RHIZOCTONIA SOLANI INOCULUM DENSITY AND SUGARBEET CULTIVAR SUSCEPTIBILITY AFFECT DISEASE ONSET AND DEVELOPMENT

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Rhizoctonia diseases (seedling damping-off and crown and root rot, RCRR), caused by *Rhizoctonia solani* AG 2-2, continue to be among the most common problems on sugarbeet in the Red River Valley and southern Minnesota. Fungicides are available for seed treatment, in-furrow, and postemergence application for control of *Rhizoctonia*, but questions continue to arise about the timing of postemergence applications. Azoxystrobin (Quadris) is effective against RCRR in sugarbeet when applied prior to infection, but is less effective or ineffective after infections have occurred (12). Thus, knowing when infections begin to occur (disease onset) is critical to making timely, effective postemergence fungicide applications.

Rhizoctonia crown and root rot is influenced by soil temperature and moisture. Bolton et al. (1) found that a daily accumulation of 11 growing degree days (GDD) was necessary for infection, and disease developed at a soil moisture holding capacity as low as 25% with enhanced development as soil moisture levels increased. Several studies have evaluated the effect of soil temperature at application of azoxystrobin on control of RCRR (6, 7, 8, and 9). Applications of azoxystrobin at 4-inch soil temperatures ranging from 50 to 73°F resulted in statistically equal disease control and recoverable sucrose per acre, but application at 62 to 67°F tended to give best results in 2003 and 2004 (7,8). This has led to the adoption of a 60-65°F 4-inch soil temperature threshold for applying postemergence fungicides for control of RCRR. However, this threshold is often reached before sugarbeet seedlings emerge, or shortly after emergence when there is not much foliage present for making a postemergence application. In addition, results have not always been consistent. In 2005, Jacobsen et al. (6) reported significant control with azoxystrobin applications at 4-inch soil temperatures up to 80°F, which was higher than in previous years. In Michigan, soil temperature thresholds did not improve efficacy of azoxystrobin applications, and the authors found planting date, seedling development, or leaf stage more reliable indicators of when to apply fungicides (9).

While soil temperature and moisture are clearly important in infection and development of RCRR on sugarbeet, other factors, such as inoculum density and cultivar resistance also may play an important role. There are examples of these in other crops. For the soilborne pathogen *Verticillium dahliae*, higher inoculum densities resulted in earlier disease onset in cauliflower compared to lower inoculum densities (13). Similarly for Fusarium wilt of chickpea, increasing inoculum density of *F. oxysporum* caused an exponential reduction in disease incubation period (10). In peanut, planting moderately resistant varieties delayed onset of epidemics of Cylindocladium black rot (5).

OBJECTIVES

A field trial was established to evaluate the effect of *R. solani* inoculum density and sugarbeet cultivar susceptibility on onset and development of Rhizoctonia damping-off and crown and root rot.

MATERIALS AND METHODS

The trial was established at the University of Minnesota, Northwest Research and Outreach Center (NWROC), Crookston. A factorial set of treatments (*R. solani* inoculum density x cultivar susceptibility x irrigation) was set up in a split-plot design with four replicates. Inoculum density treatments included 0, 20, 40, and 60 kg ha^{-1} *R. solani*-infested whole barley grain broadcast in plots and worked into the top 4 inches of soil with a Melroe multiweeder prior to planting on May 4. Cultivars included a resistant, moderate, and susceptible. Mean 2-year Rhizoctonia root rot ratings from 2013-2014 American Crystal Sugar Company tests were 3.4, 4.0, and 5.3 for the resistant, moderately resistant, and susceptible cultivars, respectively (11). Seed was sown at a 4.5-inch spacing into 6-row plots that were 25 ft long with 22-inch row spacing. Counter 20G (8 lb A^{-1}) was applied at planting for control of root maggot and 22 oz A^{-1} glyphosate (4.5 lb product ae/gallon) was applied May 28, June 16 and 23, and August 17

for control of weeds. Plots were split and rows 2 and 3 were irrigated with trickle-tape for 7 hours on July 2 and 5 hours on August 14. Cercospora leaf spot was controlled by Supertin + Topsin M (6 + 7.5 oz product in 17 gallons of water/A) applied with 8002 flat fan nozzles at 90 psi on August 3.

The center four rows of each plot were counted six times beginning 22 days after planting through August 21. The center two rows of plots were harvested September 14. Data were collected for number of harvested roots, yield, and quality. Row 3 data was used to represent irrigated rows and row 4 data was used for non-irrigated rows. Ten roots from each of rows 3 and 4 also were arbitrarily selected and rated for severity of RCRR using a 0 to 7 scale (0 = healthy root, 7 = root completely rotted and foliage dead).

Data were subjected to analysis of variance and orthogonal polynomial contrasts for comparison of main effects of inoculum density, cultivar susceptibility, and irrigation, and all possible interactions using SAS Proc GLM (SAS Institute, Cary, NC).

RESULTS

Analysis of stand count data demonstrated significant (P = 0.05) linear effects for both inoculum density and cultivar susceptibility for all stand counts beginning June 5 (4 ½ weeks after planting) and significant (P = 0.05) inoculum density by cultivar interactions only for the August 21 stand count. Effects of inoculum and cultivar on stand are summarized in Fig. 1. For all varieties, emergence reached its highest by June 12. By June 4, the daily mean 4-inch soil temperature surpassed 60°F and stayed above that threshold through the rest of the stand count dates. Emergence and stands were similar for all inoculum densities for the resistant and moderately resistant cultivars (Fig. 1A and 1B) through June 5 and for the susceptible cultivar (Fig. 1C) only at the May 26 stand count. For all cultivars, stand in non-inoculated controls remained steady throughout the growing season (Fig. 1). There was a significant linear effect of inoculum density on stand for the resistant and moderately resistant cultivars beginning June 12 through the rest of the season and for the susceptible cultivar beginning June 5 through the rest of the season. Stand continued to decline in inoculated plots through the rest of the season, but at a greater rate as cultivar susceptibility increased so that on August 21 there was a significant (P = 0.05) inoculum density by cultivar interaction (Fig. 1). Irrigation did not significantly affect stand counts (data not shown).

There were no significant (P = 0.05) inoculum density by cultivar interactions for Rhizoctonia crown and root rot rating at harvest, root, or sucrose yields (Table 1). There were significant linear and quadratic responses to inoculum density for all parameters at harvest (Table 1). Disease increased and yield parameters decreased as inoculum density increased up to 40 kg ha^{-1}, but leveled off at 60 kg ha^{-1}, illustrated for Rhizoctonia crown and root rot rating and sucrose yield in Fig. 2. There was a significant effect of cultivar on disease levels at harvest and root and sucrose yields (Table 1). The resistant and moderately resistant cultivars had lower Rhizoctonia crown and root rot ratings and higher root yield and recoverable sucrose A^{-1} than the susceptible cultivar (Table 1). The resistant cultivar had higher percent sucrose and sucrose ton^{-1} compared to the moderately resistant and susceptible cultivars (Table 1). Irrigation did not significantly (P = 0.05) affect any harvest parameters and was not involved in any interaction (data not shown).

DISCUSSION

Mean 4-inch soil temperatures were above 60°F beginning May 26 (22 days after planting), dipped below 60°F from May 29 to June 3, and then continued to stay above 60°F for the rest of the growing season (Fig. 1). Rainfall at the NWROC was 2.6, 3.7, 5.0, and 1.1 inches in May, June, July, and August, respectively. These conditions were excellent for sugarbeet emergence and conducive for Rhizoctonia damping-off and crown and root rot. The first irrigation of subplots was on July 2. Shortly after, on July 5, 2.16 inches of rain was received, effectively eliminating any extra disease pressure from the irrigation event. With 5 inches of rainfall in July, there was no need to irrigate again until the middle of August when plants were larger and not as susceptible. As a result, there was no significant effect of irrigation on plant stands or any of the harvest parameters.

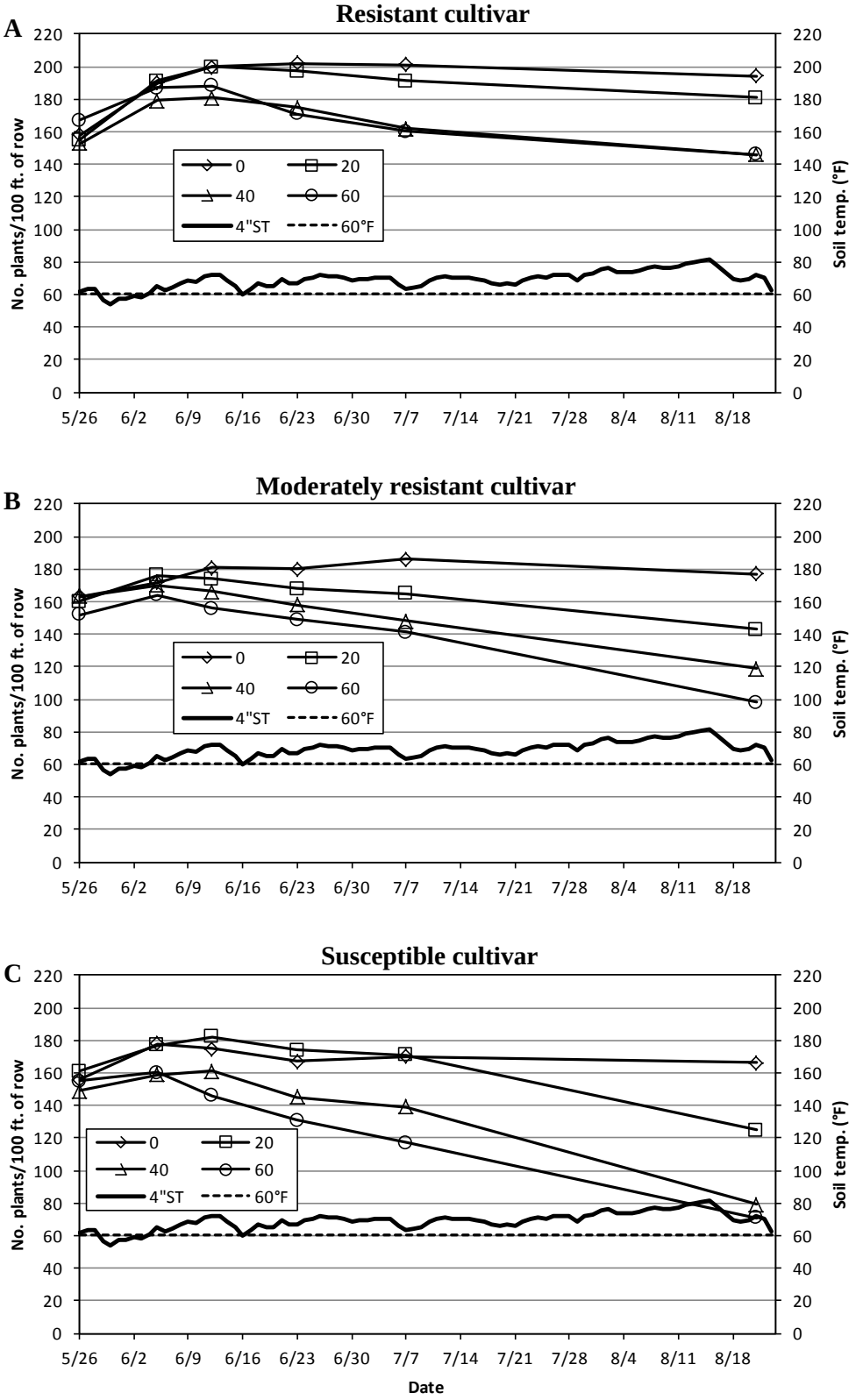

Fig. 1. Plant stand in a field trial sown May 4 for sugarbeet **A**) resistant, **B**) moderately resistant, and **C**) susceptible to Rhizoctonia crown and root rot in plots infested with *Rhizoctonia solani* at inoculum densities of 0, 20, 40, and 60 kg ha^{-1} and the mean 4-inch soil temperature (4"ST) from Eldred, MN NDAWN station. The dotted line shows 60 °F soil temperature threshold for favorability for *R. solani*-infection. Each symbol for the stand counts represents the mean of 8 plots (four replicate plots across two irrigation treatments). For stand count on August 21, there was a significant (P = 0.05) inoculum rate by cultivar interaction.

Table 1. Rhizoctonia crown and root rot, root and sugar yield for sugarbeet sown May 4, 2015 with a resistant, moderately resistant, and susceptible cultivar in a field infested with various inoculum densities of *Rhizoctonia solani*.

Main effect[W]	RCRR (0-7)	Root yield (ton A^{-1})	Sucrose yield		
			%	lb ton^{-1}	lb A^{-1}
Inoculum[X]					
0 (non-inoculated)	0.9	23.5	15.8	288	6693
20	2.9	17.5	14.4	260	4612
40	4.2	12.7	14.0	249	3226
60	4.2	14.1	14.4	257	3670
Linear[Y]	***	***	***	***	***
Quadratic[Y]	***	**	**	**	***
Cultivar					
Resistant	2.2 b	18.1 a	15.4 a	282 a	5094 a
Moderately resistant	2.9 b	19.7 a	14.5 b	259 b	5167 a
Susceptible	4.1 a	13.0 b	13.9 b	249 b	3389 b
LSD (P = 0.05)[Z]	0.7	3.4	-	-	926
Inoculum x cultivar[WY]	NS	NS	NS	NS	NS

[W] There were no significant (P = 0.05) inoculum rate by cultivar interactions, so main effects of inoculum rate and cultivar are shown separately.

[X] *Rhizoctonia solani*-infested whole grain barley inoculum was broadcast in plots at 0, 20, 40, and 60 kg ha^{-1} and worked into the top 4 inches of soil with a Melroe multiweeder prior to planting.

[Y] Response to inoculum rate and inoculum by cultivar interactions were tested using orthogonal polynomial contrasts; NS = not significant, * = significant at P = 0.05, ** = significant at P = 0.01, *** = significant at P = 0.001.

[Z] Cultivar response was tested using ANOVA and Fisher's Protected Least Significant Difference (P = 0.05); for each column, numbers sharing the same letter are not significantly different; for percent sucrose and recoverable sucrose per ton, there were missing values for quality data since one plot had no harvestable roots and mean separations are based on 95% confidence intervals.

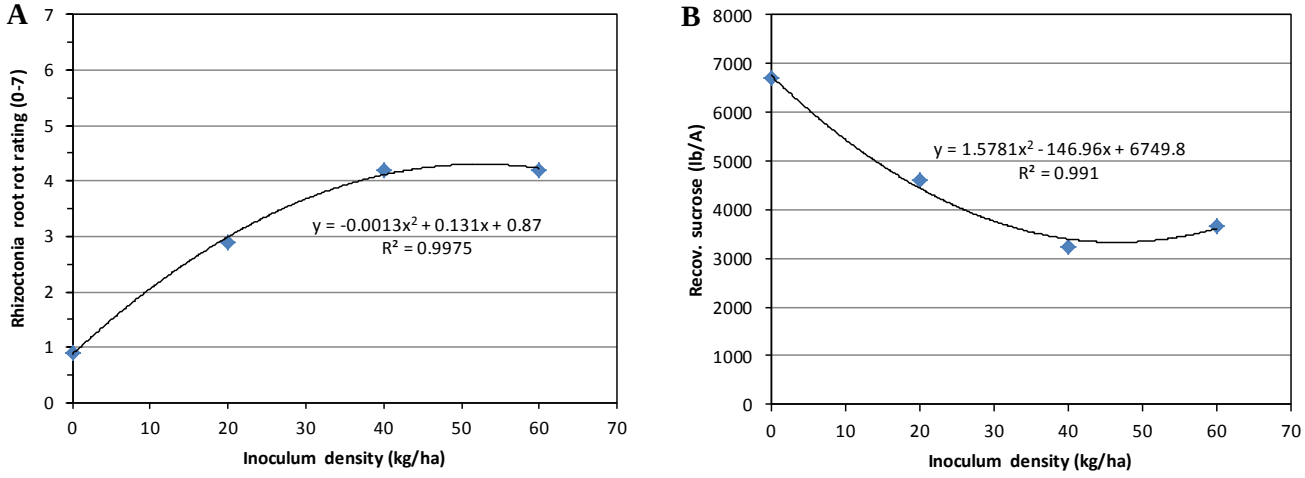

Fig. 2. Illustration of quadratic effect of *Rhizoctonia solani* inoculum density (0, 20, 40, and 60 kg ha^{-1}) on **A**) Rhizoctonia crown and root rot rating and **B**) sucrose yield (lb A^{-1}) in a field trial sown May 4. Data points in **A** represent the mean of 240 roots (10 roots per subplot x 4 replicate plots across 3 cultivars and 2 irrigation treatments). Data points in **B** represent the mean of 24 plots (4 replicate plots across 3 cultivars and irrigated and non-irrigated subplots. Quadratic effect of inoculum density on root rot rating and recoverable sucrose A^{-1} was significant at P = 0.001.

In an infested field trial planted May 19, 2010, inoculum density of 35 kg ha^{-1} *R. solani*-infested barley resulted in ~30% stand reduction over 4 weeks compared to non-inoculated plots (4). Similarly, in another infested field trial planted May 21, 2015, inoculum density of 35 kg ha^{-1} *R. solani*-infested barley resulted in ~28% stand reduction over 4 weeks and 66% stand reduction after 5 weeks compared to infested plots treated in-furrow with Quadris. In these late planted trials, plants were still small and very susceptible when warm soil conditions occurred for infection. By comparison, in this trial planted May 4, stand reduction compared to the non-inoculated plots for the susceptible variety after 4 weeks was 1, 11, and 10% for inoculum densities of 20, 40, and 60 kg ha^{-1}, respectively. These results are similar to this same trial planted May 9, 2013 (2), where stand reduction compared to the non-inoculated plots for the susceptible cultivar after 4 weeks was 3, 11, and 16% for inoculum densities of 20, 40, and 60 kg ha^{-1}, respectively. Similarly, in the trial planted May 1, 2012 (3), stand reduction compared to the non-inoculated plots for the susceptible cultivar after 4 weeks was 0, 13, and 6% for inoculum densities of 20, 40, and 60 kg ha^{-1}, respectively. These trials demonstrate the benefit of planting early in protecting seedlings from the severe stand loss that can occur when conditions are favorable while plants are still small and very susceptible. The big difference among these three trials is the severity of disease later in the season during 2015 where stand loss for the susceptible cultivar at August 21 was 25, 52, and 57% for inoculum densities of 20, 40, and 60 kg ha^{-1}, respectively. This was likely due to the favorable conditions provided by the 5 inches of rainfall in July.

A major objective of this trial was to determine the onset of disease for the different inoculum densities and cultivars. In this trial, significant effects of inoculum density on stand began at June 5 (4 ½ weeks after planting) for the susceptible cultivar and at June 12 (5 ½ weeks after planting) for the resistant and moderate cultivars. Similar to previous trials, the effect of inoculum rate on stand gradually accumulated throughout the growing season. These early and cumulative effects of inoculum density on emergence, stand, and harvest emphasize the importance of full-season control, including an at-planting treatment such as seed or in-furrow fungicide. These results, however, do not explain the late disease onset observed in some of our past field trials and in growers' fields where disease has not begun until late in the season and at-planting treatments have not provided significant benefit. Perhaps pathogen populations in some growers' fields were lower than the lowest rate in this trial and took time to increase before reaching a level where sugarbeet infection occurred. Additionally, soil type, previous crop residue, or other environmental factors may influence disease onset.

The susceptibility of the sugarbeet cultivar to Rhizoctonia affected emergence and stand throughout the growing season. Emergence was complete by 5 ½ weeks after planting, and the resistant cultivar had highest stand followed by the moderate cultivar, while the susceptible cultivar had lowest stand. Even though these stand differences remained throughout the growing season, root rot ratings, yield, and recoverable sucrose were comparable for the resistant and moderate cultivars. This is likely due to the higher yield potential of the moderately resistant cultivar compared to the resistant cultivar. In American Crystal Sugar Company's 2013 and 2014 official variety trials, the two-year mean for yield of the resistant, moderately resistant, and susceptible cultivars was 25.7, 26.9, and 25.8 ton A^{-1}, respectively (11). Although there were no significant interactions between inoculum density and sugarbeet cultivar for harvest parameters, moderately resistant and resistant cultivars outperformed the susceptible cultivar across all inoculum densities.

Knowing the field history is an important step in controlling Rhizoctonia. Growers and agricultural staff should track levels of Rhizoctonia crown and root rot on the previous sugarbeet crop and whether host crops have been in the rotation since the last sugarbeet crop. For those fields with a past history of Rhizoctonia, sugarbeet growers who choose a variety with a higher level of resistance to *R. solani* can expect less RCRR and less reduction in stand, yield, and recoverable sugar. Alternatively, growers that choose a susceptible variety will need a full-season control strategy including an at-planting (seed or in-furrow) and postemergence fungicide.

ACKNOWLEDGEMENTS

We thank the Sugarbeet Research and Education Board of Minnesota and North Dakota for funding this research; Hilleshog for providing seed; the University of Minnesota, NWROC, Crookston for providing land, equipment, and other facilities; Jeff Nielsen for plot maintenance; Tim Cymbaluk, Brandon Kasprick, Katie Sheetz, and Irwin Sylvah for technical assistance; and American Crystal Sugar Company, East Grand Forks, MN for quality analysis.

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