Potential Impact of Sheath Blight on Yield and Milling Quality of Short-Statured Rice Lines in the Southern United States

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ABSTRACT
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Comparative studies of sheath blight caused by *Rhizoctonia solani* in standard height and semidwarf U.S. rice (*Oryza sativa*) lines showed that semidwarf lines sustained more than double the reductions in both yield and milling quality sustained by closely related standard height lines. The disease developed more extensively in the semidwarfs because of the shorter distance between the waterline—the usual infection court—and the panicles. Sheath blight also severely reduced the amount of retillering and, consequently, the yield potential of the ratoon crop.

Sheath blight caused by *Rhizoctonia solani* Kühn is becoming an increasingly serious disease of rice (*Oryza sativa* L.) in the southern United States, especially in fields of long-grain rice. The sheath blight pathogen has been endemic in the United States for many years, but only in about the last 15 years has a distinction been made between sheath blight and a similar disease now called sheath spot caused by *R. oryzae* Ryker & Gooch (1). Sheath blight has been known in the Orient since 1910, and yield reductions of as much as 50% have been attributed to this disease (4).

The sheath blight pathogen is soilborne and is known to infect grassy weeds as well as rice. Rice usually becomes infected during the early to midreproductive stage, before flowering. Floating sclerotia of *R. solani* come in contact with rice and infect the outer leaf sheaths at the waterline. The pathogen can also spread from infected grasses to rice by aerial hyphae. The fungus ramifies the sheath tissue and also produces aerial hyphae that start new infections farther up the plant and spread to adjacent rice plants. In severe cases, panicles are affected before grain filling is completed, and lodging occurs because of culms weakened by the pathogen. The disease favors high temperature and relative humidity.

Recent changes in cultural practices are probably contributing to the increased prevalence and severity of sheath blight in the United States. Earlier maturing rice cultivars, the so-called 100-day rices, occupy much of the southern acreage. These cultivars are at vulnerable growth stages when the weather is more

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favorable for rapid development of sheath blight than later in the season. Midseason cultivars like Starbonnet may be genetically as susceptible to the pathogen as early cultivars, but they mature when the weather is cooler and perhaps drier. The use of nitrogen fertilizer has increased in order to realize the increased yield potential of the newer rice cultivars. The newer cultivars, although not true semidwarfs, are shorter than their predecessors. Soybeans (*Glycine max* (L.) Merr.) have emerged in recent years as the major rotation crop in the southern rice belt and are also highly susceptible to attack by the same anastomosis group (AG-1) of *R. solani* fungus that attacks rice (5). These changes in southern rice culture have apparently contributed to the increasing prevalence of sheath blight.

The first U.S.-developed commercial semidwarf long-grain cultivar, Bellemont, from the cross CI9881/PI331581, was released in the South in 1981, and other semidwarf lines are well on the way to being released (2). Bellemont is 20–30 cm shorter than any currently grown long-grain cultivars. In this paper, I present the results of several studies of sheath blight in semidwarfs and compare the relative impact of sheath blight in genetically closely related semidwarf (75–90 cm) and standard height (110–120 cm) rice lines. Experiment 1, prompted by observations that semidwarf lines were killed quickly when interplanted among standard lines, was to determine if seeding rate and the consequent differences in stand density would affect disease symptoms and the effect of the disease on yield and milling. Experiments 2 and 3 compared the effect of sheath blight on genetically related standard and semidwarf rice lines. Several pertinent observations from other incomplete studies are also discussed.

MATERIALS AND METHODS

All the studies presented were conducted at Beaumont, TX, in field plots six rows × 6.1 m (18 cm between rows) and, except for the seeding rate test (Exp. 1), drill-seeded at about 90 kg/ha. Treatments were replicated four times in a randomized complete block design. Plots were inoculated 60–62 days after emergence with 150 cc of a 2:1 (v/v) mixture of *R. solani*-infested rice hulls and rough (unhulled) rice. The inoculum was sprinkled between the center two rows of each plot. There was no evidence of movement of inoculum in the floodwater between inoculated and uninoculated check plots.

Plots were rated for disease incidence and severity a few days before harvest. A disease index (DI) was calculated by adding the products of severity ratings (0–9 scale, 1 = <20% of plants infected, 3 = 20–40%, 5 = 40–60%, 7 = 60–90%, 9 = >90%) and fractions of the area to be harvested, expressed as decimals, with different severities, eg, the DI for a plot with 20% of the harvested area rated 5, 30% rated 7, and 50% rated 9 would be 7.6 (0.2 × 5 + 0.3 × 7 + 0.5 × 9).

Plots were hand-harvested and the grain threshed with a Vogel thresher (custom built by Bill's Welding, Pullman, WA), then dried to 12% moisture. Yields were calculated from grain harvested from 4.8 m of the center two rows of each plot. Milling yields were determined on 125-g samples of grain according to standardized rice milling procedures.

In Experiment 1 seeded on 12 April 1977, a semidwarf sister line to Bellemont, B76-1292, was broadcast in rows by raising the drill shoes about 10 cm above the ground at rates of 56, 112, 168, and 224 kg/ha and then cultipacked. Grower plantings are usually at about 135–140 kg/ha. Ammonium sulfate (21% N) was applied at rates of 112 kg N/ha at first flood (four- to five-leaf stage) and 67 kg N/ha at the 2-mm panicle stage. The flood was maintained at 3–10 cm in depth until 2 wk before harvest. Weeds were controlled effectively with propanil herbicide applied 3 days before first flood at 3.4 kg a.i./ha. Plots were trimmed to 6.1 m in length, then the inner 76 cm (width) was harvested the length of the plot with a Suzue Comper 730 small plot combine (Suzue Agricultural Machinery Co., Ltd., 144-2 Gomen-cho, Nankoku-shi, Kochi-ken 783, Japan) (3).

Experiment 2 seeded on 21 April 1978 compared the effect of sheath blight on yield and milling of two standard rice cultivars and two closely related semidwarf lines under two nitrogen regimes: 135 kg N/ha applied at first flood with no topdressing at panicle initiation and 90 kg N/ha at first flood and 45 kg N/ha at the 2-mm panicle stage. Although not a common practice in commercial rice farming, frequently all the nitrogen fertilizer is applied at first

Table 1. Effect of seeding rate on disease index and yield reductions caused by *Rhizoctonia solani* in a semidwarf rice line, B76-1292, Beaumont, TX, 1977

Seeding rate (kg/ha)	Disease index[z]	Yields (kg/ha)[y] Diseased	Check	Reduction (%)
56	4.1	3358 c	5606 a	40.1
112	6.1	3039 c	5034 ab	39.6
168	5.7	3121 c	4753 b	34.3
224	6.1	2778 c	4697 b	40.8
Mean	5.5	3074	5018	38.7

[y] Values followed by the same letter are not significantly different from each other ($P = 0.05$) according to Duncan's multiple range test.
[z] Disease index of inoculated plots; check plots were free of sheath blight. Disease index is the sum of products of disease severity ratings and portions of the harvested area (expressed as decimals) rated at each severity; eg, the disease index of a harvested area with 20% rated 5, 30% rated 7, and 50% rated 9 = (0.2 × 5) + (0.3 × 7) + (0.5 × 9) = 7.6. Severity was rated on a 0–9 scale: 1 = <20% infected, 3 = 20–40%, 5 = 40–60%, 7 = 60–90%, 9 = >90%.

Table 2. Effect of sheath blight on milling yields of a semidwarf rice line, B76-1292, Beaumont, TX, 1977

Milling fractions	Milling yields (%)[a] Check	Diseased	Reduction (%)
Brown rice	79.3	77.6*[b]	2.1
Total milled rice	72.7	69.1*	5.1
Milled whole grain	66.1	54.0*	18.3

[a] Averages of 16 replicates. Values derived from hulling and milling 125-g samples of rough rice at 12% moisture.
[b] * = Significantly different from check ($P = 0.05$).

Table 3. Comparative effects of sheath blight on yield and whole-grain milling yield of standard cultivars and semidwarf Southern long-grain lines, Beaumont, TX, 1978[x]

Rice line	Disease[y] index	Yield (kg/ha) Check	Yield (kg/ha) Diseased	Reduction (%)	Whole-grain milling yield (%) Check	Whole-grain milling yield (%) Diseased	Reduction (%)
Standard							
Lebonnet	5.1 a	5,211	4,664**[z]	10.5	60.1	58.1 ns[z]	3.2
Bluebelle	6.1 b	4,924	4,314**	12.4	61.8	60.5 ns	1.8
Semidwarf							
RU7603069	7.4 c	4,850	3,564**	26.5	44.9	37.2**	17.1
PI331581	7.2 c	3,957	3,044**	23.1	51.7	45.3**	12.4

[x] Averages of eight replicates. Yield was estimated from 9.6-m row samples per plot. Whole-grain milling yield was determined on a 125-g sample of grain per plot.
[y] Disease index is the sum of products of disease severity ratings and portion of the harvested area rated at each severity, eg, the disease index for a harvested area with 20% rated 5, 30% rated 7, and 50% rated 9 = (0.2 × 5) + (0.3 × 7) + (0.5 × 9) = 7.6. Severity ratings were on a 0–9 scale: 1 = <20% infected, 3 = 20–40%, 5 = 40–60%, 7 = 60–90%, 9 = >90%. Values followed by the same letter are not significantly different from each other ($P = 0.05$) according to Duncan's multiple range test.
[z] ns = Not significantly different and ** = significantly different ($P = 0.01$) from the check.

flood in screening nurseries and disease experiments in which many lines of different maturities are planted in one- to three-row plots. The primary objective of the test was to determine the differences between standard and semidwarf lines; the nitrogen timing aspect of the experiment was secondary. The standard cultivars were Bluebelle and Lebonnet; the semidwarfs were PI331581 (Bluebelle was backcrossed on Taichung Native 1 six times) and RU7603069, a selection from the same cross as Bellemont (CI9881/PI331581).

Experiment 3 seeded on 30 April 1980 compared the effects of sheath blight on yield and milling of standard cultivars Labelle and Lebonnet and two semidwarfs, Bellemont and line RU8003070 (LB/BM). Line LB/BM is from the cross of Lebonnet and a semidwarf line related to Bellemont and is 4–5 cm taller than Bellemont. These plots received 90 kg N/ha at first flood and 67 kg N/ha at the 2-mm panicle stage as ammonium sulfate.

RESULTS AND DISCUSSION

In Experiment 1, which tested rate of seeding although no stand counts were made, differences in stand density were clearly visible in the early growth stages. By the time of inoculation with the sheath blight pathogen, the differences in stand were no longer visible because of compensation by tillering. Except for the significant difference between the average check plot yield at the lowest seeding rate and at the highest two seeding rates, there were no other statistical differences ($P = 0.05$) between yields, percent reduction in yield due to disease, or disease indices due to seeding rate (Table 1).

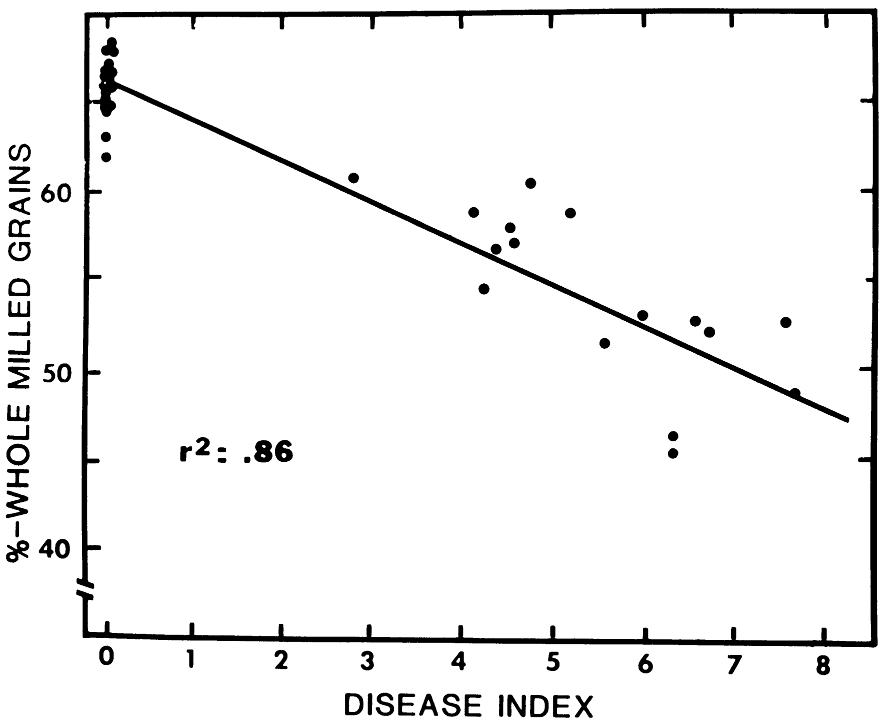

Fig. 1. The relationship of percent whole-milled rice to disease index in the semidwarf line B76-1292 (from the cross CI9881/PI331581) affected by sheath blight ($r^2 = 0.86$, $P<0.01$); $y = -2.69x + 68.66$. Disease index is the sum of products of disease severity ratings and portions of the harvested area rated at the different severities, eg, the disease index for a harvested area with 20% rated 5, 30% rated 7, and 50% rated 9 = (0.2 × 5) + (0.3 × 7) + (0.5 × 9) = 7.6. Severity ratings were on a 0–9 scale: 1 = <20% infected, 3 = 20–40%, 5 = 40–60%, 7 = 60–90%.

Table 4. Comparative effects of sheath blight on yield and whole-grain milling yield of standard cultivars and semidwarf southern long-grain lines, Beaumont, TX, 1980

Rice line	Disease[x] index	Yield (kg/ha) Check	Yield (kg/ha) Diseased[y]	Reduction (%)	Whole-grain milling yield (%) Check	Whole-grain milling yield (%) Diseased[y]	Reduction (%)
Standard							
Labelle	7.5 a	6,296	5,177*	17.8	59.8	59.0 ns	1.3
Lebonnet	8.1 a	5,440	4,385*	19.4	56.3	51.2 ns	9.1
Semidwarf							
LB/BM	8.5 ab	5,712	3,862**	32.4	49.5	34.0**	31.3
Bellemont	8.9 b	6,229	3,609**	42.1	62.5	48.8**	21.9

[x] Disease index is the sum of products of disease severity ratings and portions of the harvested area rated at each severity, eg, the disease index for a harvested area with 20% rated 5, 30% rated 7, and 50% rated 9 = (0.2 × 5) + (0.3 × 7) + (0.5 × 9) = 7.6. Severity ratings were on a 0–9 scale: 1 = <20% infected, 3 = 20–40%, 5 = 40–60%, 7 = 60–90%, 9 = >90%. Values followed by the same letter are not significantly different from each other ($P = 0.05$) according to Duncan's multiple range test.

[y] Significantly different from the check at * ($P = 0.05$) and ** ($P = 0.01$) or not significantly different from check = ns.

Analyses of milling data indicated that milling reductions because of sheath blight were independent of seeding rate. Therefore, the data were combined to present the effects of sheath blight on components of milling yield (Table 2). Sheath blight not only reduced the yield of rough rice but also reduced the kernel weight as indicated by the lower percentage of brown rice, ie, hulls made up a greater fraction of the rough rice weight in diseased plots than in check plots. Proportionately more starch was lost during milling of diseased plot samples. Most important to the farmer and rice miller, whole-grain milling was reduced greatly. Whole-grain milling yield is one of the principal determinants of the commercial value of a rice crop in the southern United States. In this study, sheath blight reduced rough rice yields 38.7% (Table 1), but that loss was increased to 50% in terms of kg/ha of milled whole-grain rice (3317 kg/ha in check plots vs. 1660 kg/ha in diseased plots).

Disease indices among the diseased plots ranged from 2.8 to 7.7 (Fig. 1). Correlations between DI and whole-grain milling yields were negative ($r = -0.754$) and highly significant ($P<0.01$), based on data from diseased plots only. The correlation was strengthened considerably ($r = -0.927$, $P<0.01$) by including data from 16 disease-free plots (Fig. 1).

Analyses of data from Experiment 2 indicated that check plot yields and reductions in yield and milling caused by sheath blight were independent of the N-fertilization regime (single or split application of 135 kg N/ha). The data were therefore combined without regard to N-regime to compare the effects of sheath blight on yield and milling of standard semidwarf rice lines (Table 3).

Data from Experiment 3 reinforce the conclusions to be drawn from the data above. When the standard cultivars Labelle and Lebonnet, currently among the leading U.S. long grains, were compared with semidwarf cultivar Bellemont and line LB/BM, the semidwarfs sustained substantially greater reductions in both yield and whole-grain milling yield than those sustained by the standard height cultivars (Table 4). It should be noted that standard height Bluebelle, Labelle, and Lebonnet are among the U.S. cultivars most susceptible to sheath blight. As the disease indices

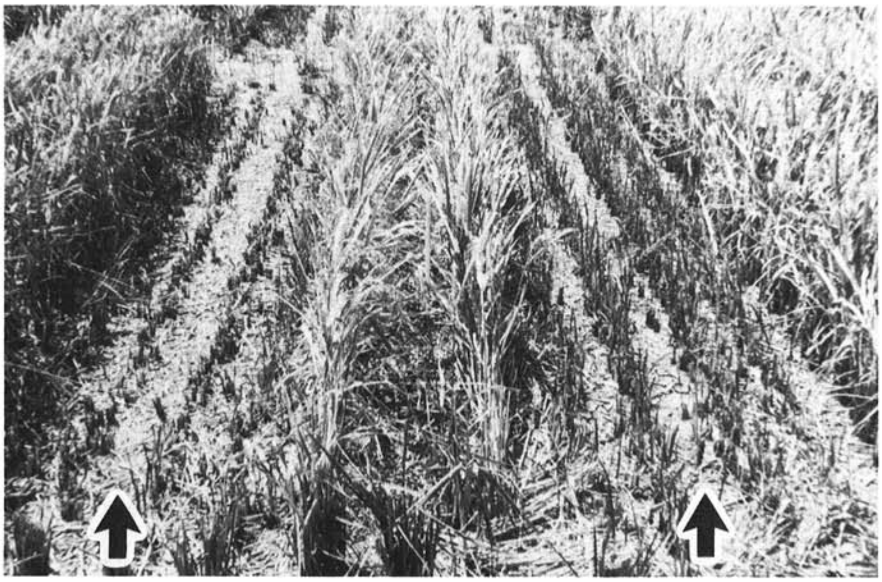

Fig. 2. Effect of sheath blight on retillering (ratooning) of B76-1292 rice stubble (arrows) 12 days after harvest. The dead stubble of a diseased plot (left) and ratooning stubble of the healthy plot are separated by unharvested border rows of the respective plots. Beaumont, TX, 1977.

indicate, sheath blight developed more extensively in the semidwarfs than in the standard height cultivars. Most infections started at the waterline and progressed upward until the flag leaf and panicle were infected. The semidwarfs appeared to be infected completely by the pathogen in a shorter time simply because of the shorter distance from infection courts near the waterline to the panicles.

In addition to interfering with grain filling, severe sheath blight causes premature ripening and drying of rice. Consequently, when the nonblighted parts of fields are at a favorable moisture for harvesting, the diseased parts of the fields are overripe and the grain too dry for good whole-grain milling yields. Labelle is noted in the industry for its superior milling quality over a broader than usual range of grain moistures. This was reflected in the only slight reduction in whole-grain milling yield caused by sheath blight in the 1980 test (Table 4).

In these and other studies, it was observed that the sheath blight pathogen killed most of the stubble and thereby severely reduced retillering (Fig. 2). This is particularly important in Texas, where about half of the rice acreage is ratoon-cropped, ie, allowed to retiller and then harvested a second time.

All of the southern U.S. long-grain cultivars are susceptible to sheath blight, and improved sheath blight resistance is among the objectives of rice breeding programs in the South. In the meantime, growers are being made aware of the potential dangers of growing the new semidwarf cultivars in fields with histories of sheath blight.

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