INTEGRATED MANAGEMENT OF RHIZOCTONIA ON SUGARBEET WITH RESISTANT VARIETIES, AT-PLANTING TREATMENTS, AND POSTEMERGENCE FUNGICIDES, 2020

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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 (1,2). These diseases can occur throughout the growing season and reduce plant stand, root yield, and quality (3-7). Warm and wet soil conditions favor infection by *R. solani*. Disease management options include rotating with non-host crops (cereals), planting partially resistant varieties, planting early when soil temperatures are cool, improving soil drainage, and applying fungicides as seed treatments, in-furrow (IF), or postemergence. An integrated approach involving multiple strategies should help managing Rhizoctonia crown and root rot (4-7).

OBJECTIVES

Field trials were established to evaluate an integrated management strategy consisting of a resistant (R) and a moderately susceptible (MS) variety with at-panting treatments alone and in combination with two different postemergence azoxystrobin application timings for 1) control of early-season damping-off and RCRR and 2) effect on plant stand, yield and quality of sugarbeet.

MATERIALS AND METHODS

The field trial was established at three locations: (1) University of Minnesota, Northwest Research and Outreach Center, Crookston, (2) Minn-Dak Farmers Cooperative, Wahpeton (MDFC), ND, (3) Southern Minnesota Beet Sugar Cooperative (SMBSC), Renville, MN. All locations were fertilized for optimal yield and quality. At each location, a combination of a resistant (R) and moderately susceptible (MS) varieties treated with fluxapyroxad (Systiva), in-furrow azoxystrobin (Quadris) on fluxapyroxad (Systiva), or untreated seed was planted in four replicate plots (Table 1). An additional treatment consisting of in-furrow azoxystrobin on untreated seed was included at the NWROC site. Plots were set up in a split-split plot design at all 3 locations. Main plots were varieties, the first split was at-panting treatments, and the last split was postemergence azoxystrobin timings. Systiva was used at 5 g ai/unit seed and applied by Germains Seed Technology, Fargo, ND. Each variety by at-planting treatment combination was planted in triplicate, so that at the 4- or 8-leaf stage, one plot of each variety by at-planting treatment combination received a postemergence 7-inch band application of azoxystrobin (14.3 fl oz product A^{-1}) while one was left as a stand-alone treatment. Controls for each variety included no at-planting treatment with each postemergence azoxystrobin timing and without postemergence azoxystrobin. Two-year average Rhizoctonia ratings in American Crystal Sugar Company tests for the resistant and moderately susceptible varieties were 3.7 and 4.4, respectively (8).

NWROC site. Prior to planting, soil was infested with a mixture of four isolates of *R. solani* AG 2-2-infested whole barley broadcast at 50 kg ha^{-1} and incorporated with a Rau seedbed finisher. The trial was sown in six-row plots (22-inch row spacing, 30-ft rows) on May 19 at 4.5-inch seed spacing. Counter 20G (8.9 lb/A) was applied at planting and Lorsban (2 pt/A) was applied on June 05 for control of root maggot. Roundup Power Max (28 oz/A) on Jun 2, Sequence (glyphosate + S-metolachlor, 2.5 pt/A) + Roundup (8 oz/A) was applied on June 19 and Roundup Power Max (28 oz/A) on Jul 29 for control of weeds. Postemergence azoxystrobin was applied in a 7-inch band in 10 gallon/A using 4002 nozzles and 34 psi on June 12 (4-leaf stage, ~3.5 weeks after planting) or June 25 (8-leaf stage, ~5 weeks after planting). Cercospora leaf spot (CLS) was controlled by Minerva Duo (16 fl oz/A) on Aug 04 and Super Tin (8 oz) + Proline (5 oz/A) on Aug 24 applied in 20 gallons water/A at 100 psi. The trial was harvested on Sept 21.

MDFC site. Prior to planting, soil was infested with a mixture of four isolates of *R. solani* AG 2-2-infested whole barley (50 kg ha^{-1}). The trial was sown in six-row plots (22-inch row spacing, 25-ft rows) on May 21 at 4.5-inch seed spacing. Dual Magnum (0.5 pt/A) + Ethofumesate 4SC (2 pt/A) was applied PRE on May 21. A tank-mix of Roundup PowerMax (5.5 lb product ae/gallon), N-tense (10 fl oz/A), Outlook (12 fl oz/A), and Ethofumesate 4SC (4 fl oz/A) was applied on June 19 and Outlook (12 fl oz/A) was applied on June 30. Postemergence azoxystrobin was applied in a 7-inch band on June 17 (5-leaf stage, 3 WAP) or June 24 (8-leaf stage, 4 WAP). Cercospora leaf spot was controlled by application of Provysol + Badge SC (5 oz/A+2 pt/A) on Jul 2, AgriTin + Manzate (8 fl oz/A+52 fl oz/A) on Jul 10, Proline 480 SC + Badge SC + Prefer 90 (5.7 fl oz/A+2 pt/A+0.125% v/v) on Jul 20, AgriTin + Manzate (8 fl oz/A+52 fl oz/A) on Jul 27, Inspire + Badge SC (7 fl oz/A+2 pt/A) on Aug 8, AgriTin + Manzate (8 fl oz/A+52 fl oz/A) on Aug 19, and Badge SC (4 pt/A) on Sept 2. All fungicides for CLS control were applied utilizing a 3pt-mounted sprayer dispersing the products in broadcast pattern at a water volume of 20 GPA with TeeJet 11002 air induction nozzles at 40 psi. The trial was harvested on Sept 29.

Table 1. Application type, product names, active ingredients, and rates of fungicides used at planting in a field trial for control of *Rhizoctonia solani* AG 2-2 on sugarbeet. Each at-plant treatment was used in combination with a Rhizoctonia resistant (2-year average rating = 3.7) and moderately susceptible (2-year average rating = 4.4) variety, and all treatment combinations in triplicate, with one set receiving a postemergence 7-inch band application of azoxystrobin (14.3 fl oz A^{-1}) at 4- or 8-leaf stage. Standard rates of Apron + Thiram and 45 g/unit Tachigaren were on all seed.

Application	Product	Active ingredient	Rate
None	-	-	-
Seed	Systiva	Fluxapyroxad	5 g a.i./unit seed
In-furrow	Quadris	Azoxystrobin	9.5 fl oz product A^{-1}

Table 2. Monthly precipitation in inches at three sites during 2020 crop season based on weather stations.

	Precipitation in inches		
Month	NWROC	MDFC	SMBSC
April	1.92	2.05	0.19
May	1.00	0.91	0.55
June	4.52	2.98	4.15
July	7.52	6.35	2.94
August	3.02	3.59	4.07
September	0.44	0.88	1.69
October	0.49	0.86	0.99
Total	**18.91**	**17.62**	**14.58**

SMBSC site. Prior to planting, soil was infested with a mixture of four isolates of *R. solani* AG 2-2-infested whole barley (50 kg ha^{-1}). The trial was sown in six-row plots (22-inch row spacing, 35-ft rows) on May 07 at 4.77-inch seed spacing. Inoculum was incorporated using the 8.5 foot field cultivator followed by a drag. Weeds were controlled using a preemergence application of Dual Magnum (0.5 pt/A) plus Norton (2 pt/A) and by postemergence applications of Roundup PowerMax (32 oz/A) on Jun 03 followed by Sequence (2.5 pts/A) on Jun 12 and Jun 23. Postemergence azoxystrobin timings were applied on June 09 (4-leaf, ~5 weeks after planting), or June 22 (8-leaf, ~6.5 weeks after planting) as 7 inch bands using 4001E nozzles at 35 psi. Cercospora leaf spot was managed by fungicide applications of Agritin + Dithane on Jul 03, Inspire XT + Dithane on Jul 13, SuperTin + Dithane on Jul 22, Minerva + Badge on Aug 03, SuperTin + Dithane on Aug 18, and Provysol + Dithane on Aug 27. All fungicides for CLS control were applied in a water volume of 21 GPA with 110025 nozzles at 50 psi. The trial was harvested on Sept 16.

At NWROC stand counts were done beginning 2 weeks after planting through 11 weeks after planting. At MDFC stand counts were done 2, 3.5, 4 and 5 weeks after planting. At SMBSC stand counts were done 3, 5, and 7 weeks after planting (WAP). Data were collected for number of harvested roots (NWROC and SMBSC), yield, and quality. Twenty roots per plot also were arbitrarily selected and rated for severity of RCRR using a 0 to 10 scale with 10%

increment for each point (0 = 0%, healthy root; 10 = 100%, root completely rotted). Disease incidence was reported as the percent of rated roots with a root rot rating > 0.

Data were subjected to analysis of variance using SAS Proc GLM (SAS Institute, Cary, NC) for main effects of variety, at-plant treatment, postemergence azoxystrobin application, and all possible interactions. Means were separated by Fisher's Protected Least Significant Difference (*P* = 0.05).

RESULTS AND DISCUSSION

NWROC site: Early part of the 2020 growing season was dry at the NWROC during the period of May – early June resulting in lower early season disease pressure. Rainfall at the NWROC was just 1.00 in. during the month of May compared to a 30-year average of 2.44. Resistant (R) and moderately susceptible (MS) varieties had similar stands from 2 to 11 weeks after planting (WAP). AT 2, 3 and 5 WAP, Systiva, Systiva + Quadris in-furrow (I-F) had higher stands followed by untreated + Quadris I-F and lowest for untreated control plots. At 4 and 6 to 11 WAP, Systiva and Systiva + Quadris I-F had higher stands followed by Systiva and untreated + Quadris I-F and lowest for untreated plots. Quadris in-furrow application caused some stand loss whereas Quadris I-F on Systiva treated seed did not show this stand reduction in 2020. Control plants had 165 plants/100 ft. row at 4.5 WAP indicating low early season disease pressure. Stand reduction with Quadris was also observed in 2017 to 2019 (4-6). Very low root rot severity and incidence were observed for both varieties at harvest. Moderately susceptible variety had significantly lower percent sucrose and higher recoverable sucrose A^{-1} (RSA) (Table 3). Significant variety by postemergence treatment interaction was observed for RSA (Table 3). Both 4- and 8-leaf postemergence applications resulted in higher RSA for both varieties but susceptible variety had much higher recovery of RSA compare to the resistant variety (Fig. 2). A significant at-plant by postemergence treatment interaction was observed for root rot severity and incidence, root yield and RSA (Table 3). Both 4- and 8-leaf postemergence applications on untreated seed, Systiva, and Systiva + Quadris I-F resulted in higher RSA with more RSA recovery on untreated and Systiva seed compared to Systiva + Quadris I-F treatment (Fig. 3). Both 4- and 8-leaf postemergence applications resulted in lower root rot with 8-leaf stage better compared to the 4-leaf stage (Fig. 4).

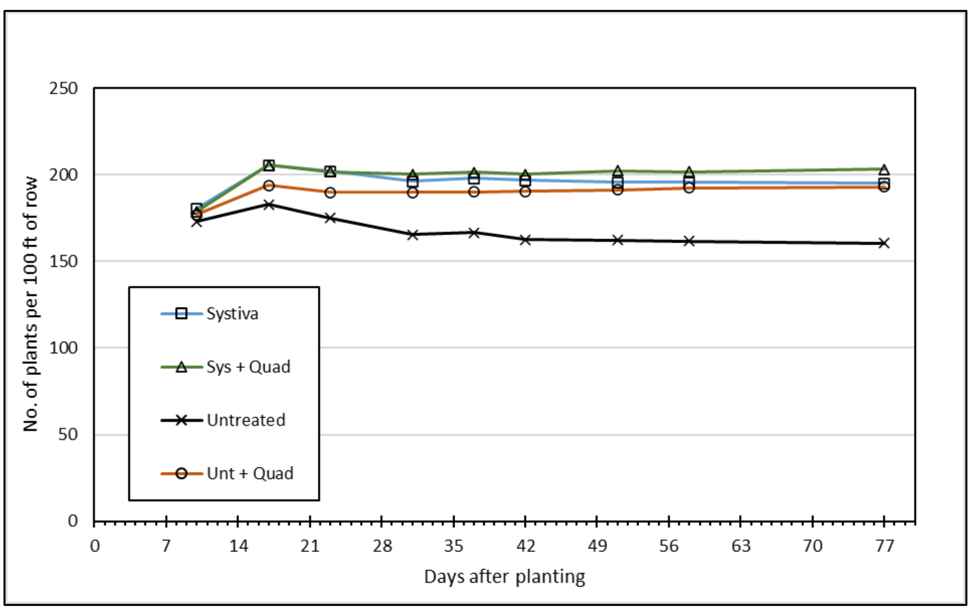

Fig. 1. NWROC site: Emergence and stand establishment for fungicide treatments at-planting or untreated control. Statistical significance of data at each timepoint was discussed in the text. Data shown represents mean of 24 plots averaged across varieties and postemergence treatments.

Table 3. **NWROC site:** Main effects of variety, at-planting, and postemergence fungicide treatments on Rhizoctonia crown and root rot and sugarbeet yield and quality in a field trial sown May 16, 2019.

Main effect (Apron + Maxim on all seed)	No. harv. roots/100 ft[T]	RCRR (0-10)[TU]	RCRR % incidence[TV]	Yield ton A^{-1}[T]	Sucrose[T] %	Sucrose[T] lb ton^{-1}	Sucrose[T] lb A^{-1}
Variety[W]							
Resistant	160	0.75	20	22.5 b	18.5 a	347	7809 b
Moderately Susceptible	167	1.04	22	27.0 a	17.9 b	335	9048 a
ANOVA p-value	0.1998	0.2003	0.5228	0.0011	0.0452	0.0553	0.0016
At-planting treatments[X]							
Untreated control	144 c	1.35 b	27 b	24.2 bc	18.1	338	8155
Systiva	163 b	1.31 b	29 b	23.9 c	18.1	340	8108
Quadris In-furrow	171 a	0.58 a	18 a	25.4 ab	18.2	340	8596
Systiva + Quadris I-F	175 a	0.33 a	10 a	25.7 a	18.4	346	8857
ANOVA p-value	<0.0001	<0.0001	0.0002	0.0371	0.1731	0.1547	0.0063
LSD (*P* = 0.05)	7.7	0.3	7.8	1.4	NS	NS	448
Postemergence fungicide[Y]							
None	155 b	1.8 c	38 c	23.5 b	18.0 b	337 b	7921 b
4-leaf Quadris	169 a	0.7 b	18 b	25.2 a	18.3 a	343 a	8626 a
8-leaf Quadris	165 a	0.2 a	8 a	25.6 a	18.3 a	343 a	8739 a
ANOVA p-value	<0.0001	<0.0001	<0.0001	0.0002	0.0367	0.0460	<0.0001
LSD (*P* = 0.05)	5.2	0.24	4.0	0.98	0.20	4.7	332
Vty x at-plant	0.3200	0.1404	0.2079	0.9551	0.7743	0.7949	0.9188
Vty x Post	**0.0184**	0.2702	0.9188	0.0748	0.3426	0.3392	**0.0251**
At-plant x Post	**0.0015**	**<0.0001**	**<0.0001**	**0.0171**	0.1986	0.2448	**0.0019**
Vty x At-plant x Post	0.4754	0.3439	0.4536	0.6947	0.5382	0.6292	0.5773

[T] Numbers followed by the same letter are not significantly different; LSD = Least Significant Difference, *P* = 0.05; NS = not significantly different

[U] RCRR = Rhizoctonia crown and root rot; 0-7 scale (adjusted rating), 0 = root clean, no disease, 10 = root completely rotted and plant dead

[V] RCRR = Rhizoctonia crown and root rot; percent of roots with rating greater than two

[W] Values represent mean of 48 plots (4 replicate plots across 4 at-planting treatments and 3 postemergence treatments)

[X] Systiva @ 5 g a.i /unit and Quadris In-furrow @ 9.5 fl oz./A via drip tube; Values represent mean of 24 plots (4 replicate plots across 2 varieties and 3 postemergence treatments)

[Y] Quadris Postemergence @ 14.5 fl oz./A in a 7 inch band; Values represent mean of 24 plots (4 replicate plots across 2 varieties and 3 at-planting treatments)

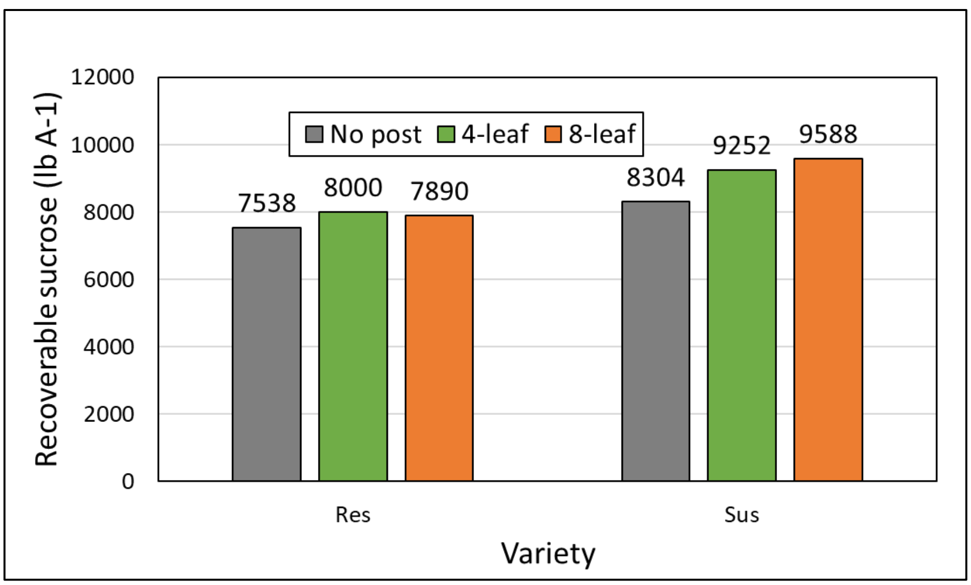

Fig. 2. NWROC site: Effect of variety and postemergence (PE) treatment interaction on recoverable sucrose. Data shown represents mean of 16 plots averaged across at-planting treatments.

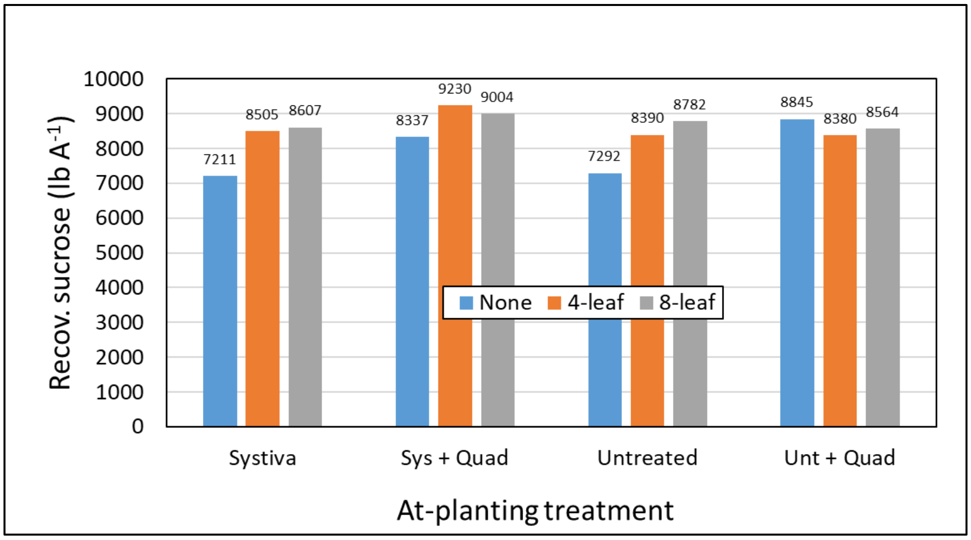

Fig. 3. NWROC site: Effect of at-panting and postemergence (PE) treatment interaction on recoverable sucrose. Data shown represents mean of 8 plots averaged across varieties.

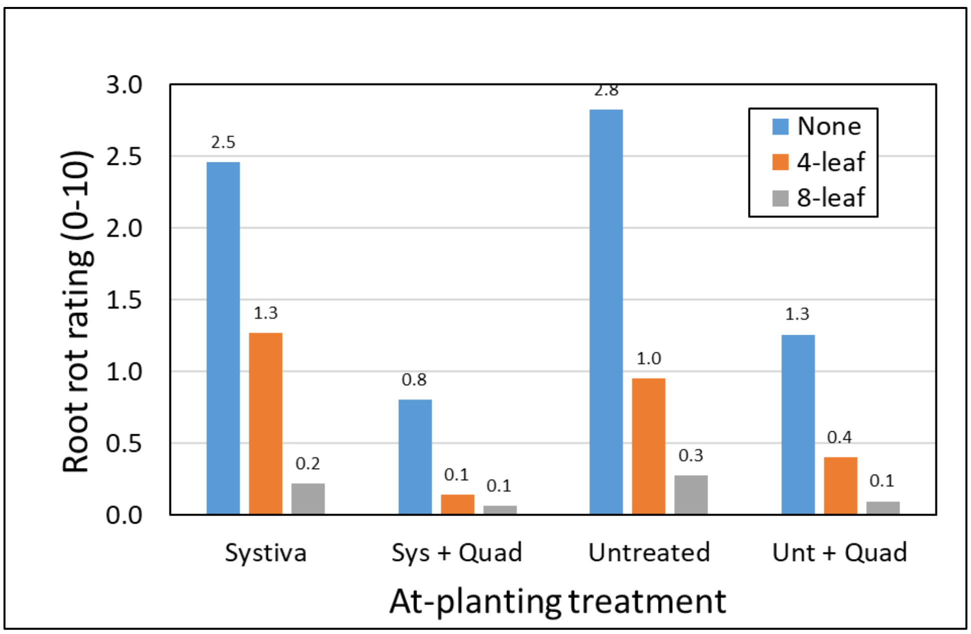

Fig. 4. NWROC site: Effect of at-panting and postemergence (PE) treatment interaction on Rhizoctonia root rot rating. Data shown represents mean of 8 plots averaged across varieties.

MDFC site: The Rhizoctonia disease pressure at this site was none to very low from planting until harvest and no statistical differences were observed for stand counts or harvest parameters except stands at 3 WAP were higher for the susceptible variety, root rot rating and % tare were lower at harvest for the susceptible variety, and purity was higher for the susceptible variety (Table 4). Variety x at-plant x postemergence treatment 3-way interaction was observed for root rot rating (Table 4).

Table 4. **MDFC site:** Main effects of variety, at-planting, and postemergence fungicide treatments on Rhizoctonia crown and root rot and sugarbeet yield and quality in a field trial sown May 31, 2019.

Main effect (Apron + Maxim on all seed)	RCRR (0-10) [TU]	RCRR % incidence[TV]	Purity	% Tare	Yield ton A^{-1} [T]	Sucrose[T]		
						%	lb ton^{-1}	lb A^{-1}
Variety[W]								
Resistant	0.3 b	11	89.7	1.7	29.4	17.5	298	8755
Moderately Susceptible	0.2 a	8	90.3	1.1	31.3	17.5	299	9359
ANOVA p-value	**0.0393**	0.0531	**0.0132**	**0.0036**	0.1803	0.7040	0.8305	0.1445
At-planting treatments[X]								
Untreated control	0.2	10	90.2	1.2	30.8	17.5	299	9219
Systiva	0.3	11	89.9	1.5	29.7	17.5	298	8856
Systiva + Quadris I-F	0.2	9	90.0	1.4	30.3	17.5	298	9056
ANOVA p-value	0.7056	0.7673	0.7725	0.9060	0.1959	0.8933	0.8384	0.4351
LSD (*P* = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Postemergence fungicide[Y]								
None	0.2	10	90.0	1.4	30.3	17.5	298	9044
4-leaf Quadris	0.2	10	90.0	1.4	30.4	17.5	298	9069
8-leaf Quadris	0.2	10	90.0	1.3	30.5	17.5	299	9115
ANOVA p-value	0.1259	0.2052	0.9213	0.3773	0.4089	0.8024	0.8391	0.5009
LSD (*P* = 0.05)	NS	NS		NS	NS	NS	NS	NS
Vty x At-plant	0.1576	0.3811	0.3979	0.8450	0.2074	0.8491	0.9540	0.3983
Vty x Post	0.2104	0.1825	0.8085	0.7519	0.3821	0.7036	0.9162	0.3126
At-plant x Post	0.1088	0.0331	0.5281	0.2075	0.0732	0.0673	0.1157	0.0340
Vty x At-plant x Post	**0.0238**	0.3939	0.9668	0.0975	0.4165	0.9882	0.9893	0.5402

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

U RCRR = Rhizoctonia crown and root rot; 0-10 scale (adjusted rating), 0 = root clean, no disease, 10 = root completely rotted and plant dead

V RCRR = Rhizoctonia crown and root rot; percent of roots with rating greater than two

W Values represent mean of 36 plots (4 replicate plots across 3 at-planting treatments and 3 postemergence treatments)

X Systiva @ 5 g a.i /unit and Quadris In-furrow @ 9.5 fl oz./A via drip tube; Values represent mean of 24 plots (4 replicate plots across 2 varieties and 3 postemergence treatments)

Y Quadris Postemergence @ 14.5 fl oz./A in a 7 inch band; Values represent mean of 24 plots (4 replicate plots across 2 varieties and 3 at-planting treatments)

SMBSC site: Good rainfall during June resulted in moderate disease pressure early in the season (Table 2). Resistant variety had higher stands at 3, 5, and 7 WAP compared to moderately susceptible variety (Fig. 5) but the difference is not statistically significant (Fig. 5). Systiva and Systiva + Quadris I-F had higher stands at 3, 5, and 7 WAP compared to untreated control treatment (Fig. 6). Untreated control had 165 plants/100 ft. row at 7 WAP indicating moderate early season disease pressure at this site and hence Systiva and Systiva + Quadris I-F had 198 and 205 plants/100 ft. row, respectively (Fig. 6). In contrary to 2018 observations (4), Quadris I-F did not reduce stands at this site in 2020 which is very similar to 2019 observation. Some rainfall during July and normal rainfall during August (Table 2) resulted in moderate late season disease pressure at this site. Resistant variety had higher % sucrose and RST and lower root rot severity and incidence compared to the susceptible variety (Table 5). Both 4- and 8-leaf postemergence application resulted in lower root rot severity and incidence, higher % sucrose and RST compared to no postemergence control (Table 5). A significant variety by postemergence treatment interaction was observed for root yield and RSA

(Table 5). Wile both varieties responded to 4- or 8-leaf application, the benefit was higher for the susceptible variety as the genetic resistance to Rhizoctonia is weak in this variety. Both 4- and 8-leaf applications resulted in increase in RSA by about 1700 lbs/A for the resistant variety and about 2800 lbs/A for the susceptible variety (Fig 7). Similar benefit from postemergence Quadris application at this location was also evident in 2016 to 2019 (4-7). Both 4- and 8-leaf applications resulted in increase in root yield by 5 tons/A for the resistant variety and 10 tons/A for the susceptible variety (Fig 8). This trial clearly demonstrates the importance of choosing a resistant variety and use of postemergence fungicides for managing Rhizoctonia diseases in the southern MN growing area.

Table 5. **SMBSC site:** Main effects of variety, at-planting, and postemergence fungicide treatments on Rhizoctonia crown and root rot and sugarbeet yield and quality in a field trial sown May 14, 2019.

Main effect (Apron + Maxim on all seed)	RCRR (0-10) [TU]	RCRR % incidence[TV]	Yield ton A^{-1}[T]	Sucrose[T] %	Sucrose[T] lb ton^{-1}	Sucrose[T] lb A^{-1}
Variety[W]						
Resistant	1.09 a	26 a	30.3	12.2 a	243 a	7414
Moderately Susceptible	1.99 b	41 b	34.0	11.5 b	229 b	7769
ANOVA p-value	<0.0001	0.0004	0.0884	0.0216	0.0231	0.4401
At-planting treatments[X]						
Untreated control	1.54	32	31.3	11.9	238	7509
Systiva	1.80	39	31.7	12.0	234	7478
Systiva + Quadris I-F	1.28	30	32.7	11.8	237	7788
ANOVA p-value	0.1891	0.1580	0.0960	0.8060	0.8028	0.4569
LSD (*P* = 0.05)	NS	NS	NS	NS	NS	NS
Postemergence fungicide[Y]						
None	3.1 b	61 c	27.1 b	10.9 b	219 b	5927 b
4-leaf Quadris	1.0 a	25 b	34.3 a	12.2 a	244 a	8348 a
8-leaf Quadris	0.5 a	15 a	34.4 a	12.3 a	247 a	8499 a
ANOVA p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
LSD (*P* = 0.05)	0.5	7.7	1.3	0.5	10	484
Vty x at-plant	0.1870	0.2210	0.4080	0.2770	0.2730	0.2300
Vty x Post	0.3650	0.3090	**0.0003**	0.1540	0.1620	**0.0050**
At-plant x Post	0.9640	0.1990	0.9540	0.8920	0.9040	0.8640
Vty x at-plant x Post	0.9750	0.5460	0.8390	0.3250	0.3580	0.4942

[T] Numbers followed by the same letter are not significantly different; LSD = Least Significant Difference, *P* = 0.05; NS = not significantly different

[U] RCRR = Rhizoctonia crown and root rot; 0-10 scale (adjusted rating), 0 = root clean, no disease, 10 = root completely rotted and plant dead

[V] RCRR = Rhizoctonia crown and root rot; percent of roots with rating greater than two

[W] Values represent mean of 36 plots (4 replicate plots across 3 at-planting treatments and 3 postemergence treatments)

[X] Systiva @ 5 g a.i /unit and Quadris In-furrow @ 9.5 fl oz./A via drip tube; Values represent mean of 24 plots (4 replicate plots across 2 varieties and 3 postemergence treatments)

[Y] Quadris Postemergence @ 14.5 fl oz./A in a 7 inch band; Values represent mean of 24 plots (4 replicate plots across 2 varieties and 3 at-planting treatments)

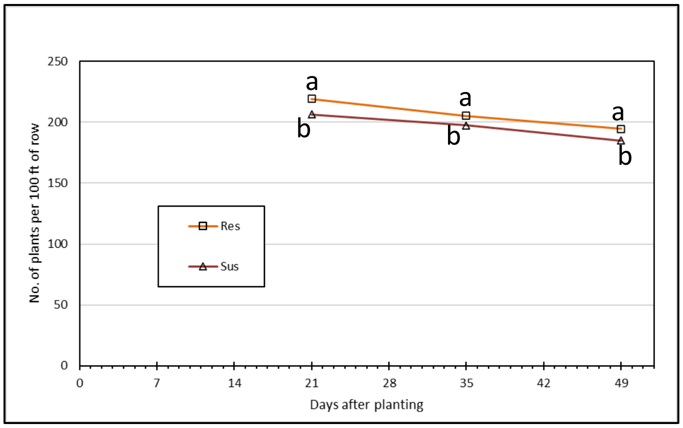

Fig. 5. SMBSC site: Emergence and stand establishment for resistant and moderately susceptible varieties. For each stand count date, values sharing the same letter are not significantly different (*P* = 0.05). Data shown represents mean of 36 plots averaged across at-planting and postemergence treatments.

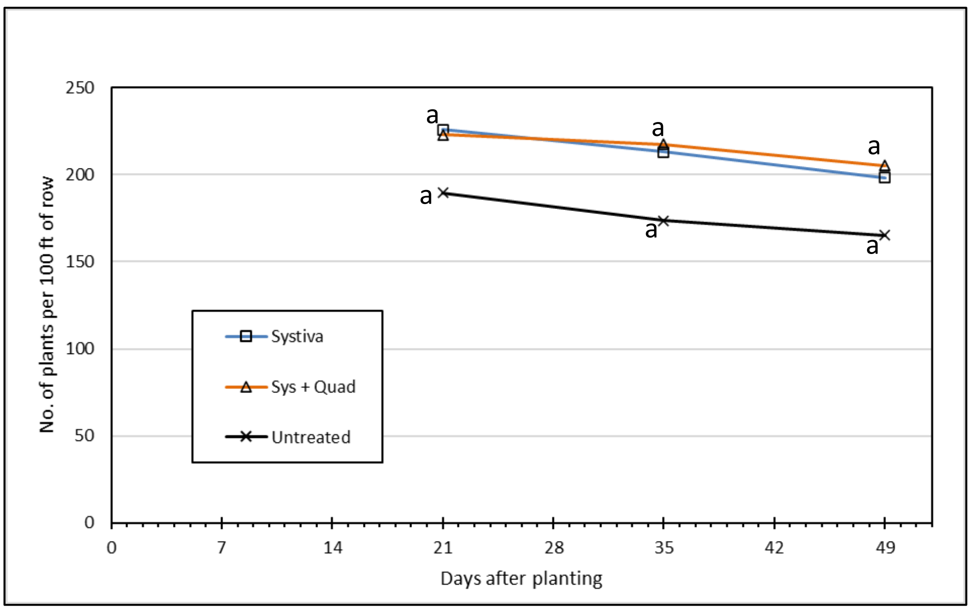

Fig. 6. SMBSC site: Emergence and stand establishment for the at-planting treatments. For each stand count date, values sharing the same letter are not significantly different (*P* = 0.05). Data shown represents mean of 24 plots averaged across varieties and postemergence treatments.

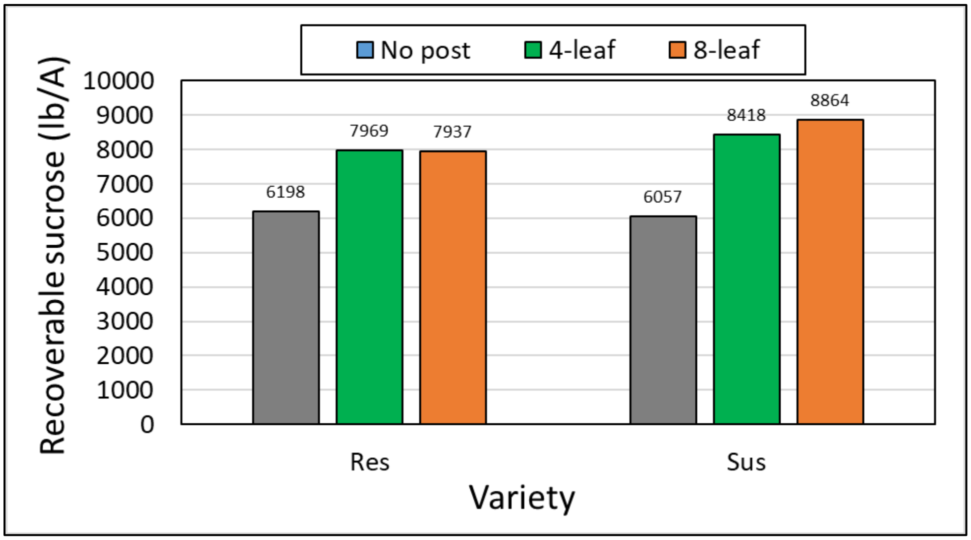

Fig. 7. SMBSC site: Effect of postemergence application on recoverable sucrose. Data shown represents mean of 12 plots averaged across varieties and at-planting treatments.

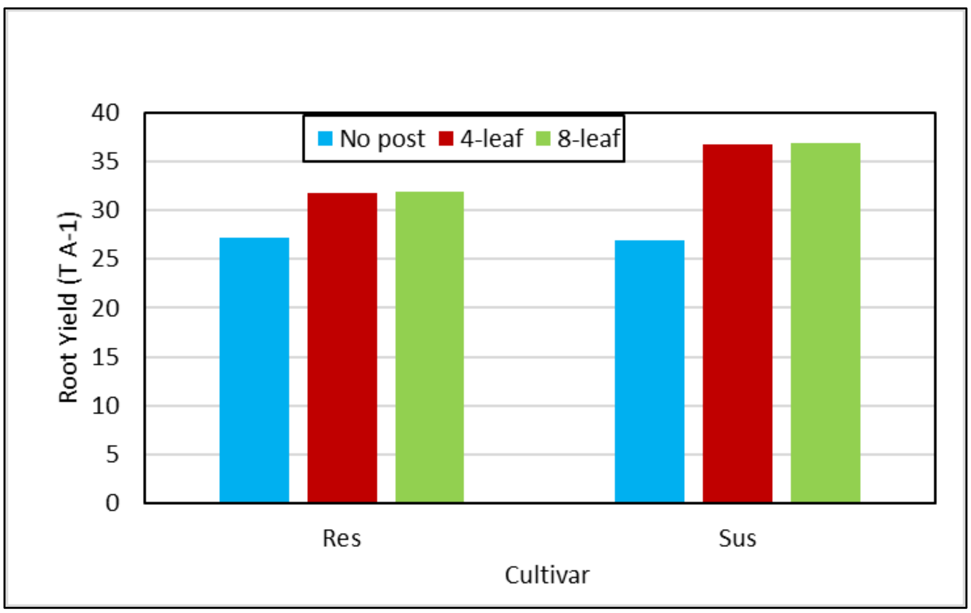

Fig. 8. SMBSC site: Effect of postemergence application on root yield. Data shown represents mean of 12 plots averaged across varieties and at-planting treatments.

ACKNOWLEDGEMENTS

We thank the Sugarbeet Research and Education Board of Minnesota and North Dakota for funding this research; BASF and Syngenta for providing products; Crystal Beet Seed for providing seed; Germains Seed Technology for treating seed; staff from the Minn-Dak Farmers Cooperative for plot maintenance and harvest at the Wahpeton site; staff from the Southern Minnesota Beet Sugar Cooperative for plot maintenance and harvest at the Renville site; the University of Minnesota, Northwest Research and Outreach Center, Crookston for providing land, equipment and other facilities; Jeff Nielsen for plot maintenance; Hal Mickelson, Donny, Anke, and Kenan for technical assistance; Minn-Dak Farmers Cooperative, Wahpeton, ND for the Wahpeton site sugarbeet quality analysis; Southern Minnesota Beet Sugar Cooperative, Renville, MN for the Renville site sugarbeet quality analysis; and American Crystal Sugar Company, East Grand Forks, MN for NWROC site sugarbeet quality analysis.

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