Selection for Resistance to Rice Sheath Blight Through Number of Infection Cushions and Lesion Type

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ABSTRACT

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Individual plants from the first through third backcrosses of the rice sheath blight-resistant cultivar Tetep to the susceptible cultivar Lemont were selected for low infection cushion counts and for resistant-type lesions in the greenhouse. Replicated progeny field tests of selfed plants from each generation were conducted. Correlations between individual backcross plants, rated for number of infection cushions and lesion type, and disease ratings of their field-tested progeny were relatively low but resistance levels were maintained. No significant differences in disease ratings were observed among generation means for the first through third backcrosses in field tests. Sheath blight resistance was transferred to a Lemont plant type. Lesion type was the best and easiest selection criterion.

Additional keywords: *Oryza sativa, Rhizoctonia solani*

Sheath blight, caused by the fungus *Rhizoctonia solani* Kühn (teleomorph *Thanatephorus cucumeris* (A. B. Frank) Donk) anastomosis group 1 IA, is the most important disease of rice (*Oryza sativa* L.) in the southern United States, causing significant yield losses each year (2,4,5,11). The fungus survives either as sclerotia or as mycelia in plant debris, floats to the surface of flood water, germinates, and infects the rice plant (5,11). The fungus then forms infection cushions and/or lobate appressoria on the plant surface (8). After initial infection, mycelium moves up the plant by surface hyphae and develops new infection structures over the entire plant. Most long-grain cultivars of rice in the United States are susceptible or very susceptible to sheath blight whereas medium- and short-grain cultivars tend to be moderately susceptible to moderately resistant (2,5).

Tetep, a primitive cultivar from Vietnam, has been identified as one of the cultivars most resistant to sheath blight (7,9). The plant, however, is tall, has weak culms, and flowers late in the season. Tetep's resistance is expressed as a reduced number of infection cushions produced by *R. solani* and as the production of oxidized phenolic compounds, which slow the spread of *R. solani* within the plant. This is manifested as a dark zone around the lesion (9). The result is fewer and smaller lesions.

Both of these resistance mechanisms tend to be overlooked in standard selection programs to incorporate sheath blight resistance into commercial cultivars because the number of infection cushions must be evaluated microscopically and plants are rated in the field on a whole plant reaction, not by lesion type. Another problem associated with screening for sheath blight resistance is poor and erratic sheath blight development in widely spaced breeding nurseries caused by less relative humidity in an open canopy. Low heritability on an individual plant basis (7) and resistance associated with late maturity and tall plant type, which are poor agronomic traits, are other problems (5,7).

The purpose of this study was to determine if the number of infection cushions and lesion type could be used as selection tools to incorporate sheath blight resistance from the unadapted cultivar Tetep (PI 280682) into the very susceptible but high-yielding cultivar Lemont (PI 475833) (1) in a backcross program.

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MATERIALS AND METHODS

Inoculum. A virulent isolate of *R. solani* (LR172) isolated from a naturally infected rice plant (cv. Lebonnet) in Louisiana was used. The fungal inoculum was produced on a moist autoclaved rice seed/rice hull mixture (2:1, v/v). The fungus was incubated in the dark for 12–14 days at 30 C, and the grain-hull inoculum was broken into small (1–4 mm diameter) particles consisting of several rice grains held together by fungal mycelium.

Greenhouse evaluations. Crosses were made between Lemont and Tetep. The F_1 plants were grown in the field and backcrossed to Lemont as the recurrent parent. The BC_1 F_1 plants were grown in the greenhouse and rated for sheath blight resistance on the basis of lesion margin width and infection structure number.

Individual BC_1 F_1 seeds were planted in pots in the greenhouse along with three individual plants of the parents. Seedlings were flooded at the five-leaf growth stage and given the equivalent of 93 kg/ha each of N, P, and K. Plants at the early tillering stage of growth were inoculated by placing a small piece of infected rice hull under the outer leaf sheath at the water level. Two tillers were inoculated per plant. Plants were maintained in a moist chamber at approximately 100% relative humidity. After 48 hr, the infected leaf sheaths were collected and placed in a 5% formaldehyde fixing solution. Sections of the leaf sheath were stained by simmering them for 3 min in aniline blue-lactophenol, and the number of infection cushions formed in a 0.5-cm^2 area located 1 cm above the inoculation point was determined (2). Post-penetrational resistance (dark lesion margin) was visually rated 96 hr after inoculation on a scale of 1–3, where 1 = narrowed margin on lesion (<2 mm), 2 = intermediate (2–3 mm), and 3 = wide margin (>3 mm). Seven to 10 individual plants with both low infection cushion numbers and wide lesion margins were backcrossed to Lemont. No selection for plant type was made. Remnant F_2 seed from each selfed BC_1 F_1 plant was retained for later field evaluations. The greenhouse selection procedure was repeated for the BC_2 F_1 and BC_3 F_1 generations, resulting in BC_2 F_2 and BC_3 F_2 seeds.

Field evaluations. Individual plants in 144 progeny lines randomly selected from the BC_{1-3} F_2 generations and the two parents were transplanted into the field at the five-leaf growth stage (28 days old) in 1986. Thirty-three BC_1 F_2, 51 BC_2 F_2, and 60 BC_3 F_2 progeny lines were included. Ten plants per line and parents were planted into each of two replicates (20 plants per line). Fertilizer was preplant incorporated at the level of 93 kg/ha N-P-K. Plants were spaced 25 cm apart with 25 cm between rows. Each plant was inoculated, as previously described, 33 days after transplanting at the late tillering stage. Julian date of heading and plant height (centimeters) were recorded.

Plants in the field were rated for disease 30–35 days after heading on a linear 0–9 scale, where 0 indicated no infection and 9 indicated plant death (3). Vertical disease progression (lesion height) was measured at the same time as the disease rating. This height was divided by the plant height to give a disease index between 0 and 1.

RESULTS

Greenhouse evaluation. Means for number of infection cushion ranged from 216.3 for Lemont to 81.7 for Tetep per 0.5 cm^2 (Table 1). Lesion type was consistent for the parents (Table 1). The number of infection cushions varied considerably in the Lemont and Tetep parent plants, although the mean values for Lemont were consistently higher than those for Tetep. Means of the F_1 backcross plants from each generation were intermediate between the susceptible and resistant parents.

Field evaluation. In field tests conducted in 1986, disease reaction positively correlated with disease index for all lines on a line mean basis ($r = 0.79$, $P < 0.01$). Both disease severity criteria gave the same ranking of lines in statistical analysis (Table 2).

The two parents were different for both disease reaction and disease index in field tests (Table 2). The means of progeny from the three backcross generations tested were intermediate between the two parents. Although disease resistance did not differ among the generations, differences were observed for lines within generations in each backcross. The means of the lines tested in the BC_{1-3} F_2 generations were intermediate in disease reaction between the two parents by both criteria. Individual plants within the lines were identified with disease reactions similar to one or the other parent. When lines were rated visually (disease rating), no line from the first through third backcross progeny tests was as resistant as Tetep or as susceptible as Lemont. When rated according to disease index, however, one line in the second backcross (ln 160, disease index = 0.8) and one line in the third backcross (ln 106, disease index = 0.9) were not significantly different from Lemont (disease index = 0.9).

Disease reaction ratings were negatively correlated to days to flowering in the BC_{1-3} F_2 field test ($r = -0.50$ to -0.62, $P < 0.01$). Low correlations were noticed between number of infection structures and disease reaction ($r = 0.08$ to 0.24, nonsignificant). Negative correlations between lesion type and disease reaction were higher than number of infection cushions ($r = -0.30$ to -0.35, $P < 0.05$). Julian date of heading was highly variable between and among lines. The BC_{1-3} F_2 lines were intermediate between the two parents. Individual plants within lines, however, ranged from 7 days earlier than Lemont to 7 days later than Tetep.

Table 1. Mean number of infection cushions produced by *Rhizoctonia solani* and mean lesion type for individual BC_{1-3} F_1 plants and their parental lines evaluated in a moist chamber in the greenhouse

Population	Mean number of infection cushions[y]	SD	Mean lesion type[z]	SD
BC_1 F_1	89.1	59.73	1.9	0.84
BC_2 F_1	120.6	62.52	2.3	0.95
Lemont	190.2	50.89	1.0	0.00
Tetep	81.6	64.93	3.0	0.00
BC_3 F_1	133.4	73.90	1.9	0.92
Lemont	216.3	87.20	1.0	0.00
Tetep	88.0	76.22	3.0	0.00

[y]Number of infection cushions in a 0.5-cm^2 area 1 cm above the point of inoculation 48 hr after inoculation.

[z]Rated visually on a scale of 1–3, 96 hr after inoculation, where 1 = <2 mm, 2 = 2–3 mm, and 3 = >3 mm.

Table 2. Average sheath blight severity, plant height, and date of heading of the BC_{1-3} F_1 lines tested in the field at the Rice Research Station, Crowley, LA, in 1986

Population	Disease index[x]	Disease reaction[y]	SD	Plant height (cm)	SD	Julian date of heading	SD
Lemont	0.9 a[z]	6.7 a	0.92	90	15	198	1.4
BC_3 F_2	0.6 b	4.5 b	0.98	102	15	197	3.9
BC_2 F_2	0.6 b	4.1 b	0.88	99	14	203	5.2
BC_1 F_2	0.5 b	3.6 b	0.61	109	16	206	11.5
Tetep	0.3 c	2.2 c	0.35	141	14	206	0.7

[x]Disease index = vertical disease progression/plant height at maturity.

[y]Disease reaction rated visually on a 0–9 scale where 0 = no disease and 9 = plant dead and collapsed 30–35 days after heading.

[z]Means with the same letters are not statistically different according to Duncan's multiple range test ($P = 0.05$).

DISCUSSION

High parent variability in number of infection cushion indicates a low heritability and high environmental variation for this trait. Selection on the basis of the number of infection cushions and lesion type was effective enough to maintain the mean resistance level of the backcross population through the generations needed (Table 2) to maintain sheath blight resistance and develop a Lemont-type germ plasm (10). However, it would appear that the effect of these mechanisms is overridden by the effect of days to flowering on disease expression in field tests of early generation material.

Because of the high correlations of days to flowering to disease reaction and disease index, selection on the basis of either of these criteria would likely produce undesirable late genotypes. The tall and late-flowering growth habit of Tetep contributes to its level of resistance, but studies of resistance mechanisms (7) and greenhouse seedling tests (9) indicate that plant type is not the only major factor controlling disease resistance in the line. Tetep and Lemont are distantly related, and in early generations, a great deal of variability for plant type and maturity is expressed. As the Lemont plant type was approached, segregation for heading date decreased (Table 2). By the BC_3 generation, the mean days to flowering was near that of the Lemont parent, varying within 1 wk, although more variability existed than in the inbred parent.

The semidwarf plant type of Lemont is highly desirable because of its lodging resistance, which allows heavy fertilization for high yield potential, but this characteristic contributes to sheath blight susceptibility (5,6). It may not be possible to recover a line with both disease resistance as high as that of Tetep and the semidwarf plant type. However, a number of individual plants with relatively high resistance levels and a desirable phenotype were selected and may provide enough protection in the field to reduce the need for fungicide treatments for sheath blight under most circumstances (10).

Selection for disease resistance through the number of infection cushions is not recommended because it was tedious and time consuming and heritability was low. Higher correlations between lesion type and disease reaction and ease of evaluation make this selection system easier and more efficient than counting infection cushions. This system would allow early generation testing and reselection for crossing on a single plant basis in the greenhouse rather than in the field, where unfavorable environmental conditions for disease development limit selection. This would help maintain sheath blight resistance while making additional crosses to break linkages between resistance and tall late plant type. However, standard screening methods of testing progeny rows in the field would be easier and more accurate in later generation testing when seed quantity is large enough to grow thick progeny rows.

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