Adult-Plant Resistance of Rice Cultivars to Bacterial Blight

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ABSTRACT

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Selected rice cultivars expressed more resistance to bacterial blight (*Xanthomonas campestris* pv. *oryzae*) as plants developed. This resistance was comparable to adult-plant resistance to diseases of other crops. Some cultivars were resistant to four races, and others, to only one or two races. The disease severity on some cultivars gradually decreased from seedling to flag leaf, whereas in others, it showed a distinct change to a resistant reaction on a certain leaf. The leaf showing resistance varied with cultivars. Wase Aikoku 3 had adult-plant resistance to three races but seedling resistance to another. The adult-plant resistance of rice to bacterial blight appears to be race-specific.

Adult-plant resistance is defined as resistance that is expressed as the plant matures (13). This phenomenon has been observed and studied with various plant diseases. Cases of adult-plant resistance of wheat to stem and leaf rust and that of oats to crown rust have been documented (4,10,12).

For rice bacterial blight (*Xanthomonas campestris* pv. *oryzae*), Wakimoto and Yoshii (14) noted that disease reactions varied when rice cultivars were tested at different growth stages. Horino and Ezuka (5) devised a spray-inoculation method to test rice cultivars for bacterial blight resistance. When the plants were inoculated at the 1.5- or the four- to five-leaf stage, the reaction to the strains was not always the same, and some seedlings of Wase Aikoku 3 showed reactions different from those of adult plants. They speculated that the resistance was not fully expressed in young seedlings. Ezuka et al (2) found that the resistance of Wase Aikoku 3 increased as the plants advanced in age. They concluded that the resistance of Wase Aikoku 3 and other similar cultivars was not fully expressed at seedling stage, postulating a form of adult resistance.

At the International Rice Research Institute (IRRI), resistance of rice cultivars to bacterial blight was distinguished into two general groups: seedling resistance and adult-plant resistance (8). The growth stage when the transition from susceptible to resistant responses occurred varied with cultivars (15). Because the adult-plant resistance of rice to bacterial blight has still not been well confirmed and characterized, 13 cultivars were selected for further evaluation on the basis of preliminary tests. This paper reports our results.

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MATERIALS AND METHODS

Thirteen cultivars were studied; nine were grown commercially and seven were used as resistance sources for bacterial blight in China. Wase Aikoku 3, which in Japan showed resistance as plants matured, was also included. Taichung (Native) 1 (TN1) was used as a susceptible check, and IR1545-339 (IR1545) was included as a check for differential resistance to races 1, 2, 3, and 4 at both tillering and flowering stages. Shi-zu, identified earlier at IRRI as resistant at all stages to the four races, was included as a resistant check (Table 1).

X. campestris pv. *oryzae* strains PX061, PX086, PX079, and PX071 representing races 1, 2, 3, and 4, respectively, in the Philippines, were used. The inoculum of each strain was prepared from 72-hr culture grown on peptone-sucrose agar slants. Inoculum was adjusted to a concentration of about 10^9 cells per milliliter.

To test for resistance at the seedling stage, the 13 cultivars were sown in plastic trays with 15 seeds per row. Four rows of each cultivar 20 days (three-leaf stage) after sowing were inoculated with each strain.

To evaluate the adult-plant response, seeds of each cultivar were sown in seed boxes in the greenhouse. Seedlings were transplanted to 15-cm clay pots, four plants per pot, 14 days after seeding. The soil was fertilized with NPK (9-6-6 g/m^3) in the forms of $(NH_4)_2SO_4$, P_2O_5, and K_2O before transplanting, and additional nitrogen at the rate of 3 g/m^3 was applied 1 wk before inoculation. The positions of leaves on the main culm were marked in order of emergence, starting from the second leaf to the flag leaf. The disease scores of different leaf positions in a cultivar were therefore based only on data from the main culm.

Fully expanded leaves were inoculated in the following sequence: first at 2- to 3-leaf stage, then at the 6- to 8-, 9- to 10-, 11- to 12-, and 13- to 14-leaf stages, and finally on the flag leaf of the same plant. Usually, 2–3 (leaf stage) referred to seedling stage, 6–12 to tillering to maximum tillering stage, and 13–15 to booting stage, depending on the cultivar. The leaf-clipping method was used for inoculation (7). A split-plot design for two-factor experiments with three replicates was used (3). Three leaves of each leaf position per replicate were inoculated with each strain. Disease was measured according to the Standard Evaluation System for Rice (6) 2 wk after inoculation.

Table 1. Cultivar identification and sources

Cultivar	IRRI Acc. No.	Origin	Gene for resistance
Guai Zhou Magu*[a]	...	China[b]	Unknown
Nangen 11*	...	China[b]	Unknown
3330*	...	China[b]	Unknown
Peng Chiu Mang*	7287	China[c]	Unknown
Nangen 15*	...	China[c]	Unknown
Kwang-er-ai 5*	32551	China[c]	Unknown
Taichung Sen 5	38893	China[c]	Unknown
Wan Mi Hsiang	1149	China[c]	Unknown
Chin Kong Tao 3	7303	China[c]	Unknown
Wase Aikoku 3*	...	Japan	*Xa3*
IR1545	32624	IRRI	*xa5*
TN1	105	China[c]	Unknown
Shi-zu	...	China[b]	Unknown

[a] * = Resistant sources used in China.
[b] From China.
[c] From IRRI germ plasm bank.

Table 2. Adult-plant resistance of rice cultivars at seedling, maximum tillering, and adult growth stages

Cultivar	Disease scores[y] to strain (race)											
	PX061 (race 1)			PX086 (race 2)			PX079 (race 3)			PX071 (race 4)		
	SS[z]	MTS	BS	SS	MTS	BS	SS	MTS	BS	SS	MTS	BS
Shi-zu	1.0 a	1.3 a	1.0 a	3.0 a	1.0 a	1.0 a	1.0 a	2.5 a	1.3 a	1.0 a	1.2 a	1.0 a
IR1545-339	1.8 a	3.0 b	1.0 a	3.5 a	3.0 b	1.0 a	3.2 a	2.0 a	1.0 a	6.8 c	5.0 d	6.0 d
Peng Chiu Mang	6.5 b	3.1 b	1.2 a	6.1 b	1.3 a	1.0 a	6.0 b	3.0 b	1.0 a	6.2 b	3.2 b	1.0 a
Nangen 11	6.5 b	4.0 c	1.0 a	6.3 bc	3.0 b	1.0 a	6.5 bc	3.3 b	1.0 a	6.0 b	3.5 b	1.0 a
Nangen 15	6.7 b	5.5 e	2.0 b	6.5 bc	3.0 b	1.7 bc	6.5 bc	5.6 d	2.8 b	7.0 c	5.1 d	1.0 a
Chin Kong Tao 3	7.0 bc	4.3 cd	3.5 d	6.7 bc	3.7 c	1.7 bc	6.7 bc	4.8 c	1.2 a	7.3 d	6.6 e	6.8 f
Taichung Sen 5	7.0 bc	4.7 d	3.0 cd	7.5 d	4.7 d	2.0 c	9.0 f	5.4 cd	3.0 b	8.0 d	4.3 c	3.0 b
Wase Aikoku 3	7.0 bc	6.5	3.0 cd	7.0 cd	6.8 e	2.0 c	1.0 a	2.5 b	2.0 b	5.8 b	5.5 de	2.5 c
3330	7.5 c	5.7 ef	3.5 d	6.7 cd	3.3 bc	1.6 abc	7.2 d	5.4 cd	2.7 b	7.2 d	5.5 de	4.0 c
Guai Zhou Magu	8.5 d	5.5 e	1.0 a	8.5 e	3.1 b	1.1 a	8.0 e	5.2 cd	1.0 a	7.0 c	5.0 d	1.4 a
Kwang-er-ai 5	8.5 d	6.2 f	2.7 c	6.5 cd	5.0 d	1.5 bcd	9.0 f	7.0 e	2.7 b	9.0 e	7.0 fg	2.8
Wan Mi Hsiang	9.0 d	5.4 e	4.7 e	7.0 cd	3.0 b	1.3 bc	8.5 f	5.0 c	5.0 c	9.0 e	6.0 e	5.0 d
TN1	9.0 d	8.0 g	6.8 e	9.0 a	6.7 e	4.3 d	9.0 f	7.3 e	6.3 c	9.0 e	7.3 g	7.0 e

[y] Based on disease scale of 1–9, where 1 = 1% of leaf area affected and 9 = 50% of leaf area infected. Means in a column followed by a common letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.
[z] SS = seedling stage, MTS = maximum tillering stage, and BS = booting stage.

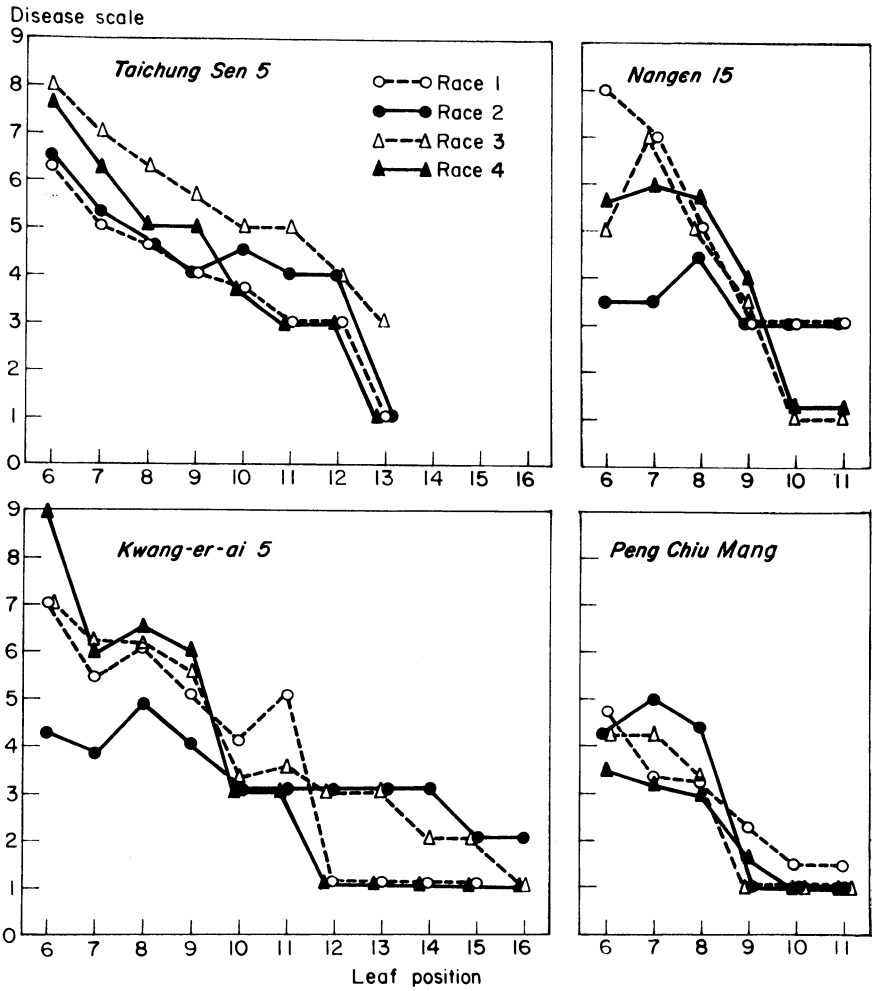

Fig. 1. Gradual increase in resistance from low to high leaf positions of four rice cultivars in response to infection by the four races of *Xanthomonas campestris* pv. *oryzae*.

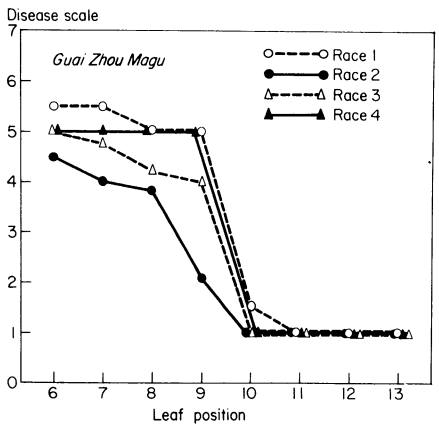

Fig. 2. Distinct resistance response of leaf position 10 of Guai Zhou Magu to infection by races 1, 2, 3, and 4 of *Xanthomonas campestris* pv. *oryzae*. The 13th leaf was the flag leaf.

RESULTS

All cultivars were evaluated 21 and 45 days after sowing and at the booting stage. Most cultivars were susceptible at the seedling stage but became resistant to one or all of the four races as the plants grew older (Table 2). Disease scores were significantly different between the three growth stages of the cultivars. Disease scores to race 1 of Guai Zhou Magu decreased from 8.5 to 5.5 to 1 at the seedling, maximum tillering, and booting stages, respectively. A similar trend was observed for the other races. With the four races, the disease score in Kwang-er-ai 5 decreased from a mean of 8.3 at seedling to 6.3 at maximum tillering to 2.4 at booting. With Shi-zu, however, disease scores were not affected by plant growth stage. TN1 was susceptible to moderately susceptible to the four races at all growth stages. The lesions, however, were longer on seedlings than on mature plants. IR1545 was resistant to races 1, 2, and 3 but susceptible to race 4, regardless of growth stage (Table 2).

The cultivars that became more resistant as the plants matured showed two patterns of disease development from seedling to flag leaf. Resistant cultivars such as Taichung Sen 5, Nangen 15, Kwang-er-ai 5, and Peng Chiu Mang gradually increased in resistance with each new leaf, and resistance was fully expressed by the flag leaf (Fig. 1). With Guai Zhou Magu, plants were susceptible until the nine-leaf stage and then became distinctly resistant from the 10th leaf to flag leaf (Fig. 2).

Leaves of cultivars responding to infection with *X. campestris* pv. *oryzae* were at different positions. Some cultivars showed resistance earlier than others. Guai Zhou Magu, Nangen 15, Nangen 11, and Peng Chiu Mang were resistant from the ninth leaf position, whereas Taichung Sen 5 was resistant from the 11th or 12th leaf positions. The flag leaves, however, were all very

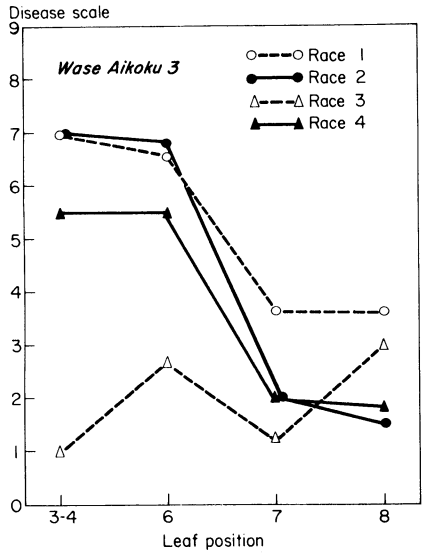

Fig. 3. Response of Wase Aikoku 3 from the third leaf position to flag leaf (no. 8) to four races of *Xanthomonas campestris* pv. *oryzae*.

resistant to bacterial blight.

Guai Zhou Magu, Nangen 11, Peng Chiu Mang, Nangen 15, Kwang-er-ai 5, and Taichung Sen 5 were resistant to these races at booting, whereas Wan Mi Hsiang, 3330, and Chin Kong Tao 3 were resistant to one or two races at booting. The main effects of cultivars and of races were highly significant as was the interaction effect. Wase Aikoku 3 was susceptible to races 1, 2, and 4 at seedling and resistant at booting, but it was resistant to race 3 at all growth stages (Fig. 3).

DISCUSSION

Adult-plant resistance to plant disease has been observed in various crops. In the wheat cultivar Thatcher, Nazareno and Roelfs (9) found no relationship between the independent *Sr* genes for seedling resistance and adult-plant resistance to rust. Heagle and Moore (4) indicated that less crown rust developed on adult than seedling oat plants. These resistances were largely non-race-specific. Bartos et al (1) analyzed the adult-plant resistance to leaf rust in wheat cultivars Thatcher and Red Bobs and indicated that as seedlings, both were susceptible to races 9 and 161. By plant maturity, however, Thatcher became resistant to race 9 but not to 161, whereas Red Bobs remained susceptible to both races.

With rice bacterial blight, Wakimoto and Yoshii (14) noted the variation in disease reactions among rice cultivars when plants were tested at different growth stages. When evaluation was done at the seedling stage, results were more variable. Horino and Ezuka (5) and Ezuka et al (2) showed the resistance expression of Wase Aikoku 3, and a group of rice-derived cultivars had a high level of resistance. The disease reactions to the bacterial strains were more stable on the flag leaves than on seedlings and were quite consistent in all strains in Japan. The *Xa-6* gene, conferring bacterial blight resistance in Zenith and Malagkit Sungsong, was expressed at the booting stage (11,15). In our study, the resistance of Wase Aikoku 3 was expressed at the flag leaf stage, but the resistance to race 3 was also expressed in the seedling stage. The adult-plant resistance of rice to bacterial blight appears quite stable. Our results indicated that resistance effective at the seedling stage, as in Shi-zu, was not affected by growth stage or races. The susceptibility of TN1 to the four races was not altered, but the disease score decreased as plants grew older. Similarly, the differential resistance of IR1545 was independent of growth stage, although the disease score tended to decrease at later growth stages.

Adult-plant resistance was expressed consistently on the flag leaves of the cultivars evaluated (Table 2). The actual leaf position when resistance was shown varied according to cultivars—earlier in some, such as Guai Zhou Magu, Nangen 15, Peng Chiu Mang, etc., and later in others, such as Taichung Sen 5.

The adult-plant resistance was also race-specific, as in Wan Mi Hsiang, which was resistant to one race, and 3330, which was resistant to two races.

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