Rhizoctonia Root Rot on Sugarbeet Cultivars Having Varied Degrees of Resistance[1]

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ABSTRACT

To address a concern that yield losses may be greater in resistant than in susceptible sugarbeet cultivars, five cultivars, including a susceptible and two moderately resistant commercial varieties, a resistant three-way experimental hybrid, and a highly resistant breeding line, were tested in the field in 1989, 1990, and 1991 for their reaction to inoculation with *Rhizoctonia solani* (AG-2-2). Generally, rankings of the cultivars for percent decreases (inoculated versus noninoculated) in root and recoverable sucrose yield and percent sucrose and percent purity tended to be proportional to disease severity indices. With the exception of percent purity in 1990, positive significant or highly significant coefficients of linear correlation between disease index differences (inoculated versus noninoculated) and percent decreases in yield and purity parameters each year indicated that there were no hidden losses to Rhizoctonia root rot in resistant germplasms.

Additional Key Words: *Beta vulgaris, Rhizoctonia solani, Thanatephorus cucumeris,* disease losses.

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Rhizoctonia root and crown rot of sugarbeet *(Beta vulgaris* L.), induced by the soilborne fungus *Rhizoctonia solani* Kühn (teleomorph, *Thanatephorus cucumeris* (A. B. Frank) Donk) is endemic in beet producing areas of the United States. Because the fungus survives for long periods in soil and no chemicals are registered or completely effective for its suppression, genetic resistance offers the best and most economical means of disease management.

In the late 1950s, J. O. Gaskill began an intensive breeding program to develop resistance to *R. solani.* Substantial improvement in Rhizoctonia resistance was reported (Gaskill, 1968), and two resistant germplasms were released to sugarbeet breeders in 1966. We have continued this germplasm enhancement effort (Hecker and Ruppel, 1977), and several improved germplasms have been released or registered for use as pollinators in commercial hybrids (e.g., Hecker and Ruppel, 1985, 1988, 1991).

There has been some concern among sugarbeet breeders and sugar producers that there might be greater percent losses of root or sucrose yield in cultivars developed with resistance to *R. solani* compared with susceptible cultivars, when disease symptoms are mild or absent. To resolve this concern, we conducted experiments in our *Rhizoctonia*-inoculated field nursery to test the null hypothesis that the relationships between disease severity and yield parameters were not positively or linearly correlated.

MATERIALS AND METHODS

Experiments were conducted in Fort Collins, CO, in 1989, 1990, and 1991 on sites that had been in barley for the previous 3 yr. Four-row plots, planted in mid-May, were 6.1 m (20 ft) long, with 56 cm (22 in) between rows and a 25-cm (10-in) within-row plant spacing. Disease evaluations and yield determinations were based only on the center two rows of each plot. A highly susceptible commercial hybrid (HM55), two moderately resistant commercial hybrids (HH32 and ACH184), resistant experimental hybrid FC505CMS/FC708//FC712 (hereafter = FCHY), and resistant breeding line FC 709 (Hecker and Ruppel, 1988) were used in all tests. Among the parents of the experimental three-way hybrid, FC 505CMS is susceptible, and the two pollinators are resistant breeding lines.

Preparation of colonized barley-grain inoculum of *R. solani* (isolate R-9; AG-2-2) and inoculations in the field have been described (Ruppel et al., 1979). Inoculum, containing approximately 82-104 colony-forming units of *R. solani* per gram, was applied in mid- or late July at a rate of 12 g/6.1-m row.

Roots in each plot were lifted in the third week of September and rated for rot on a scale of 0 to 7, with 0 = no rot and 7 = plant dead (Hecker and Ruppel, 1977; Ruppel et al., 1979). Roots 5 cm (2 in) or more in diameter were topped, washed, weighed, and analyzed for sucrose and thin-juice purity by standard procedures (Association of Official Agricultural Chemists, 1955; Carruthers and Oldfield, 1961); we assumed that smaller-diameter roots would not be recovered in normal harvest operations. Recoverable sucrose and disease index (DI) were calculated for each plot.

In 1989, a preliminary 2 X 5 factorial experiment was arranged in a randomized complete-block design with two replicates. Treatments were inoculated versus noninoculated cultivars. In 1990 and 1991, experiments were arranged in the same design with four replicates.

To account for inherent differences in yield among sugarbeet cultivars, noninoculated plots of each cultivar were included in each replicate, and percent decreases in root yield, recoverable sucrose, % sucrose, and % purity, transformed to arcsine-square roots, were subjected to analyses of variance (ANOVA); actual percentages are presented in the tables. Due to residual inoculum in the field, inadvertent spread of inoculum via cultivation practices, or experimental error, a small level of disease was recorded in noninoculated plots; thus, statistical analyses were performed on the differences in disease indices (DI) between inoculated versus noninoculated plots. Mean separations were performed by Duncan's multiple range test. Correlation analyses were performed to relate DI differences to percent decreases in root yield, % sucrose, % purity, and recoverable sucrose. Due to a significant year effect, data from each year are presented separately.

RESULTS AND DISCUSSION

1989 Preliminary Experiment. Although differences among cultivars were striking (Table 1), the small degrees of freedom in the ANOVAs precluded detection of statistical significance in disease indices or any yield parameter. However, mean comparisons between the commercial hybrids, FCHY, and FC 709 for percent decreases in root yield, recoverable sucrose, and % sucrose indicated an inverse relation between disease severity and yield. When disease index means (differences between inoculated versus noninoculated) were correlated with mean yield parameters (percent decreases), coefficients of linear correlation (Table 4) were positive and significant or highly significant for root yield, recoverable sucrose, % sucrose, and % purity.

There was no loss in root yield in either FCHY or FC 709, the most resistant germplasms in these tests (Table 1); indeed, inoculated plots produced slightly higher root yields than noninoculated controls, as indicated by negative percent decreases. Commercial hybrids lost 29-49%. Similarly, percent loss in recoverable sucrose in the commercial hybrids was four to 26 times greater than in the resistant experimental germplasms. Decreases in % sucrose and % purity also were greater in the commercial hybrids than in the resistant experimental germplasms.

The apparent superior performance of the highly susceptible HM55 versus resistant HH32 and ACH184 was an artifact due to a relatively higher amount of naturally occurring disease in the noninoculated control plots of this cultivar than in controls of the resistant commercials. The DIs of inoculated and noninoculated HM55 were 6.2 and 1.6, respectively; the mean DI in controls of both HH32 and ACH184 was 0.5. Increased disease severity in noninoculated HM55 caused greater yield losses in the control, resulting in smaller percent decreases in all yield parameters and purity compared with the resistant commercials.

Table 1. Differences in disease index (DI) and percent decreases in root yield, recoverable sucrose, % sucrose, and % purity between inoculated and noninoculated treatments in cultivars having varied levels of resistance to *Rhizoctonia solani* in a 1989 field experiment inoculated with *R. solani* AG-2-2.

Cultivar†	DI‡	Root yield	Recoverable sucrose	Percent sucrose	Percent purity
		% decrease			
HM55	4.6	29.3	51.7	23.9	8.8
HH32	4.7	48.5	73.1	32.6	15.9
ACH184	3.6	40.9	68.5	38.0	10.6
FCHY	3.0	-1.6	18.9	17.4	4.5
FC 709	1.7	-4.9	2.8	5.9	0.6

† HM55, HH32, and ACH184 = susceptible, moderately resistant, and moderately resistant commercial hybrids, respectively; FCHY = experimental resistant hybrid FC505CMS/FC708//FC712; FC 709 = resistant breeding line.

‡ Disease index on a scale of 0 to 7, with 0 = no rot and 7 = plant dead. Data are differences between inoculated and noninoculated treatments.

1990 Experiment. Disease indices in the noninoculated treatments were low (<1.0 in all cultivars except HH32, which had a DI of 1.0) and did not confound comparisons among cultivars. All cultivars were ranked according to their known levels of resistance, although differences were not always significant (Table 2). Susceptible HM55 had the highest DI difference and percent decreases in root yield, recoverable sucrose, and % sucrose. ACH184 tended to have the best performance of the commercial hybrids and was comparable to our resistant experimental cultivars; statistically, however, ACH184 was not different than HH32 in yield and quality parameters. In field studies over several years, ACH184 always showed a slightly higher degree of resistance to *R. solani* than HH32 (Ruppel and Hecker, unpublished).

Correlation coefficients (Table 4) were positive and highly significant between DI differences and percent decreases in root yield, recoverable sucrose, and % sucrose, but insignificant for percent decrease in % purity, substantiating the general linear relationship between disease severity and yield losses obtained in 1989.

Table 2. Differences in disease index (DI) and percent decreases in root yield, recoverable sucrose, % sucrose, and % purity between inoculated and noninoculated treatments in cultivars having varied levels of resistance to *Rhizoctonia solani* in a 1990 field experiment inoculated with *R. solani* AG-2-2.

Cultivar[†]	DI[‡]	Root yield	Recoverable sucrose	Percent sucrose	Percent purity
		% decrease			
HM55	4.2 a[§]	41.9 a	61.2 a	28.0 a	4.8 a
HH32	1.3 b	14.6 ab	14.5 ab	5.8 ab	-0.4 dc
ACH184	1.2 b	1.3 b	3.6 b	3.5 b	0.1 bc
FCHY	0.4 b	3.3 b	-9.8 b	-2.2 b	-4.8 d
FC 709	0.5 b	7.4 b	10.6 ab	-1.7 b	1.0 ab

[†] HM55, HH32, and ACH184 = susceptible, moderately resistant, and moderately resistant commercial hybrids, respectively; FCHY = experimental resistant hybrid FC505CMS/FC708//FC712; FC 709 = resistant breeding line.

[‡] Disease index on a scale of 0 to 7, with 0 = no rot and 7 = plant dead. Data are differences between inoculated and noninoculated treatments.

[§] Means within columns followed by the same letter are not significantly different according to Duncan's multiple range tests at $P = 0.05$.

1991 Experiment. Results of our 1991 test were similar to those of 1990, with much less variation (Table 3). DIs of the noninoculated controls all were <1.0. In DI differences and percent decreases in yield and purity parameters, the cultivars performed as expected given their known degrees of resistance to *R. solani.* With the exception of percent decreases in recoverable sucrose and % purity, the more resistant ACH184 performed significantly better than resistant HH32 or susceptible HM55. Highly resistant breeding line FC 709 was superior to all of the commercial cultivars, and the resistant FCHY was comparable to ACH184. Cultivars HM55 and HH32 were not significantly different in any parameter. Correlation coefficients (Table 4) between DI and percent decreases in yield and purity parameters were positive and highly significant.

Table 3. Differences in disease index (DI) and percent decreases in root yield, recoverable sucrose, % sucrose, and % purity between inoculated and noninoculated treatments in cultivars having varied levels of resistance to *Rhizoctonia solani* in a 1991 field experiment inoculated with *R. solani* AG-2-2.

Cultivar[†]	DI[‡]	Root yield	Recoverable sucrose	Percent sucrose	Percent purity
		% decrease			
HM55	5.4 a[§]	88.0 a	93.2 a	67.5 a	13.2 a
HH32	4.4 a	70.2 a	89.4 ab	59.6 a	8.7 a
ACH184	3.3 b	22.5 b	56.3 bc	32.9 b	8.1 a
FCHY	2.6 b	10.8 bc	32.5 cd	17.0 bc	4.8 ab
FC 709	1.7 c	-4.3 c	12.8 d	14.2 c	1.0 b

[†] HM55, HH32, and ACH184 = susceptible, moderately resistant, and moderately resistant commercial hybrids; FCHY = experimental resistant hybrid FC505CMS/FC708//FC712; FC 709 = resistant breeding line.

[‡] Disease index on a scale of 0 to 7, with 0 = no rot and 7 = plant dead. Data are differences between inoculated and noninoculated treatments.

[§] Means within columns followed by the same letter are not significantly different according to Duncan's multiple range tests at $P = 0.05$.

Table 4. Correlations of differences in disease index versus percent decreases in root yield, recoverable sucrose, % sucrose, and % purity between inoculated and noninoculated treatments across sugarbeet entries in field tests of cultivars having varied degrees of resistance to *Rhizoctonia solani* (AG-2-2).

Year	Root yield	Recoverable sucrose	% sucrose	% purity
1989	0.86**(0.003)	0.85**(0.004)	0.66*(0.05)	0.72*(0.03)
1990	0.58**(0.01)	0.67**(0.004)	0.79**(0.0001)	0.45NS(0.07)
1991	0.88**(0.0001)	0.88**(0.0001)	0.86**(0.0001)	0.68**(0.003)

*,** Significant and highly significant, respectively, at probability levels given in parentheses.

From our preliminary data and larger tests in 1990 and 1991, we concluded that there were no hidden losses in the experimental germplasms due to *R. solani,* as measured in our inoculated experiments. Indeed, the consistent, positive linear relationship between DI differences and percent decreases in yield and quality characters of the five cultivars indicated our resistant germplasms were relatively unaffected by the pathogen.

The performance of our three-way hybrid, FCHY, having two resistant parents in its pedigree, indicated that our germplasm enhancement efforts are producing lines that are approaching commercial acceptance. For example, in 1991, FCHY yielded 44.5 t/ha (19.9 T/A) of roots at 15.9% sucrose, with a purity of 92.6% in the noninoculated plots. In the same test, susceptible HM55 produced 47.7 t/ha (21.3 T/A) roots at 16.1% sucrose, with a purity of 93.2%. In inoculated plots, HM55 yielded 5.2 t/ha (2.3 T/A) versus 38.8 t/ha (17.3 T/A) for FCHY. Introgression of resistance to *R. solani* into all parents of a hybrid would ensure that resultant varieties possess the highest possible degree of quantitative resistance to this ubiquitous pathogen without loss of sugar quality and yield.

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