Race-Specific Partial Resistance to Blast in Temperate Japonica Rice Cultivars

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ABSTRACT

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Twenty-nine of 53 japonica rice cultivars and breeding lines tested for resistance to blast disease in nursery trials in Korea and the Philippines showed complete resistance at one or both locations. Seventeen of 24 entries that tested qualitatively susceptible at both locations showed slower disease progress in the Philippines. Greenhouse tests using japonica cultivars Daechang, Nagdong, and Palgeum, and a susceptible check indicated that Korean isolates were more aggressive than Philippine isolates on the japonica cultivars; the isolates were equally aggressive on the susceptible check. The results suggest that race-specific partial resistance caused the slow disease progress on japonica rices in the Philippine nursery test.

Blast disease of rice is often important in temperate rice production areas. In Korea, an epidemic occurred in 1978 on cultivars derived from crosses between tropical indica and temperate japonica rices (4). Since then, the proportion of indica-japonica cultivars grown has gradually declined to about 20% of the area, mostly in the southern part of the peninsula where cold tolerance is not as critical as in the north and where virus disease resistance of indica-japonica cultivars is desirable. The morpho-agronomic characteristics of the indica-japonica cultivars are typical of indica rices. In general, Korean indica-japonica cultivars exhibit isoenzyme patterns of indicas (J. C. Glaszmann, *personal communication*). In this paper, we consider indica-japonica cultivars to be indica rices.

Blast occurs annually on Korean japonica cultivars. The level of damage varies with location, weather, cultivar maturity, and the inherent level of partial resistance expressed by various cultivars. The term "partial resistance" (11), synonymous with the term "field resistance" (15) used in Japan, is used here for cultivars showing typical sporulating blast lesions, but with less diseased leaf area than fully susceptible cultivars. Few Korean japonica rices show complete race-specific resistance to all Korean races of *Pyricularia oryzae* Cav., the causal fungus of blast. Differences among cultivars observed in the field are due in part to differences in partial resistance. In certain rice cultivars, partial resistance is associated with more durable resistance (17).

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Korean pedigree and elite breeding lines are evaluated for blast resistance during the winter season (November–February) in the Philippines at the International Rice Research Institute (IRRI). For indica cultivars, the tests assess potential vulnerability to blast. Many indica cultivars show complete resistance in Korea, but varying levels of susceptibility in the Philippines. If an indica cultivar that is highly susceptible at IRRI becomes widely grown in Korea it is considered to be at risk. Experience has shown that matching races will eventually develop (4).

For japonica cultivars, the practical use of the IRRI tests is uncertain because little is known about how environment and pathogen differences affect their comparative responses in Korea and the Philippines. Although japonica cultivars usually are more resistant in the tropics than in temperate areas (10), some that showed partial resistance in Japan were susceptible at IRRI (9). The partial resistance of these cultivars was reported to be specific to certain isolates of the pathogen (6). For complete resistance, there may be populations of *P. oryzae* that are specialized on indica or japonica germ plasm (8). It is not clear if a pattern of specificity also occurs for partial resistance because only a few cases of race-specific partial resistance have been documented (6,7,15).

The purpose of the work reported here was 1) to compare the blast resistance of Korean japonica germ plasm measured in nursery tests in the Philippines and in Korea and 2) to determine if race-specific partial resistance affects the reactions of temperate japonica cultivars evaluated in the tropics at IRRI.

MATERIALS AND METHODS

Upland nursery experiments were carried out in 1986 in the Philippines at IRRI and in Korea at Icheon Experiment Station, Rural Development Administration. Fifty-three japonica cultivars and advanced breeding lines from Korea were grown at each site, with two hills per cultivar and 15 seeds per hill. The distance between hills was 15 cm within each cultivar and 20 cm between cultivars. An inoculum spreader row was planted at the side of each hill. The spreader rows were sown to cultivars that were susceptible to many of the races of *P. oryzae* present at each site. In the IRRI test, the susceptible indica line, IR442-2-58, was used as the spreader row; in Korea, a mixture a susceptible indica (Yushin) and a susceptible japonica (Nagdong) was used. At IRRI, the indica cultivar IR50 was used as a susceptible check. The design was a randomized complete block with three replications.

Daily maximum and minimum temperatures were taken from meteorological stations at each site.

Naturally infected seedlings were obtained by sowing plots of the spreader cultivars several weeks before the test entries were sown. These infected seedlings served as the primary inoculum for the trials and were transplanted beside the spreader rows 7–14 days after seeding. The plots were covered with polyethylene sheets for three consecutive nights after inoculation.

Disease was scored beginning 14 days after seeding at IRRI and 20 days after seeding in Icheon, with six readings at 3- to 4-day intervals in each experiment. Scoring was based on a visual estimate of percentage of diseased leaf area. The area under the disease progress curve values for each cultivar were calculated using Shaner and Finney's formula (14). Combined analysis of variance used the area under the disease progress curve data. Cultivars were grouped based on significant differences at 5% by LSD.

Inoculation experiments. To test for differences in aggressiveness on japonica cultivars, three isolates of *P. oryzae* from the Philippines and three from Korea were tested under uniform conditions in the growth chamber at the E.I. du Pont de Nemours & Company Experiment Station, Wilmington, DE. Three japonica cultivars (Daechang, Nagdong, and Palgeum) were used. Indica cultivar CO 39 was included as a susceptible check. Six plants of each cultivar were grown in vermiculite in 10-cm-diameter plastic pots. One pot served as the experimental unit. Three replications were used. Plants were watered with Hoagland's solution and kept at 25 C with 85% relative humidity and 14 hr of light. Light intensity in the growth chamber varied between 700 and 900 $\mu E \cdot s^{-1} \cdot m^{-2}$. Plants were inoculated 14–15 days after planting.

The Philippine isolates were taken from Korean japonica cultivars Daechang, Nagdong, and Palgeum grown at the IRRI site where the field experiment was conducted. The Korean isolates representing common races compatible with Korean japonica cultivars were obtained from the collection at the Institute of Agricultural Sciences, Suweon, Korea. Rice seed and fungus isolates were imported under Animal and Plant Health Inspection Service permits 60036 and PPQ-526-BPS Barbara Valent 11-20-86, respectively.

To ensure a homogeneous pathogen population, all strains were purified by isolating a single conidium. Conidia were collected from cultures growing on oatmeal agar by washing with a 0.25% solution of gelatin (Sigma No. G-0510) (3). Suspensions containing 50,000 conidia per milliliter were sprayed onto the plants using an artist's airbrush (Paasch H No. 1). Plants were inoculated inside a plastic bag that was then sealed to maintain high humidity.

After 20–24 hr of incubation in the dark, inoculated plants were removed from the bags and placed in the growth chamber. The percentage of diseased leaf area of the two topmost leaves was rated 7 days after inoculation on this scale: 0 = no infection, 1 = > 0–10%, 2 = 11–25%, 3 = 26–50%, 4 = 51–75%, 5 = 76–90%, and 6 = 91–100%.

RESULTS AND DISCUSSION

Of the cultivars tested in the nursery, 29 were completely resistant at one or both test locations. Cultivars Baegam, Boggwang, IRI 373, Jinbu 4, Namyang 3, Nongbaeg, Odae, Sobaeg, and Unbong showed complete resistance at both sites.

Among the japonica cultivars tested, complete resistance was more common in the Philippine trial than in the Korean trial (14 resistant in Philippines only; 6 resistant in Korea only; 9 resistant at both sites). This result contrasts with that seen with indica cultivars, where complete resistance is common in Korean tests. These observations are expected, however, because the race patterns in a given region depend on the cultivars normally grown there (2,16). Only indica cultivars are grown throughout most of the production areas of the Philippines; mostly japonica cultivars are grown near the Icheon site in Korea. Presumably, the population of the pathogen trapped by the spreader rows reflects the population present in the surrounding production areas because the spreader cultivars were widely susceptible.

Cultivars were considered quantitatively susceptible when typical spindle-shaped lesions occur on most plants. Using this criterion, 24 of the test cultivars were susceptible at both locations. Most showed more disease in Korea (17 more susceptible in Korea; 7 equally susceptible at both sites). The disease progress curves for Daechang, Nagdong, and Palgeum exemplify the reactions of many of the cultivars that showed susceptibility at both locations (Fig. 1). The susceptible indica check in the Philippine trial, IR50, showed more than 90% diseased leaf area by 30 days after seeding.

Several explanations for the relatively slow disease progress of the japonica cultivars in the Philippine trial are possible. There could have been a low frequency of matching races, making it impossible to accurately assess the level of partial resistance in the field (12). This possibility is unlikely, though. Japonica cultivars that are highly susceptible in Korea, including Daechang, Nagdong, and Palgeum, were planted two times in sequential blast nurseries (six sequential plantings each time) at IRRI in an attempt to build up a population of matching blast races. The cultivars consistently showed little disease (J. M. Bonman, *unpublished data*). If the initially low disease was due simply to a low frequency of matching races, the disease should have increased with sequential sowing.

Environmental differences may have influenced the relative blast susceptibility of japonica cultivars at the two locations because meteorological conditions at the two test sites differed during the time the experiments were conducted. In the Philippines, the mean day temperature was 32.1 C and the mean night temperature was 23.1 C. In Korea, the mean day temperature was 27.4 C and the mean night temperature was 19.2 C. Hemmi and Abe (5) found that plants grown at 20 C are more susceptible than plants grown at higher temperatures. Cultivars from temperate regions may be more sensitive to this effect than are tropical cultivars (10). The lower temperatures during the Korean trial would presumably favor disease there compared with the Philippines.

However, data from the inoculation experiments support another hypothesis—that race specificity was the primary cause of the different reactions of the cultivars in the Philippine and Korean tests. In the inoculation tests, Korean isolates of *P. oryzae* caused more disease on the three japonica cultivars tested than did the Philippine isolates (Table 1). Isolates from both locations produced typical lesions, indicating compatibility with the test cultivars (Fig. 2). The many lesions induced by the Korean isolates often coalesced (Fig. 2). Susceptible check CO 39 was equally susceptible to all six isolates. Thus, the Korean japonica cultivars apparently exhibited partial resistance that was specific to the Philippine isolates of the pathogen.

Because of this race specificity, it is not possible to assess the potential susceptibility of Korean japonica cultivars in Philippine tests. Such assessments should be done at locations where primarily japonica cultivars are grown because such locations have similar virulence patterns (1).

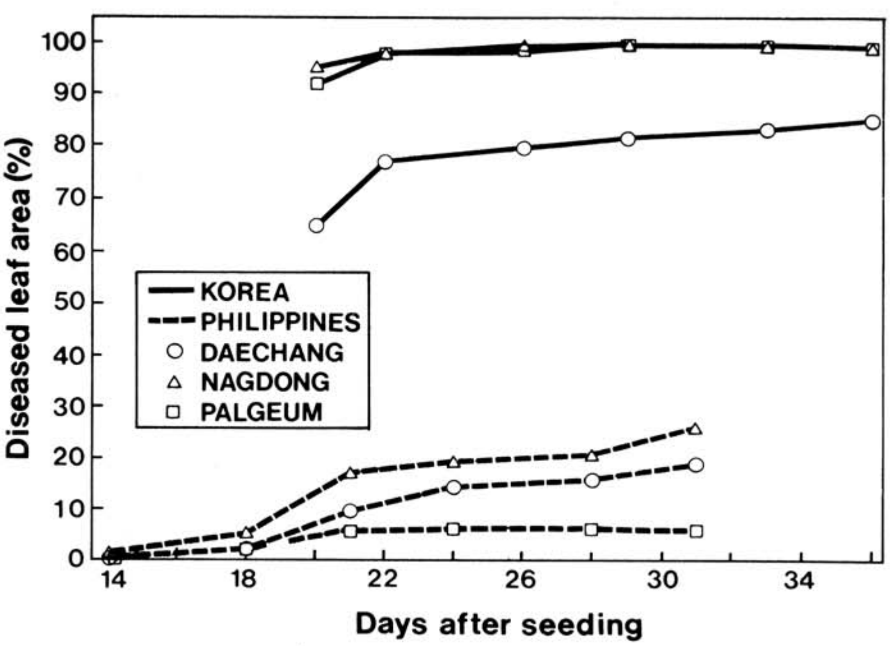

Fig. 1. Blast disease progress in three japonica rice cultivars in nursery plot trials in Korea and the Philippines.

Our results are similar to those of Ikehashi and Kiyosawa (6). They selected isolates of *P. oryzae* from the Philippines and Japan that could infect 24 Japanese (presumably japonica) cultivars. In greenhouse tests, most of the cultivars were less susceptible to the Philippine isolates. However, it is not clear from their paper how disease was measured.

By classifying cultivars as either susceptible or resistant, Morishima (8) used a pattern analysis procedure to group isolates of *P. oryzae*. She concluded that there were groups of races specialized on either indica or japonica germ plasm. In Korea, a similar pattern of pathogen specialization is observed (13). Our data, and the data of others (7,15), indicate that specialization occurs not only for complete resistance, but also for partial resistance. How this race-specific partial resistance relates to the indica and japonica race groups is not known. It seems likely, however, that isolates able to cause only a few lesions on susceptible japonica cultivars would be more common in the indica race group than in the japonica race group.

Table 1. Disease scores for four rice cultivars inoculated with isolates of *Pyricularia oryzae* from Korea and the Philippines[a]

Cultivar	Isolates[b] Korean	Philippine	Difference
Nagdong	5.1	1.8	3.3**[c]
Daechang	4.5	1.3	3.2**
Palgeum	4.8	1.3	3.5**
CO 39	4.9	4.5	0.4 ns[d]

[a] Mean of three replications. Percentage diseased leaf area of the two topmost leaves rated as 0 = no infection, 1 = > 0–10%, 2 = 11–25%, 3 = 26–50%, 4 = 51–75%, 5 = 76–90%, 6 = 91–100%.

[b] Three isolates from each location tested. Location means presented; no significant isolate differences within location.

[c] Significantly different at 1% by LSD.

[d] Not significant.

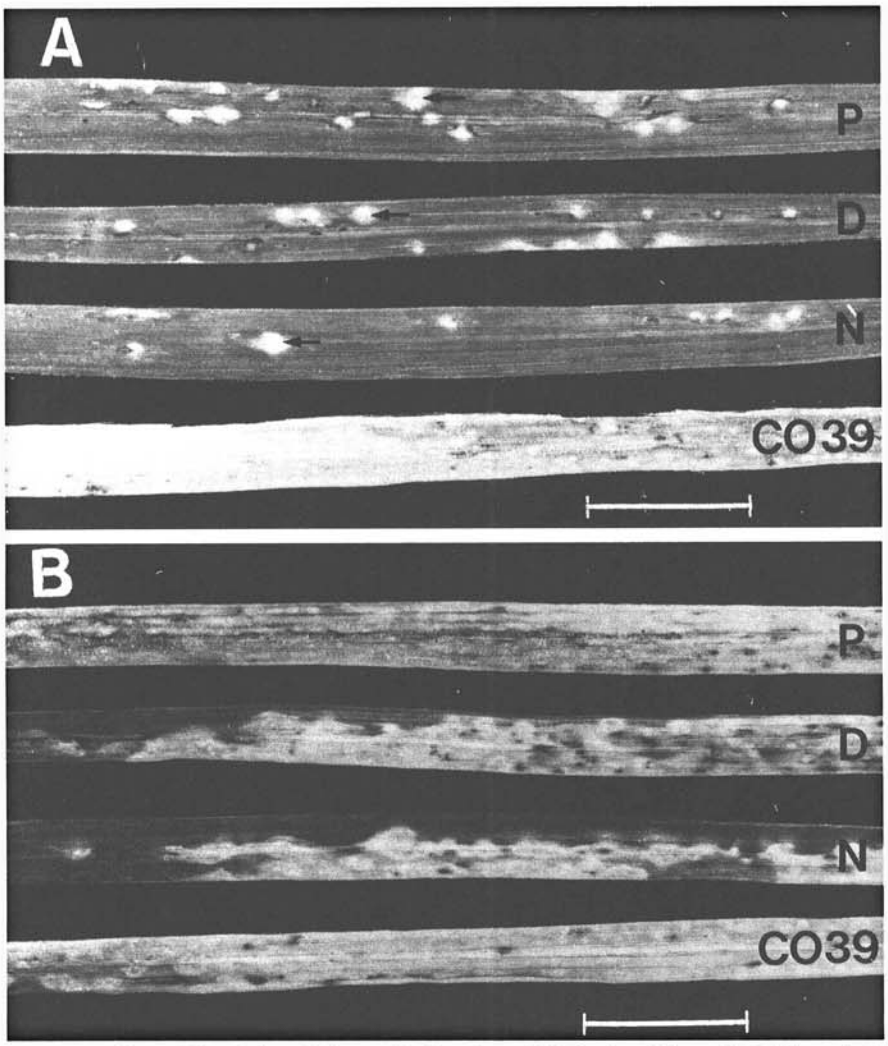

Fig. 2. Reactions of rice cultivars Palgeum (P), Daechang (D), Nagdong (N), and CO 39 inoculated with isolates of *Pyricularia oryzae* from **(A)** the Philippines and **(B)** Korea. Arrows indicate typical individual lesions caused by the Philippine isolate. Scale bar = 1 cm.

Our results differ from the nursery observations made by Ou (9). He found that many cultivars classified as having field resistance in Japan were highly susceptible at IRRI. In our experiment, even the most susceptible Korean japonica cultivars showed slow disease development in the Philippine tests. Perhaps the apparent difference is related to environmental conditions during the time the trial was conducted and to the interpretation of disease scores.

Ou (9) classified cultivars using a standard IRRI scale for blast that is often used by rice breeders, in which entries with scores of 7–9 are considered highly susceptible. In IRRI nursery tests, we often observe scores of 7 or 8 on partially resistant cultivars, such as IR36, during times when infection is high. Our data support the general observation that japonica cultivars are more resistant in the tropics than in temperate areas (10).

The resistance of the japonica cultivars to the Philippine isolates may be similar to the race-specific partial resistance found in Japan in cultivars Chogoku 31 and St 1 (15). The resistance of those cultivars was controlled monogenically, and was not durable. Genetic studies should be undertaken to determine the inheritance of partial resistance in the japonica cultivars to Philippine isolates of *P. oryzae*.

LITERATURE CITED

1. Ahn, S. W., and Seshu, D. V. 1987. Geographical variation of virulence patterns of the rice blast fungus. Page 152 in: Abstracts of the 11th International Congress of Plant Protection. 5-9 October 1987, Manila, Philippines.
2. Bonman, J. M., Vergel de Dios, T. I., and Khin, M. M. 1986. Physiologic specialization of *Pyricularia oryzae* in the Philippines. Plant Dis. 70:767-769.
3. Crawford, M. S., Chumley, F. G., Weaver, C. G., and Valent, B. 1986. Characterization of the heterokaryotic and vegetative diploid phases of *Magnaporthe grisea*. Genetics 114:1111-1129.
4. Crill, P., Ham, Y. S., and Beachell, H. M. 1981. The rice blast disease in Korea and its control with race prediction and gene rotation. Korean J. Breed. 13(2):106-114.
5. Hemmi, T., and Abe, T. 1932. Studies on the rice blast disease. II. Relation of the environment to the development of blast disease. Bull. Dep. Agric. For., Jpn. 47. 204 pp. (in Japanese)
6. Ikehashi, H., and Kiyosawa, S. 1981. Strain-specific reaction of field resistance of Japanese rice varieties revealed with Philippine strains of rice blast fungus, *Pyricularia oryzae* Cav. Jpn. J. Breed. 31:293-301.
7. Marchetti, M. A., and Xinghua, L. 1986. Screening techniques to identify slow-blasting rice lines. Pages 317-327 in: Progress in Upland

Rice Research. The International Rice Research Institute, Manila, Philippines.
8. Morishima, H. 1969. Differentiation of pathogenic races of *Pyricularia oryzae* into two groups, "indica" and "japonica." SABRAO Newsl. 1(2):81-94.
9. Ou, S. H. 1979. Breeding for blast resistance—a critical review. Pages 81-137 in: Proceedings of the Rice Blast Workshop. The International Rice Research Institute, Manila, Philippines.
10. Ou, S. H. 1985. Rice Diseases. Commonwealth Agricultural Bureaux. 380 pp.
11. Parlevliet, J. E. 1979. Components of resistance that reduce the rate of epidemic development. Annu. Rev. Phytopathol. 17:203-222.
12. Parlevliet, J. E. 1983. Can horizontal resistance be recognized in the presence of vertical resistance in plants exposed to a mixture of pathogen races? Phytopathology 73:379.
13. Ryu, J. D., Yeh, W. H., Han, S. S., Lee, Y. H., and Lee, E. J. 1987. Regional and annual fluctuation of races of *Pyricularia oryzae* during 1978-1985 in Korea. Korean J. Plant Pathol. 3:174-179.
14. 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.
15. Toriyama, K. 1975. Recent progress of studies on horizontal resistance in Japan. Pages 65-100 in: Proceedings of the Seminar on Horizontal Resistance to the Blast Disease of Rice. Ser. CE-No. 9, Centro Internacional de Agricultura Tropical. 8-12 October 1971, Cali, Colombia.
16. Yamada, M. 1985. Pathogenic specialization of rice blast fungus in Japan. JARQ 19:178-183.
17. Yeh, W. H., and Bonman, J. M. 1986. Assessment of partial resistance to *Pyricularia oryzae* in six rice cultivars. Plant Pathol. 35:319-323.