists of five leaves.

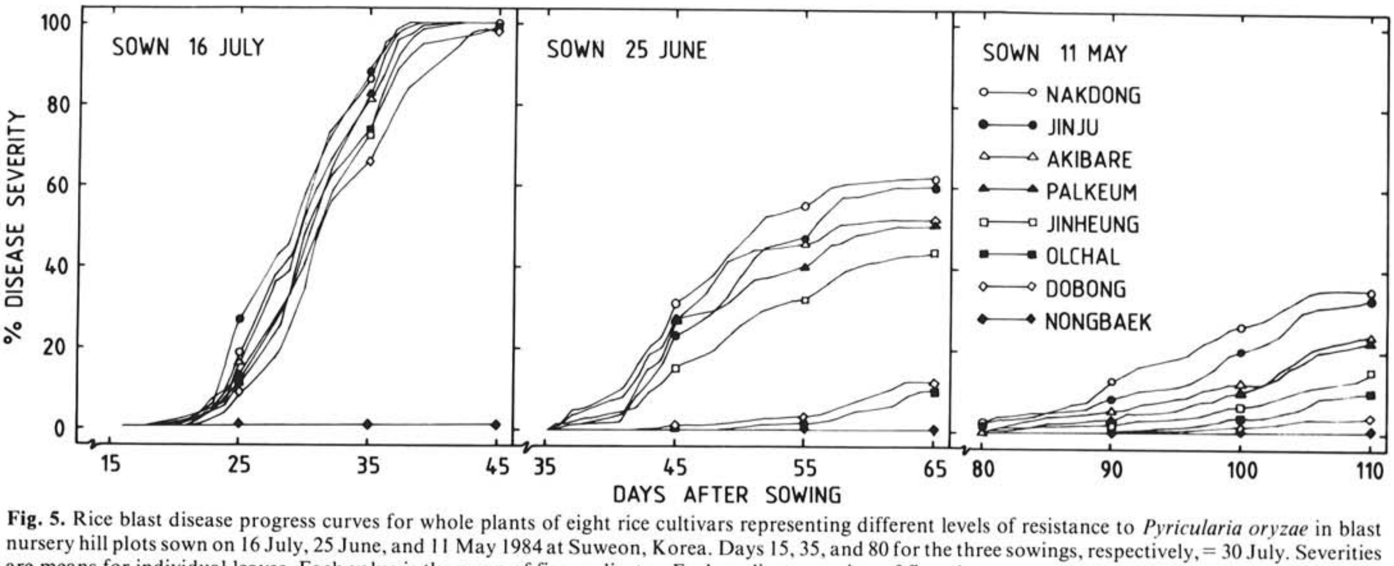

Fig. 5. Rice blast disease progress curves for whole plants of eight rice cultivars representing different levels of resistance to *Pyricularia oryzae* in blast nursery hill plots sown on 16 July, 25 June, and 11 May 1984 at Suweon, Korea. Days 15, 35, and 80 for the three sowings, respectively, = 30 July. Severities are means for individual leaves. Each value is the mean of five replicates. Each replicate consists of five plants.

TABLE 1. Areas under disease progress curves (AUDPC) in whole plants of eight rice cultivars at three growth stages in an evaluation of adult-plant resistance to *Pyricularia oryzae* in blast nursery hill plots, Suweon, Korea, in 1983 and 1984

	AUDPC[v]			
	1983	1984		
Cultivar	First sowing[w]	Third sowing[x]	Second sowing[y]	First sowing[z]
Nakdong	95.6 ab	155.4 ab	117.1 a	57.8 a
Jinju	70.0 b	159.9 a	100.3 b	46.8 b
Akibare	52.6 c	150.0 b	99.2 b	31.0 c
Palkeum	37.0 d	146.1 bc	91.5 c	26.8 d
Jinheung	8.9 e	138.8 c	70.7 d	17.6 e
Olchal	5.0 ef	138.3 c	6.7 e	9.5 f
Dobong	3.8 f	124.8 d	11.1 e	4.7 g
Nongbaek	0.3 g	2.0 e	0.3 f	0.3 h

[v] Values in the same column followed by the same letter are not statistically different ($P = 0.05$) according to Duncan's multiple range test.
[w] Rated 65–95 days after sowing on 11 May.
[x] Rated 15–45 days after sowing on 16 July.
[y] Rated 35–65 days after sowing on 25 June.
[z] Rated 80–110 days after sowing on 11 May.

new races of *P. oryzae* (3). Therefore, rice cultivars that sustain low populations of *P. oryzae* at the seedling stage but arrest the development of the fungus at later growth stages are desirable for reducing selection pressure for new races (14).

At three plant growth stages, eight rice cultivars showing various types of resistance to blast were compared on a quantitative basis for disease severity by natural infection in nursery hill plots. With aging of plants, blast infection gradually decreased on all cultivars tested, indicating that all rice plants, both resistant and susceptible, became resistant to leaf blast at later growth stages, although levels of resistance varied according to genotype. The cultivars Olchal and Dobong, which were highly susceptible at the seedling stage but resistant to blast at later growth stages, were evaluated as adult-plant resistant in the field.

Leaf position on the same plant may play an important role in assessing quantitative levels of blast infection in rice cultivars. Resistance levels could not be quantitatively differentiated by blast infection on leaves of seedling plants, but disease severities on the seventh or ninth leaves of mature plants at the early sowings distinctly varied among the cultivars tested. The data suggest that adult-plant resistance may be evaluated more accurately by monitoring blast infection on a particular leaf at later growth stages than ratings of whole-plant infection. Our observations demonstrate that lower leaves were more severely infected by blast than upper leaves. It is assumed that histological and physiological changes occurred in leaf tissues during aging of plants (6).

Quantitative differences among susceptible cultivars in susceptibility to blast were not easily observed on leaves or whole plants at the early seedling stage in the field (Figs. 2 and 5). These results are consistent with the findings of Ezuka et al (5) that differences among cultivars possessing a lower level of field resistance to rice blast were more distinct in the paddy field in the blast nursery. Similarly, Ordónez (10) could not detect any differences between barley cultivars in susceptibility to powdery mildew at the four- or five-leaf stages but could after the six leaf stage, although the blast rice and powdery mildew barley systems might function differently.

Conspicuous changes in susceptibility to blast in the cultivars Olchal and Dobong at later growth stages did not seem to be due to a shift of races of *P. oryzae* during the blast rating period, because plants of different ages were simultaneously exposed to populations of these races.

Because the rate of blast development depends on environment as well as host genotype, we would expect the measured level of adult-plant resistance in the cultivars Olchal and Dobong to vary among years. However, the data from 1983 and 1984 experiments revealed the same trends consistently expressed in relative levels of resistance to blast at later plant growth stages. Although the amount of blast on Olchal and Dobong differed between 1983 and 1984, as indicated by the disease severity or AUDPC, adult-plant resistance was always evident in Olchal and Dobong compared with Nakdong and Jinju.

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