Leaf and Neck Blast Resistance in Tropical Lowland Rice Cultivars

J. M. BONMAN, B. A. ESTRADA, and J. M. BANDONG, International Rice Research Institute, P.O. Box 933, Manila, Philippines

ABSTRACT

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Pyricularia oryzae, the rice blast pathogen, can infect both leaves and panicle neck nodes. The leaf blast and neck blast resistance of 27 tropical lowland rice cultivars and breeding lines was assessed and classified relative to a susceptible check, IR50, and a partially resistant check, IR36. Leaf blast resistance was scored in four upland miniplot trials. Neck blast resistance was scored in five inoculated, lowland field plantings. The classification of the relative leaf blast resistance of entries in the miniplots was generally consistent for resistant and susceptible lines, but varied between trials for lines with intermediate resistance. The classification of neck blast resistance of intermediate and susceptible lines also varied between trials, mostly due to differences in flowering date. The mean leaf blast values from the miniplot trials were positively correlated with the mean neck blast values ($r = 0.81$, $P = 0.01$) from the lowland trials. Some lines, however, were exceptions to this general relationship. The lines IR25604-99-1-3-2-2 and IR37704-98-3-2-2 were leaf blast susceptible, but resistant to neck blast in most of the lowland plantings. Lines of particular interest to breeders should be screened for neck blast resistance; improved methods are required, particularly for neck blast testing.

Blast, caused by *Pyricularia oryzae* Cav., is an important disease of rice (*Oryza sativa* L.) in many production areas worldwide (9). The disease has two commonly recognized phases: leaf blast and neck blast. Leaf blast occurs most often during the plant's vegetative stage when spindle-shaped lesions appear on the leaf blade and necrotic lesions are found at the leaf collar. Although leaf infection is sometimes found at the reproductive and ripening stages, the most destructive symptom during these stages is neck blast, characterized by infection at the panicle base. When the fungus colonizes the panicle neck node and adjacent tissues the flow of photosynthates to the developing grains can be inhibited, resulting in light grains or empty panicles. In farmers' fields, neck blast is often more destructive than leaf blast.

In tropical lowland rice, blast is usually damaging only in susceptible cultivars such as IR50; it is not a problem in partially resistant cultivars such as IR36 (14). The miniplot method of Marchetti (8) was introduced at the International Rice Research Institute (IRRI) to evaluate the many elite breeding lines from the IRRI breeding program (3). This method can be used conveniently in upland nurseries for assessing relative disease progress until about 40 days after seeding. At IRRI, resistance of rice lines to a field population of *P. oryzae* is evaluated relative to IR36 and IR50, the two agricultural checks (3).

One drawback of using upland (aerobic soil) nursery plantings to test blast resistance is that the results may not reflect the responses of the lines when they are grown to maturity in lowland (flooded soil) conditions. Not only are the cultural conditions different, but the resistance of lines to leaf blast at the seedling stage may differ from their resistance to neck blast. The purpose of this work was to compare the leaf blast resistance of lowland rice lines, evaluated in upland miniplots, with their neck blast resistance, evaluated in lowland field plots.

MATERIALS AND METHODS

Leaf blast. The upland miniplot method (8) was used to measure disease progress in four trials from late 1985 to early 1987 at the IRRI blast nursery. Twenty-seven rices that showed a wide range of leaf blast susceptibility in pilot trials were used. The cultivar Tetep, which shows few lesions in IRRI nursery tests, was used as the barrier between plots; a row of the susceptible line IR442-2-58 was used as the inoculum spreader row in all tests. Ammonium sulfate was applied at seeding to the plots at 120 kg N/ha. Naturally infected IR442-2-58 seedlings were transplanted 10 days after seeding in groups beside the spreader row and opposite the center row of each three-row plot to ensure uniform infection. Plots were scored every 3–4 days from about 20 to 40 days after

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seeding. Area under the disease progress curve values (ADPC) were calculated (11) and reduced to values relative to the number of days of observation (RADPC). A randomized complete block design was used with four replications in the first trial, two in the second and third trials, and three in the fourth trial.

An analysis of variance was performed for each trial using the RADPC values. Test entries were classified as resistant when they were equal to or more resistant than IR36, and as susceptible when equal to or more susceptible than IR50. Entries with scores between the two checks were classified as intermediate. All comparisons were based on an LSD test at the 5% level of significance. A combined analysis of variance was performed over all four trials and cultivar comparisons were made using the cultivar × trial mean square as the error term.

Neck blast. The 27 cultivars and elite lines were planted in lowland field plots. Five plantings were made: three as part of an experiment sown in 1986, and two in separate experiments in 1987. In the 1986 experiment, seeds were sown in wet beds in February, and seedlings were transplanted to the field 3 wk later. The three plantings were made at 10-day intervals. The experimental design was a split-plot with cultivars as main plots and planting dates as subplots. Ammonium sulfate was applied to each plot before transplanting (100 kg N/ha) and at maximum tillering (60 kg N/ha). Each main plot was 3 × 3 m and was divided into three subplots 1 × 3 m each. Hills were 20 × 20 cm apart with two or three seedlings transplanted per hill.

To ensure infection, each plot was inoculated using two methods simultaneously. In the first method, seedlings of IR442-2-58 were exposed in the IRRI blast nursery until symptoms appeared. A tray of the diseased seedlings was placed at canopy height in the center of each lowland plot at the beginning of booting. Every 7–10 days the trays were replaced with newly infected seedlings until about 1 wk before harvest.

In the second inoculation method, a conidial suspension was sprayed on each entry as it reached heading stage. The inoculum was obtained by covering beds of infected seedlings with a polyethylene sheet at 1700 hr. At 0530 hr the next day, the lesions on the seedlings were sporulating. Leaves were cut 2–4 cm above the soil surface and then were stored in a bucket at 4 C until 1600 hr. The leaves were then washed in distilled water to dislodge the conidia and the conidial concentration was adjusted to 60,000 conidia/ml using a hemacytometer. About 700 g fresh weight of leaves were required for 1 L of suspension. The suspension was sprayed on the plots at about 1700 hr. The ability of the conidia to germinate was checked routinely.

Neck blast was scored 4–7 days before harvest. From each plot, 10–12 hills were chosen at random and harvested. The panicles from these hills were rated for neck blast infection using the scale of Ahn and Mukelar (1). The percentage of panicles with severe neck blast infection (scores of 7–9) was calculated and correlation analysis and analysis of variance were performed.

In the 1987 experiment, each line was sown once per experiment in 1 × 3 m plots. In each experiment, the entries were stagger-seeded so that all entries would flower at about the same time. In the first experiment, all entries matured from 21 to 28 October and in the second, all entries matured from 18 November to 2 December. All other procedures were the same as in the 1986 experiment.

As with the miniplot results, the entries were classified relative to IR36 and IR50. A combined analysis of variance was performed for the data from the five plantings and cultivar comparisons were made using the cultivar × planting date mean square as the error term.

RESULTS

In the nursery miniplot experiments, a wide range of susceptibility to leaf blast was recorded. The diseased leaf area at the final reading was always greater than 70% for the most susceptible lines. Results for the most resistant and most susceptible lines were consistent in all experiments (Table 1). However, for rices that fell between IR36 and IR50 in susceptibility, the classification of resistance varied between trials. For

Table 1. Classification of relative leaf and neck blast resistance in 27 tropical lowland rice cultivars and lines[a] based on comparisons between values of relative area under the disease progress curve from four miniplot trials, and percentage of severe neck blast from five lowland plantings[b]

Line no.	Cultivar or line	Relative area under disease progress curve[c]					Severe neck blast					
		1	2	3	4	Mean	1	2	3	4	5	Mean
1	IR35546-52-3-3-2	0.2 R	0.1 R	0.1 R	0.2 R	0.2 R	4.1 R	10.2 R	19.3 R	0.2 R	6.1 R	8.0 R
2	IR31868-64-2-3-3-3	0.6 R	0.2 R	0.6 R	0.3 R	0.4 R	3.0 R	5.3 R	9.7 R	0.0 R	4.1 R	4.4 R
3	IR28224-3-2-3-2	0.4 R	0.9 R	0.6 R	0.3 R	0.6 R	10.0 R	9.5 R	8.3 R	0.2 R	1.7 R	5.9 R
4	IR31802-48-2-2-2	1.1 R	0.6 R	0.7 R	0.4 R	0.7 R	4.9 R	6.6 R	14.4 R	2.5 R	3.5 R	6.4 R
5	IR32429-47-3-1-2	1.3 R	1.2 R	0.4 R	0.3 R	0.8 R	8.5 R	3.2 R	2.4 R	4.3 R	3.7 R	4.4 R
6	IR32429-122-3-1-2	2.9 R	2.0 R	1.0 R	0.4 R	1.6 R	3.1 R	7.9 R	20.9 R	0.5 R	3.2 R	7.1 R
7	IR29723-143-3-2-1	4.3 R	4.3 R	2.7 R	1.8 R	3.3 R	8.3 R	5.6 R	12.2 R	1.7 R	4.2 R	6.4 R
8	IR64	6.3 R	5.6 R	5.9 R	2.5 R	5.1 R	7.5 R	11.4 R	10.6 R	3.6 R	5.6 R	7.8 R
9	IR32453-20-3-2-2	4.8 R	6.1 R	9.1 R	1.9 R	5.5 R	26.9 S	8.1 R	11.7 R	3.2 R	2.5 R	10.5 R
10	IR58	8.6 R	6.2 R	6.9 R	3.6 R	6.3 R	8.1 R	17.6 R	35.8 S	1.6 R	6.8 R	14.0 R
11	IR36 (R check)	9.1	6.2	8.3	3.2	6.7	9.6	22.7	22.0	6.3	4.1	13.0
12	IR29723-17-3-2-1	12.9 I	8.0 R	9.3 R	3.6 R	8.4 R	5.4 R	32.0 I	24.0 R	1.2 R	10.3 R	14.6 R
13	IR35293-125-3-2-3	16.1 I	8.1 R	8.2 R	4.1 R	9.1 R	21.3 S	23.2 R	20.3 R	8.9 I	6.7 R	16.1 R
14	IR29692-65-2-3-3	13.7 I	9.1 S	9.1 R	5.6 R	9.4 R	9.4 R	37.5 S	27.9 R	11.1 I	5.5 R	18.3 R
15	IR29670-15-2-3	20.7 S	11.7 S	13.4 I	7.7 R	13.4 S	14.5 I	32.4 I	29.9 R	12.8 I	8.0 R	19.5 I
16	IR29725-109-1-2-1	11.2 I	7.8 R	18.0 S	16.8 S	13.5 S	16.7 S	52.2 S	41.9 S	14.5 S	19.9 S	29.1 S
17	IR66	21.4 S	10.9 S	11.4 I	9.2 I	13.2 S	17.8 S	24.3 R	10.9 R	3.1 R	8.1 R	12.8 R
18	IR18818-87-2-2-2	21.8 S	13.3 S	17.8 S	5.0 R	14.5 S	24.8 S	29.9 I	19.7 R	6.5 R	4.6 R	17.1 R
19	IR29692-99-3-2-1	26.0 S	14.8 S	15.8 S	4.5 R	15.3 S	10.7 I	35.8 S	38.1 S	10.9 I	8.1 R	20.7 I
20	IR29725-22-3-3-3	28.8 S	15.0 S	16.5 S	10.8 I	17.8 S	14.9 I	31.4 I	46.3 S	5.5 R	11.1 R	21.8 I
21	IR50 (S check)	27.0	13.0	18.4	16.4	18.7	16.0	40.5	43.3	17.3	25.2	28.5
22	IR29723-88-2-3-3	29.1 S	18.2 S	13.0 I	18.7 S	19.8 S	23.8 S	22.8 R	43.4 S	11.0 I	13.5 I	22.9 S
23	IR35361-59-3-3-2	23.9 S	19.7 S	18.1 S	18.1 S	19.9 S	56.8 S	39.5 S	43.7 S	11.9 I	19.6 S	34.3 S
24	IR37704-98-3-2-2	30.5 S	15.2 S	17.8 S	17.9 S	20.3 S	20.5 S	31.4 I	13.9 R	5.4 R	8.5 R	15.9 R
25	IR25604-99-1-3-2-2	23.0 S	11.7 S	18.9 S	34.9 S	22.1 S	10.6 I	14.5 R	13.1 R	3.7 R	3.6 R	9.1 R
26	IR28150-84-3-3-2	31.5 S	14.5 S	24.4 S	19.8 S	22.6 S	43.8 S	28.4 R	45.0 S	22.5 S	17.8 S	31.5 S
27	IR35546-17-3-1-3	33.2 S	16.3 S	15.7 I	27.2 S	23.1 S	53.5 S	59.2 S	40.0 S	11.5 I	8.0 R	34.4 S

[a] Lines classified as resistant (R), intermediate (I), or susceptible (S) relative to checks.

[b] R = same or more resistant than IR36, I = resistance between IR36 and IR50, S = same or more susceptible than IR50. Classification within each trial or planting based on LSD ($P = 0.05$).

[c] Maximum possible value = 100.

example, line 15 was classified as susceptible in trials 1 and 2, intermediate in trial 3, and resistant in trial 4 (Table 1). Based on the mean value for the four trials, line 15 was classified as susceptible.

In general, neck blast was more severe in 1986 (plantings 1–3) than in 1987 (plantings 4 and 5) (Table 1). However, IR36 was consistently resistant compared with IR50. Therefore, the neck blast resistance of other lines and cultivars could be classified relative to the two checks.

The analysis of variance for the three plantings in 1986 showed a significant interaction between cultivar and planting date. The cultivars and lines were grouped into early maturing, medium maturing, and late maturing, and the interaction was partitioned based on this grouping. The relative magnitude of the mean squares indicated that the planting × cultivar interaction could be explained primarily by differences in growth duration. Among the three groups, the largest effect was contributed by the difference between the early maturing group and the rest.

The lines that were classified as resistant to leaf blast also were classified as neck blast resistant in most of the five lowland plantings (Table 1). However, the lines classified as intermediate or susceptible, based on their leaf blast reactions, sometimes were classified as resistant to neck blast. Lines 24 and 25 were consistently susceptible to leaf blast, yet were as resistant as IR36 to neck blast in four of the five lowland plantings.

Besides lines 24 and 25, lines 17 and 18 were classified as leaf blast susceptible in the miniplots, yet neck blast resistant in the lowland plantings on the basis of comparisons of the mean values (Table 1).

The mean percentage of severe neck blast of the five lowland field plantings was positively correlated with the mean RADPC values from the miniplot tests ($r = 0.81$, $P = 0.01$). The correlation was higher when lines 17, 18, 24, and 25 were not considered ($r = 0.95$, $P = 0.01$).

DISCUSSION

The relative leaf blast resistance of the test entries with intermediate resistance varied between trials. Thus, methods should be revised so that the resistance of such entries can be more reliably assessed. Increasing the plot size, which could be expected to reduce interplot interference and increase the magnitude of the differences between the two checks, could be one way to achieve this objective.

The leaf blast scores for lines 1–5 were low, indicating that matching races of *P. oryzae* were probably not present during the tests. In spite of the lack of matching races, lines 1–5 showed some incidence of severe neck blast in the lowland experiments. Perhaps segregation for blast resistance was occurring within these lines, because even released cultivars such as IR64 are found to segregate for some characters (6). Because leaf blast was scored on a per plot basis, individual susceptible plants may have gone undetected in the upland miniplots. The plants severely affected by neck blast may have been susceptible segregants. However, further work using purified lines is required to establish if segregation for blast resistance is occurring within cultivars.

Results from the assessment of neck blast resistance across experiments were less consistent than the leaf blast measurements. In the 1986 trial, variation in the dates of flowering of the test entries was the primary cause of this inconsistency. In each of the 1986 plantings, lines of similar neck blast resistance, but of different maturity, may have differed in neck blast scores because of inoculum or weather during flowering. For example, the early maturing lines (lines 4–6, 10, 11, 14–16, 19–21) generally had lower neck blast scores during the first planting than in later plantings (Table 1). The low scores were probably due to a combination of two factors. First, these lines flowered in the first planting from late April to early May, during a period of wind, little rainfall, and high temperatures—conditions that do not favor blast development (12). Second, because these were the first plots to flower, there may have been less inoculum present from adjacent plantings than there was in later plantings.

In the 1987 lowland experiments, staggered seeding was used to synchronize the date of flowering. However, time of flowering still differed by more than a week between some lines, which may have introduced variation.

To eliminate this problem in large screening tests, successive plantings of the susceptible check could be included rather than stagger-seeding each entry. The data for each line could then be expressed relative to the susceptible-check planting that flowered at the same time. The neck blast screening method can also be improved by determining the time of sowing that is most likely to favor neck blast development.

Results from miniplot trials can be used to select leaf blast resistant lines that are likely to be resistant to neck blast under lowland conditions. Also, because neck blast is usually of greater concern than leaf blast in most tropical lowland rice environments, lines such as 24 and 25 may have agriculturally useful blast resistance even though they are susceptible in the miniplots. Field trials emphasizing neck blast evaluation should be undertaken for lines being considered for release and for lines of particular interest to breeders, even if such lines are susceptible in miniplots.

The differential reactions of lines 24 and 25 to leaf and neck blast can be explained by assuming that leaf blast and neck blast resistance are not linked in these lines. For complete, race-specific resistance, leaf blast and neck blast resistance are apparently closely correlated (10), with only one reported exception (13). For partial resistance, Ahn and Rubiano (2) also found a close relation between the degree of susceptibility to leaf blast and neck blast in 15 cultivars. Others, however, have observed a lack of correspondence between the results of leaf blast and neck blast resistance tests. Chung et al (4) observed that some cultivars were resistant to leaf blast in the field but highly neck blast susceptible. They recorded the opposite reaction for another cultivar (4). Recently, Koh et al (7) characterized the adult plant resistance to leaf blast in several temperate japonica rices in Korea. Although some of these cultivars were highly susceptible as seedlings (7), they were relatively resistant to neck blast in the field (5). Thus, a growing body of knowledge indicates that the relative level of resistance to leaf blast and neck blast differs in certain rice cultivars.

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LITERATURE CITED

1. Ahn, S. W., and Mukelar, A. 1986. Rice blast management under upland conditions. Pages 363-374 in: Progress in Upland Rice Research. Int. Rice Res. Inst., Manila, Philippines.
2. Ahn, S. W., and Rubiano, M. 1984. Relationship between susceptibility to leaf blast (Bl) and panicle Bl severity. Int. Rice Res. Newsl. 9(5):13.
3. Bonman, J. M., Yeh, W. H., and Bandong, J. M. 1986. Assessment of partial resistance to blast in lowland rice cultivars. (Abstr.) Phytopathology 76:1105.
4. Chung, H. S., Choi, G. H., and Shakya, D. 1980. Slow blasting of rice cultivars at leaf and heading stages in paddy field. Office of Rural Development, Suweon, Korea. 50 pp. (in Korean with English summary)
5. Hwang, B. K., Koh, Y. J., and Chung, H. S. 1987. Effects of adult-plant resistance on blast severity and yield of rice. Plant Dis. 71:1035-1038.
6. International Rice Research Institute. 1987. Annual Report for 1986. International Rice Research Institute, Manila, Philippines. 639 pp.
7. Koh, Y. J., Hwang, B. K., and Chung, H. S. 1987. Adult-plant resistance of rice to leaf blast. Phytopathology 77:232-236.
8. Marchetti, M. A. 1983. Dilatory resistance to rice blast in USA rice. Phytopathology 73:645-649.
9. Ou, S. H. 1985. Rice Diseases. 2nd ed. Commonwealth Agricultural Bureaux, Kew, Surrey, England. 380 pp.
10. Ou, S. H., and Nuque, F. L. 1963. The relation between leaf and neck blast resistance to the rice blast disease. Int. Rice Comm. Newsl. 12:30-34.
11. 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.
12. Suzuki, H. 1975. Meteorological factors in the epidemiology of rice blast. Annu. Rev. Phytopathol. 13:239-256.
13. Willis, G. M., Allowitz, R. D., and Menvielle, E. S. 1968. Differential susceptibility of rice leaves and panicles to *Pyricularia oryzae* (Abstr.) Phytopathology 58:1072.
14. Yeh, W. H., and Bonman, J. M. 1986. Assessment of partial resistance to *Pyricularia oryzae* in six rice cultivars. Plant Pathol. 35:319-323.