SEED AND IN-FURROW FUNGICIDES ON A RESISTANT AND SUSCEPTIBLE VARIETY WITH AND WITHOUT POSTEMERGENCE QUADRIS FOR CONTROL OF *RHIZOCTONIA* ON SUGARBEET

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Rhizoctonia damping-off and crown and root rot (RCRR) caused by *Rhizoctonia solani* AG 2-2 have been the most common root diseases on sugarbeet in Minnesota and North Dakota for several years (1-3). Disease can occur throughout the growing season and reduces plant stand, root yield, and quality. Control options include rotating with non-host crops (cereals), planting partially resistant varieties, planting early when soil temperatures are cool, cultivating and draining soil, and applying fungicides as seed treatments, in-furrow (IF), or postemergence. An integrated management strategy should take advantage of multiple control options to reduce Rhizoctonia crown and root rot.

OBJECTIVES

A field trial was established to evaluate an integrated management strategy consisting of a resistant and a susceptible variety with seed treatment or in-furrow fungicides alone and in combination with a postemergence Quadris application for 1) control of early-season damping-off and RCRR and 2) effect on yield and quality of sugarbeet. A growth room trial also was conducted to evaluate efficacy of seed treatments used in the field trial in controlling damping-off under controlled conditions favorable for disease.

MATERIALS AND METHODS

Field trials. The trial was established at three locations, one at the University of Minnesota, Northwest Research and Outreach Center, Crookston, another near St. Thomas, ND, and a third near Foxhome, MN. All locations were fertilized for optimal yield and quality. At each location, a combination of a resistant and susceptible variety with each fungicide seed treatment (applied by Germains Seed Technology, Fargo, ND) and in-furrow treatment shown in Table 1 was planted in four replicate plots in a randomized complete block design. In-furrow treatments were applied using a t-band with a nozzle directly behind the disc openers with 30 psi and 6 gallons total volume A^{-1}. Each variety by at-planting treatment combination was planted in duplicate, so that at 5 to 6 weeks after planting, one plot of each variety by at-planting fungicide treatment combination received a postemergence 7-inch band application of Quadris (14.3 fl oz A^{-1}) while one was left as a stand-alone treatment. Controls for each variety included no seed or in-furrow fungicide treatment at planting with and without postemergence Quadris. Two-year average Rhizoctonia ratings in American Crystal Sugar Company tests for the resistant and susceptible varieties were 3.4 and 4.9, respectively (4). Counter 20G (9 lb A^{-1}) was applied at planting for control of sugarbeet root maggot and 3 gallons A^{-1} starter fertilizer (10-34-0) was applied across all treatment combinations.

NWROC site. Prior to planting, soil was infested with *R. solani* AG 2-2-infested whole barley (35 kg ha^{-1}). The trial was sown in six-row plots (22-inch row spacing, 30-ft rows) on May 10 at 4.5-inch seed spacing. Glyphosate (4.5 lb product ae/gallon) was applied on May 29, June 13, and July 8 (22 oz A^{-1}) for control of weeds. Postemergence application of Quadris was made on June 19 (40 days after planting). Cercospora leafspot was controlled by application of Headline (9 oz product) in 20 gallons of water A^{-1} with a tractor-mounted sprayer with TeeJet 8002 flat fan nozzles at 100 psi on August 21.

St. Thomas site. The trial was sown in a field naturally infested with *R. solani* in six-row plots (22-inch row spacing, 30-ft rows) on June 3 at 4.5-inch seed spacing. Despite application of 9 lb A^{-1} Counter 20G at planting and two postemergence Lorsban applications by the grower cooperator, late planting created poor timing for peak root maggot fly counts while seedlings were young, and the site was lost due to severe root maggot damage.

Table 1. Application type, product names, active ingredients, and rates of fungicides used at planting in field trials for control of *Rhizoctonia solani* AG 2-2 on sugarbeet. Each at-plant treatment was used in combination with a Rhizoctonia resistant and susceptible variety, and all treatment combinations were duplicated, with one set receiving a postemergence 7-inch band application of Quadris (14.3 fl oz A^{-1}).

Application	Product	Active ingredient	Rate
None	-	-	-
Seed	Metlock	Metconazole + Rizolex	0.21 + 0.5 g a.i./unit seed
Seed	Penthiopyrad	Penthiopyrad	14 g a.i./unit seed
In-furrow	Headline	Pyraclostrobin	12 fl oz product A^{-1}
In-furrow	Quadris	Azoxystrobin	14.3 fl oz product A^{-1}
In-furrow	Vertisan	Penthiopyrad	28.5 fl oz product A^{-1}

Foxhome site. The trial was sown in six-row plots (22-inch row spacing, 30-ft rows) on May 16 at 4.5-inch seed spacing. Glyphosate (4.5 lb product ae/gallon) tank-mixed with AMS (8.5 lbs A^{-1}) and Fusilade DX (12 oz A^{-1}) was applied on June 13. This weed control application was repeated again on July 1 (less the graminicide). Postemergence application of Quadris was made on June 24 (39 days after planting). Cercospora leafspot was controlled by separate applications of Inspire (7 oz A^{-1}) on July 25 and TPTH/Topsin (5 & 7.6 oz A^{-1}, respectively) on August 9. All fungicides for CLS control were applied utilizing a UTV-mounted sprayer dispersing the products in broadcast pattern at a water volume of 15 GPA with TeeJet 8002 flat fan nozzles at 80 psi.

Stand counts were done beginning 2 weeks after planting through 7 weeks after planting. The trial was harvested September 19 at the NWROC and October 1 at Foxhome. Data were collected for number of harvested roots (NWROC only), yield, and quality. Twenty roots per plot 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 using SAS Proc GLM (SAS Institute, Cary, NC) for main effects of variety, at-plant treatment, postemergence Quadris application, and all possible interactions.

Growth room trials. The same seed treatment fungicides tested in the field were evaluated under controlled environment conditions in a growth room. Seed (16 seed/10 x 10 x 10 cm pot) was sown at a 2-cm depth in natural field soil infested with *R. solani* AG 2-2 intraspecific group IIIB at a rate of 35 kg ground infested barley ha^{-1} (≈35 mg/700 cc soil/pot). Soil was watered thoroughly and pots were incubated at ≈77 °F for 4 weeks.

Emerged seedlings were counted three times weekly. Dying seedlings were removed and assayed in the laboratory to determine cause of death. Necrotic portions of hypocotyls and roots were rinsed in 0.5% sodium hypochlorite, rinsed twice with deionized water, and placed in quad-portioned petri dishes with ≈5 ml deionized ultra-filtered water. Hypocotyls were microscopically examined after 48 hr to verify presence of *R. solani* or other soilborne pathogens.

After 4 weeks, remaining plants were gently removed from soil, washed, and rated on a 0 to 3 scale where 0 = no disease and 3 = dead seedling. The number of plants that died during the 4 week assay and root rot ratings were used to calculate a root rot index (0-100 scale; 0 = no disease, 100 = all plants died during the assay).

RESULTS

NWROC field trial site: There were no interactions for stand data so main effects of variety and at-planting treatments are illustrated in Fig. 1. Emergence was good for both varieties, but was a little slower for the resistant variety (Fig. 1A). At 18 days after planting, stand was significantly ($P = 0.05$) lower for the resistant variety than the susceptible variety, but stands from 25 to 48 days after planting were not significantly different between varieties (Fig. 1A). Emergence and stand was significantly ($P = 0.05$) affected by at-planting fungicide treatment (Fig. 1B). Stand from 18 to 48 days after planting was lowest in plots treated with Quadris in-furrow, intermediate in plots treated with Headline in-furrow, and highest for all other treatments (Fig. 1B).

NWROC site

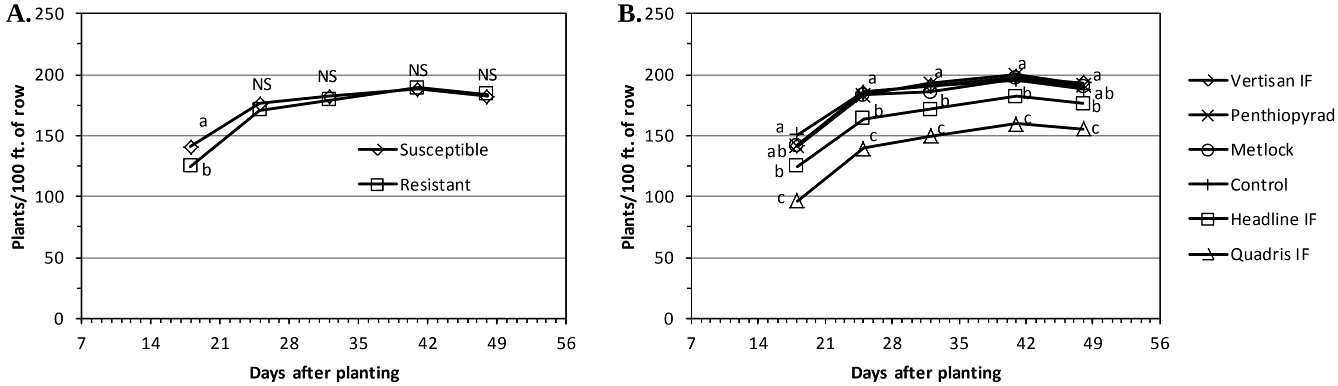

Fig. 1. Stand from the NWROC site for **A**) resistant and susceptible sugarbeet varieties and **B)** sugarbeet treated with various fungicides for control of *Rhizoctonia solani* either on seed or in-furrow (IF). For each stand count date, values followed by the same letter are not significantly different (P = 0.05); NS = not significantly different. Data shown in **A** represent mean of 48 plots averaged across at-planting and postemergence treatments and in **B** represent mean of 16 plots averaged across varieties and postemergence treatments.

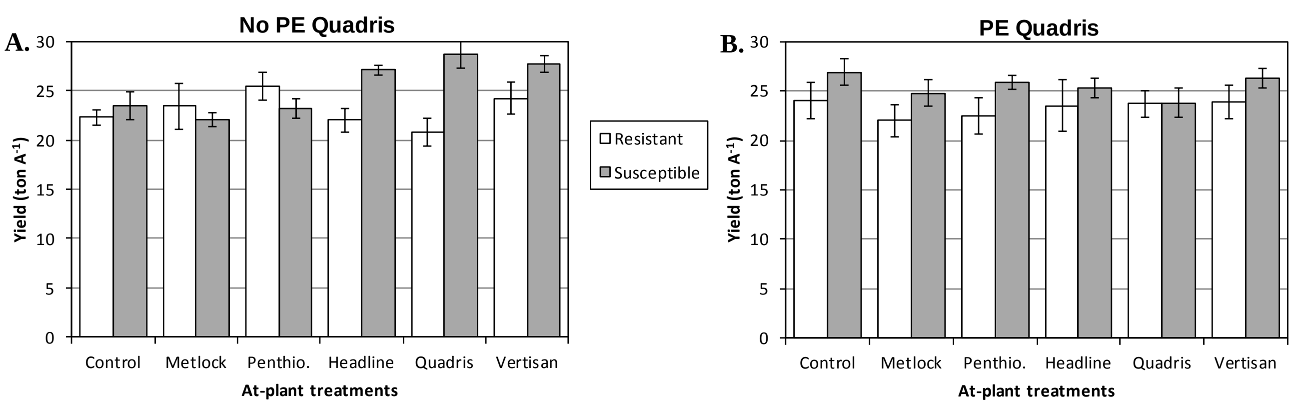

Fig. 2. Yield of Rhizoctonia resistant and susceptible sugarbeet varieties with different fungicides for control of *Rhizoctonia solani* on seed or in-furrow when **A**) no postemergence Quadris was applied and **B**) postemergence Quadris was applied on June 19, 40 days after planting. Bars represent the mean of 4 replicate plots. Error bars are plus and minus one standard error.

There was a significant three-way (variety x at-plant treatment x postemergence treatment) interaction for yield and recoverable sucrose A^{-1} illustrated for yield in Fig. 2. The interaction was similar for both yield and recoverable sucrose. When no postemergence Quadris was applied, the susceptible variety benefited from the in-furrow fungicide applications but not the seed treatments (Fig. 2A). When postemergence Quadris was applied, however, in-furrow fungicides did not benefit either variety and yields were fairly uniform across at-planting treatments (Fig. 2B).

There were no other interactions for harvest parameters, and main effects are summarized in Table 2. The middle and later portions of the growing season were very dry, resulting in very low disease pressure. In the absence of disease pressure, there were no differences between varieties in root rot rating, percent sucrose, or recoverable sucrose ton^{-1}, and the susceptible variety had significantly higher number of harvested roots, yield and recoverable sucrose A^{-1} (Table 2). There were significant differences among at-planting treatments for number of harvested roots but not for RCRR ratings, yield, and quality variables (Table 2). Number of harvested roots was reduced in plots treated with Quadris in-furrow compared to all other treatments and for plots treated with Headline in-furrow compared to plots treated with Vertisan. Postemergence Quadris application did not significantly affect harvest parameters other than its involvement in the interaction described above. Root rot rating was significantly lower (P = 0.05) in Quadris-treated plots compared to plots without Quadris (Table 2), but the difference was not biologically meaningful.

Table 2. **NWROC:** Main effects of variety, at-planting (seed or in-furrow), and post-emergence fungicide treatments on Rhizoctonia crown and root rot and sugarbeet yield and quality. Significant variety by at-planting by postemergence treatment interaction is illustrated in Fig. 2.

Treatment and rate (Allegiance + Thiram on all)	No. harv. roots/100 ft[W]	RCRR (0-7)[X]	Yield ton A^{-1}	Sucrose %	Sucrose lb ton^{-1}	Sucrose lb A^{-1}
Variety						
Resistant	157	1.4	23.1	16.0	297	6862
Susceptible	166	1.4	25.4	16.1	300	7631
ANOVA p-value	0.018	0.618	<0.0001	0.219	0.251	<0.0001
At-planting treatments						
Untreated control	165 ab	1.3	24.1	16.0	297	7177
Metlock suite @ 0.21 + 0.5 g a.i./unit[Y]	164 ab	1.4	23.1	16.0	297	6878
Penthiopyrad @14 g a.i./unit	164 ab	1.4	24.3	16.1	300	7272
Headline @ 12 fl. oz./A	157 b	1.4	24.5	16.2	302	7389
Quadris @ 14.3 fl. oz./A	142 c	1.3	24.2	15.9	297	7175
Vertisan @ 28.5 fl. oz./A	175 a	1.3	25.5	16.0	297	7588
ANOVA p-value	<0.0001	0.137	0.157	0.712	0.813	0.190
LSD (*P* = 0.05)	12.5	NS	NS	NS	NS	NS
Postemergence fung.						
None	160	1.4	24.2	16.0	297	7186
Quadris @ 14.3 fl. oz./A	158	1.3	24.4	16.1	300	7307
ANOVA p-value	0.238	0.049	0.704	0.448	0.377	0.441
Interactions[Z]						
Vty. x At-plant trmt.	NS	NS	NS	NS	NS	NS
Vty. x PE fung.	NS	NS	NS	NS	NS	NS
At-plant x PE	NS	NS	NS	NS	NS	NS
Vty. x At-plant x PE	NS	NS	**	NS	NS	*

W Numbers followed by the same letter are not significantly different; LSD = Least Significant Difference, *P* = 0.05.
X RCRR = Rhizoctonia crown and root rot; 0-7 scale, 0 = root clean, no disease, 7 = root completely rotted and plant dead.
Y Metlock suite = metconazole + rizolex @ 0.21 + 0.5 g a.i./unit.
Z * = significant at *P* = 0.05, ** = significant at *P* = 0.01, NS = not significantly different

Foxhome field trial site. Emergence and stand establishment were excellent for all treatments. There was a significant variety by at-planting treatment interaction for stand at 40 and 48 days after planting illustrated in Fig. 3. On the resistant variety Quadris in-furrow resulted in the highest stands 40 and 48 days after planting (Fig. 3A), while in the susceptible variety, Quadris was the second lowest for stand at 40 and 48 days after planting (Fig. 3B). In general, stands were significantly (*P* = 0.05) higher for the susceptible variety than the resistant variety from 13 to 48 days after planting.

At harvest there was a significant variety by at-planting treatment interaction for RCRR rating (Table 3), but no other significant interactions. Main effects of variety, at-planting, and postemergence treatments are summarized in Table 3. The variety by at-planting treatment interaction is evident by a uniform and low RCRR rating for all at-planting treatments on the resistant variety, but some significant differences among at-planting treatments on the susceptible variety (Table 3). On the susceptible variety, RCRR ratings were significantly lower for plots treated with Quadris in-furrow compared to all other treatments except Vertisan in-furrow, which was intermediate (Table 3). There was a significant main effect of variety on all harvest parameters (Table 3). The resistant variety had higher yield, percent sucrose, recoverable sucrose ton^{-1}, and recoverable sucrose A^{-1} (Table 3). There were no significant (*P* = 0.05) differences among at-planting treatments for any harvest parameters (Table 3). Postemergence application of Quadris had no significant effect on RCRR rating or root and sucrose yield (Table 3).

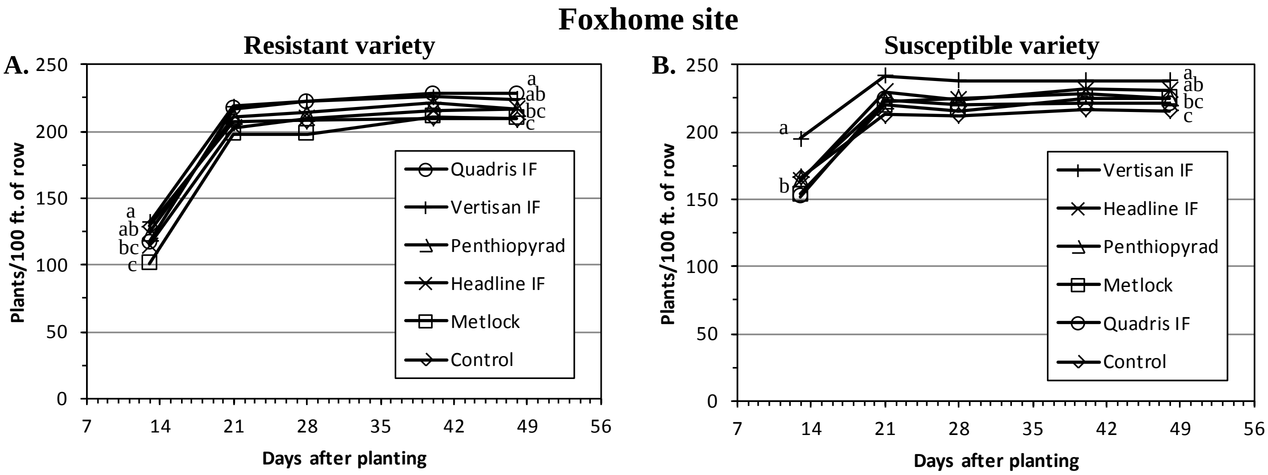

Fig. 3. Stand from the Foxhome site for **A**) resistant and **B)** susceptible sugarbeet varieties treated with various fungicides for control of *Rhizoctonia solani* either on seed or in-furrow (IF). At 13 and 48 days after planting, values followed by the same letter are not significantly different (*P* = 0.05). Data shown in **A** and **B** represent mean of 8 plots averaged across postemergence treatments.

Table 3. **Foxhome:** Main effects of variety, at-planting (seed or in-furrow), and post-emergence fungicide treatments on Rhizoctonia crown and root rot (RCRR) and sugarbeet yield and quality. Resistant and susceptible varieties are shown separately for RCRR due to significant variety by at-planting interaction.

Treatment and rate (Allegiance + Thiram on all)	RCRR (0-7)[WX]		Yield ton A^{-1}	Sucrose %	Sucrose lb ton^{-1}	Sucrose lb A^{-1}
Variety						
Resistant	1.2		25.8	16.2	273	7060
Susceptible	1.3		24.0	15.7	266	6396
ANOVA p-value	<0.0001		<0.0001	<0.0001	<0.0018	<0.0001
At-planting treatments	Resistant	Susceptible				
Untreated control	1.2	1.4 ab	25.0	16.1	271	6789
Metlock suite @ 0.21 + 0.5 g a.i./unit[Y]	1.2	1.4 a	24.2	15.9	267	6474
Penthiopyrad @14 g a.i./unit	1.1	1.5 a	25.2	15.9	269	6786
Headline @ 12 fl. oz./A	1.1	1.4 a	24.8	16.0	270	6718
Quadris @ 14.3 fl. oz./A	1.1	1.1 c	25.4	16.0	270	6869
Vertisan @ 28.5 fl. oz./A	1.2	1.2 bc	25.1	15.8	268	6732
ANOVA p-value	0.400	0.0001	0.355	0.833	0.926	0.468
LSD (*P* = 0.05)	NS	0.14	NS	NS	NS	NS
Postemergence fung.						
None	1.3		25.0	16.0	269	6748
Quadris @ 14.3 fl. oz./A	1.2		24.9	15.9	270	6708
ANOVA p-value	0.098		0.616	0.788	0.845	0.726
Interactions[Z]						
Vty. x At-plant trmt.	*		NS	NS	NS	NS
Vty. x PE fung.	NS		NS	NS	NS	NS
At-plant x PE	NS		NS	NS	NS	NS
Vty. x At-plant x PE	NS		NS	NS	NS	NS

W Numbers followed by the same letter are not significantly different; LSD = Least Significant Difference, *P* = 0.05.

X RCRR = Rhizoctonia crown and root rot; 0-7 scale, 0 = root clean, no disease, 7 = root completely rotted and plant dead.

Y Metlock suite = metconazole + rizolex @ 0.21 + 0.5 g a.i./unit.

Z * = significant at *P* = 0.05, NS = not significantly different.

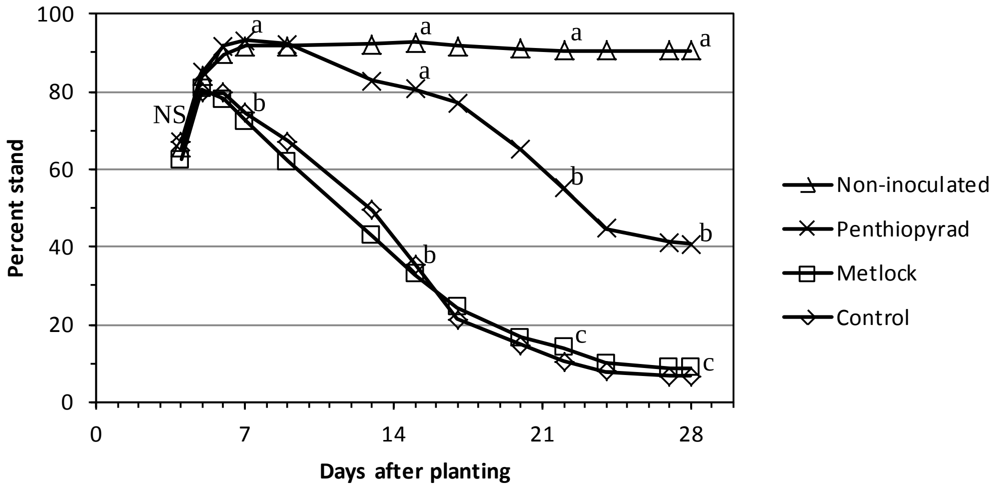

Fig. 4. Percent stand of sugarbeet treated with various fungicides compared to an untreated control (all seed was treated with metalaxyl + Thiram). Seed was planted into a natural field soil infested with *Rhizoctonia solani* AG 2-2 ground barley grain at 35 kg ha^{-1} (≈35 mg/ 700 cc soil/pot) and incubated at ≈77 °F for 4 weeks. Stands at 4, 7, 15, 22, and 28 days after planting that are followed by the same letter are not significantly different (P = 0.05); NS = not significantly different.

Growth room trials. Emergence was excellent for treated seed and the untreated control (Fig. 4). Stand began declining for the untreated control and Metlock-treated seed by 7 days after planting, and stands were significantly higher for penthiopyrad-treated seed and the non-inoculated control. Stand for the penthiopyrad-treated seed began to decline at 13 days after planting, but at a slower rate than the untreated control. Final stands 28 days after planting were 91, 41, 9, and 7% for the non-inoculated control, penthiopyrad-treated seed, Metlock-treated seed, and untreated control, respectively. Root rot indices were lowest for the non-inoculated control (5) followed by penthiopyrad-treated seed (63) and highest for Metlock-treated seed (92) and the untreated control (94).

DISCUSSION

The 2013 growing season at the NWROC began cool and wet, but was extremely dry for the middle and late parts of the growing season. Rainfall for July and August in 2013 was 0.92 and 1.28 inches respectively, compared to 30-year averages of 3.16 and 3.12, respectively. As a result, disease pressure was very low, at-planting and postemergence treatments for Rhizoctonia did not affect sugarbeet yield or quality, and the susceptible variety performed better than the resistant variety. Mean Rhizoctonia crown and root rot ratings ranged from 1.3 to 1.4 on a 0-7 scale. These ratings are much too low to reduce sugarbeet yield and quality.

Similarly, at Foxhome, the 2013 growing season began cool and wet and ended drier than normal. Total rainfall for May and June was 7.5 inches compared to the North Dakota Agricultural Weather Network normal of 6.5 inches. During July and August, however, total rainfall was 2.4 inches compared to the normal of 5.6 inches. There was some minor disease pressure at Foxhome, but it was very patchy. Mean Rhizoctonia crown and root rot ratings ranged from 1.1 to 1.2 for the resistant variety and from 1.1 to 1.5 for the susceptible variety. In contrast to the NWROC site, at Foxhome the resistant variety significantly outperformed the susceptible variety in both sugarbeet yield and quality indicating at least some effect of Rhizoctonia crown and root rot pressure. Two-year (2011-2012) means from American Crystal Sugar Company variety trials for yield were 25.4 and 25.6 and for percent sucrose were 17.58 and 17.53 for the resistant and susceptible varieties, respectively (4).

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