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

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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). Disease can occur throughout the growing season and reduces plant stand, root yield, and quality (3). Warm and wet soil conditions favor infection. 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 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 (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 yield and quality of sugarbeet.

MATERIALS AND METHODS

The trial was established at three locations, one at the University of Minnesota, Northwest Research and Outreach Center, Crookston, one at Wahpeton (MDFC), ND and one at Renville (SMBSC), MN. All locations were fertilized for optimal yield and quality. At each location, a combination of a R and MS variety treated with fluxapyroxad (Systiva), in-furrow azoxystrobin (Quadris), or untreated was planted in four replicate plots. 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 R and MS varieties were 4.0 and 4.8, respectively (6).

NWROC site. Prior to planting, soil was infested with *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 04 at 4.5-inch seed spacing. Counter 20G (8.9 lb/A) was applied at planting and Lorsban (1 pt/A) was applied on June 4 for control of root maggot. Sequence (glyphosate + S-metolachlor, 2.5 pt/A) was applied on May 24 and glyphosate (4.5 lb product ae/gallon) was applied on May 31 and June 19 (28 oz/A), and July 9 (32 oz/A) for control of weeds. Postemergence azoxystrobin timings were applied in a 7-inch band in 10 gallon/A using 4002 nozzles and 34 psi on June 4 (4-6 leaf stage, ~4.5 weeks after planting) or June 19 (8-10 leaf stage, ~6.5 weeks after planting). Cercospora leaf spot was controlled by Supertin + Topsin M (6 + 10 oz/A) on August 2 applied in 17 gallons water/A with 8002 flat fan nozzles at 90 psi.

MDFC site. Prior to planting, soil was infested with *R. solani* AG 2-2-infested whole barley (50 kg ha^{-1}). The trial was sown in six-row plots (22-inch row spacing, 30-ft rows) on May 24 at 4.5-inch seed spacing. Roundup PowerMax (5.5 lb product ae/gallon) tank-mixed with N-tense (10 oz A^{-1}) and Outlook (18 oz A^{-1}) was applied on June 22.

Postemergence azoxystrobin was applied in a 7-inch band on June 26 (4-leaf stage, 4 weeks after planting) or July 6 (8-leaf stage, 5.5 weeks after planting). Cercospora leafspot was controlled by separate applications of Inspire XT + Badge SC (7 oz A^{-1} & 16 oz A^{-1}, respectively) on July 24, Super Tin + Manzate (8 fl. oz A^{-1} & 51.2 fl. oz A^{-1}, respectively) on Aug 07, Minerva + Manzate (13 fl oz A-1 & 38.4 oz A-1 on Aug 17, and Super Tin + Badge SC (8 fl oz. A^{-1} & 32 oz A^{-1}) on Aug 29. All fungicides for CLS control were applied utilizing a 3pt-mounted sprayer dispersing the products in broadcast pattern at a water volume of 15 GPA with TeeJet 8002 flat fan nozzles at 80 psi.

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 = 4.0) and moderately susceptible (2-year average rating = 4.8) 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	Kabina ST	Penthiopyrad	14 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 2017 crop season based on weather stations.

	Precipitation in inches		
Month	NWROC	MDFC	SMBSC
May	1.72	0.60	3.12
June	7.82	5.34	6.33
July	1.47	4.53	6.92
August	1.67	3.39	2.03
September	2.31	2.34	9.17
October (01-23)			2.63
Total	**14.99**	**16.20**	**30.20**

SMBSC site. Prior to planting, soil was infested with *R. solani* AG 2-2-infested whole barley (50 kg ha^{-1}). The trial was sown in six-row plots (22-inch row spacing, 30-ft rows) on May 16 at 4.77-inch seed spacing. Inoculum was incorporated using the 8.5 foot cultivator followed by the drag. Weeds were controlled by application of Dual Magnum (8 oz A^{-1}) on May 17, Powermax (28 oz A^{-1}) + Dual magnum (16 oz A^{-1}) on June 8 and Powermax (22 oz A^{-1}) + Dual Magnum (16 ozA^{-1}) on June 28. Postemergence azoxystrobin timings were applied on June 05 (4-leaf, ~3 weeks after planting), or June 22 (8-leaf, ~5 weeks after planting) as 7 inch bands using 4001E nozzles at 35 psi. Fungicides were applied for controlling Cercospora leaf spot on July 11 (TPTH + Topsin, 8 & 20 oz A^{-1}, respectively), July 24 (Inspire XT + Dithane F-45, 7 & 32 oz A^{-1}, respectively), Aug 03 (TPTH + Badge SC, 8 & 32 oz A^{-1}, respectively), Aug 09 (Dithane F-45, 51.2 oz A^{-1}), Aug 17 (Minerva + Badge SC, 13 & 32 oz A^{-1}, respectively) and Aug 29 (Supertin + Dithane F-45, 8 & 51.2 oz A^{-1}, respectively). All fungicides for CLS control were applied in a water volume of 19.3 GPA with 11002 nozzles at 70 psi.

At NWROC stand counts were done beginning 2 weeks after planting through 8 weeks after planting. At MDFC stand counts were done 4 through 7 weeks after planting. At SMBSC stand counts were done 3 and 5 weeks after planting. The trial was harvested on Sept 18 at the NWROC, Oct 02 at Wahpeton and Oct 24 at Renville. 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). Disease incidence was reported as the percent of rated roots with a root rot rating > 2.

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 2018 growing season was drier at the NWROC during the period of April- May resulting in lower early season disease pressure. Rainfall at the NWROC was just 1.72 inch during the month of May compared to a 30-year average of 3.04 inches. Resistant and moderately resistant varieties had similar stands from 2 to 8 weeks after planting (WAP). Systiva treatment had higher stands from 3 to 7 WAP compared to Quadris in-furrow and control treatments. At 8 WAP Systiva had higher stands, intermediate for Quadris in-furrow and lowest for control treatments (Fig. 1). Control plots had 184 plants/100 ft. row at 8 WAP indicating very low early season disease pressure at this site. There was a significant variety x postemergence treatment interaction for root rot incidence and number of harvestable roots per 100 ft. Resistant variety had significantly lower incidence of Rhizoctonia root rot compared to the moderately resistant variety (Table 3). Even though enough rainfall was received in the month of June, relatively dry conditions during Jul-Sept resulted in very low disease pressure as reflected in the root rot ratings at harvest. There were no significant differences between Quadris in-furrow, Systiva seed treatment or control treatments for any harvest parameters (Table 3). Both 4- and 8-leaf Quadris applications resulted in significant reduction in root rot, increase in yield, percent sucrose, recoverable sugar A^{-1} (RSA), and recoverable sucrose T^{-1} (RST) compared to control (Table 3). Similar benefit from postemergence Quadris application was also evident in 2016 and 2017 (4,5). Root rot incidence was lower in the resistant variety compared to the susceptible variety (Fig. 2) and Quadris postemergence application reduced root rot incidence in the susceptible variety compared to no Quadris application (Fig. 2).

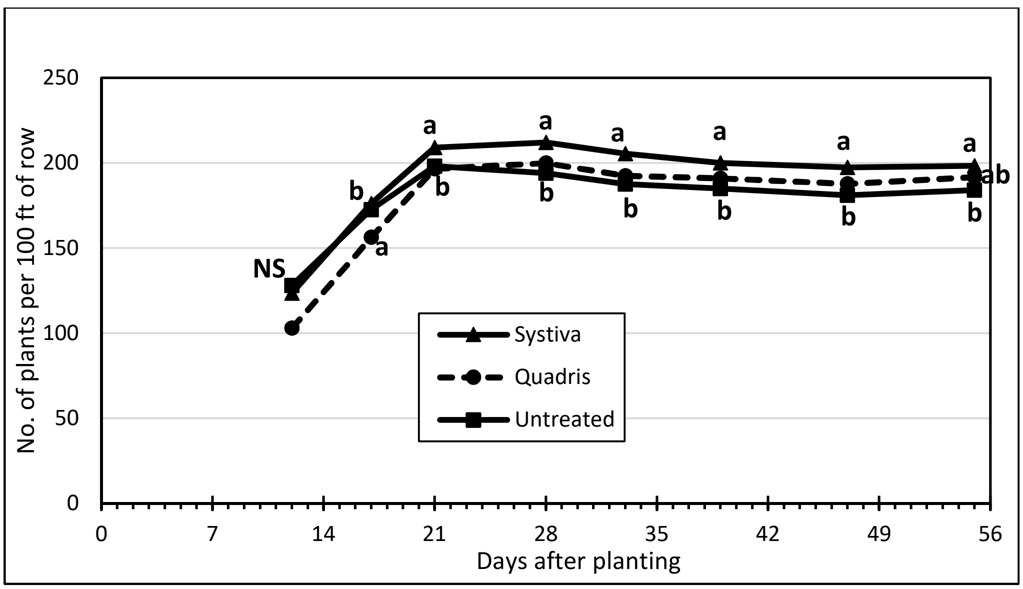

Fig. 1. NWROC site: Emergence and stand establishment for fungicide treatments at planting or untreated control. For each stand count date, values sharing the same letter are not significantly different ($P = 0.05$); NS = not significantly different. Data shown represents mean of 24 plots averaged across 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 04, 2018.

Main effect	No. harv.	RCRR	RCRR %	Yield	Sucrose[T]		
(Apron + Maxim on all seed)	roots/100 ft[T]	(0-7)[TU]	incidence[TV]	ton A^{-1}[T]	%	lb ton^{-1}	lb A^{-1}
Variety[W]							
Resistant	159	0.3	3.3	21.0	18.1	338	7087
Moderately Susceptible	164	0.7	13.1	21.8	16.6	304	6609
ANOVA p-value	0.42	0.06	**0.02**	0.66	0.05	0.05	0.22
LSD (*P* = 0.05)	NS	NS	7.7	NS	NS	NS	NS
At-planting treatments[X]							
Untreated control	160	0.5	8.1	22.5	17.4	322	6856
Systiva @ 5 g a.i /unit	162	0.5	9.0	20.5	17.3	318	6472
Quadris In-furrow	163	0.4	7.5	21.2	17.4	324	7216
ANOVA p-value	0.74	0.67	00.76	0.27	0.92	0.81	0.18
LSD (*P* = 0.05)	NS	NS	NS	NS	NS	NS	NS
Postemergence fungicide[Y]							
None	153 b	0.9 a	16.5 a	20.4 b	17.0 b	313 b	6372 b
4-leaf Quadris @ 14.3 fl. oz./A	166 a	0.3 b	3.8 b	21.8 a	17.5 a	325 a	7068 a
8-leaf Quadris @ 14.3 fl. oz./A	165 a	0.3 b	4.4 b	21.9 a	17.5 a	325 a	7103 a
ANOVA p-value	**0.01**	**<0.0001**	**<0.0001**	**0.04**	**0.01**	**0.01**	**0.0006**
LSD (*P* = 0.05)	9	0.19	3.2	1.2	0.4	9.3	391
Vty x at-palnt	NS	NS	NS	NS	NS	NS	NS
Vty x Post	**0.04**	NS	**0.02**	NS	NS	NS	NS
At-plant x Post	NS	NS	NS	NS	NS	NS	NS
Vty x At-plant x Post	NS	NS	NS	NS	NS	NS	NS

[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, 7 = 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] Values represent mean of 24 plots (4 replicate plots across 2 varieties and 3 postemergence treatments)

[Y] Values represent mean of 24 plots (4 replicate plots across 2 varieties and 3 at-planting treatments)

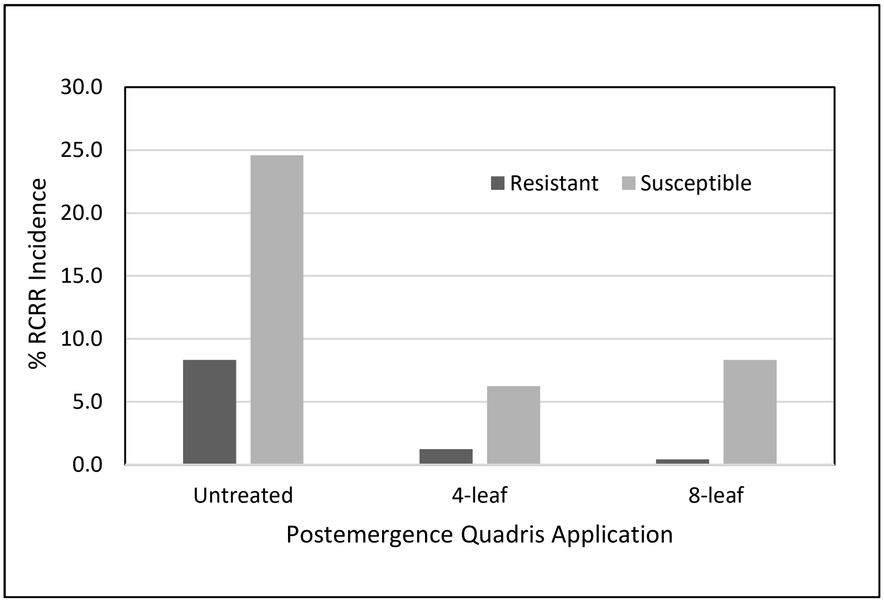

Fig. 2. NWROC site: Effect of variety and postemergence treatments on Rhizoctonia root rot incidence (percent of roots with rating greater than two).

MDFC site: Resistant and moderately resistant varieties had similar stands from 4 to 7 weeks after planting (WAP). Systiva had higher stands from 3 to 7 WAP compared to Quadris in-furrow and control treatments, which were similar, except 5 WAP where Systiva was highest, intermediate for Quadris in-furrow and lowest for control (Fig. 3). Control plants had 186 plants/100 ft. row at 7 WAP indicating very low early season disease pressure at this site. This site received good rainfall from June through September and yet disease pressure was low until harvest. There were significant variety x postemergence treatment interactions for RCRR rating, RCRR incidence and % recoverable sucrose (Table 4). Resistant variety had significantly higher percent sucrose, RST, and purity whereas moderately resistant variety had higher yield (Table 4). Quadris in-furrow had significantly lower root rot compared to Systiva and control treatments (Table 4). Postemergence application (4- or 8-leaf) significantly reduced root rot severity and incidence and 8-leaf application increased yield and RSA compared to no postemergence application (Table 4). RCRR rating and incidence was lower in the resistant variety compared to susceptible variety and hence 4- or 8-leaf Quadris application was effective on the susceptible variety to lower root rot rating and incidence (Fig. 4 A & B). This demonstrates the importance of choosing a resistant variety for managing Rhizoctonia diseases. Similar benefit from postemergence Quadris application at this location was also evident in 2016 and 2017 (4,5). Percent sucrose was higher for the resistant variety and not affected by postemergence Quadris, but was increased with postemergence Quadris applications in the susceptible variety (Fig. 4C).

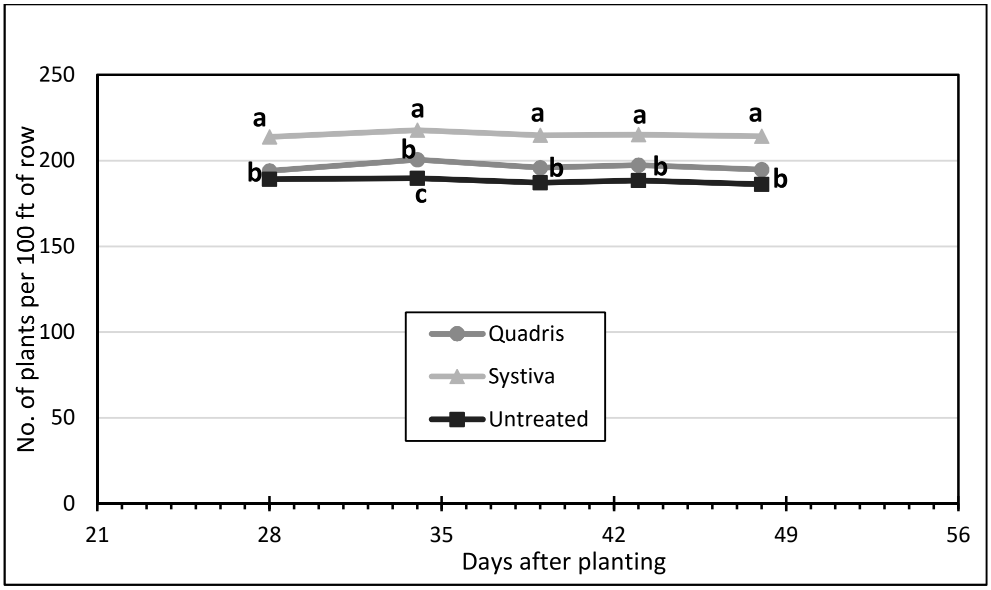

Fig. 3. MDFC site: Emergence and stand establishment for fungicide treatments at planting or untreated control. For each stand count date, values sharing the same letter are not significantly different (P = 0.05); NS = not significantly different. Data shown represents mean of 24 plots averaged across varieties and postemergence treatments.

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 24, 2018.

Main effect (Apron + Maxim on all seed)	RCRR (0-7) [TU]	RCRR % incidence[TV]	Yield ton A^{-1T}	Sucrose[T] %	Sucrose[T] lb ton^{-1}	Sucrose[T] lb A^{-1}
Variety[W]						
Resistant	0.1	1.8	25.9	15.1	236	6106
Moderately Susceptible	0.3	5.3	28.4	14.4	220	6247
ANOVA p-value	0.09	0.09	0.01	0.02	0.009	0.10
LSD (P = 0.05)	NS	NS	1.8	0.5	8.8	NS
At-planting treatments[X]						
Untreated control	0.2 a	4.4	27.1	14.7	226	6077
Systiva @ 5 g a.i /unit	0.2 a	4.6	27.1	14.8	230	6216
Quadris In-furrow	0.1 b	1.7	27.3	14.8	229	6236
ANOVA p-value	0.04	00.06	0.89	0.57	0.34	0.29
LSD (P = 0.05)	0.15	NS	NS	NS	NS	NS
Postemergence fungicide[Y]						
None	0.3 a	6.5 a	26.3 b	14.7	227	5953 b
4-leaf Quadris @ 14.3 fl. oz./A	0.1 b	2.5 b	27.1 b	14.7	227	6155 b
8-leaf Quadris @ 14.3 fl. oz./A	0.1 b	1.7 b	28.0 a	14.8	230	6421 a
ANOVA p-value	0.01	0.01	0.001	0.43	0.57	0.002
LSD (P = 0.05)	0.16	3.5	0.9	NS	NS	250
Vty x At-plant	NS	NS	NS	NS	NS	NS
Vty x Post	**0.02**	**0.03**	NS	**0.03**	NS	NS
At-plant x Post	NS	NS	NS	NS	NS	NS
Vty x At-plant x Post	NS	NS	NS	NS	NS	NS

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, 7 = 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 Values represent mean of 24 plots (4 replicate plots across 2 varieties and 3 postemergence treatments)

Y Values represent mean of 24 plots (4 replicate plots across 2 varieties and 3 at-planting treatments)

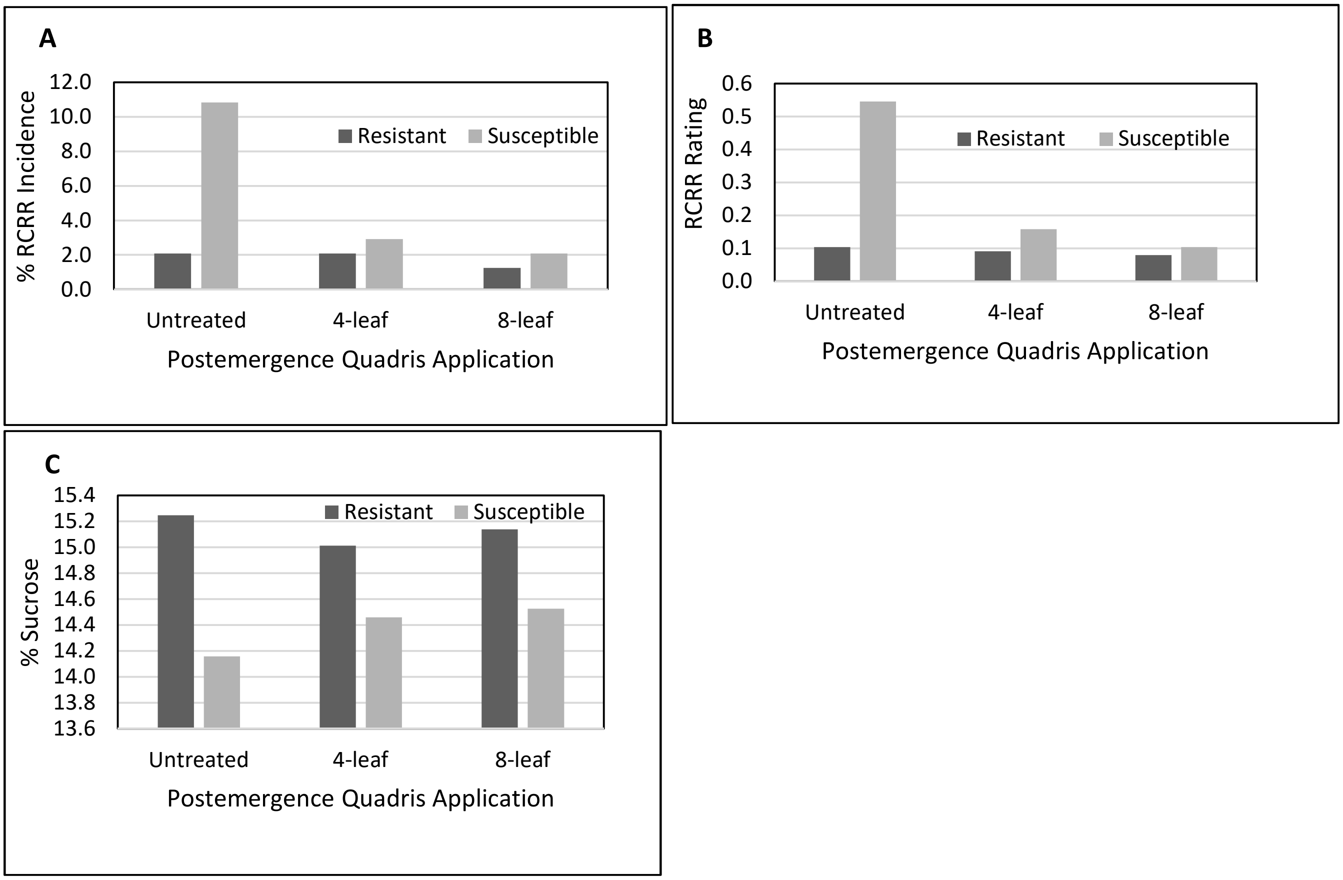

Fig. 4. MDFC site: Effect of variety and postemergence treatments on **A)** RCRR incidence and **B)** RCRR rating and **C)** percent sucrose. Rhizoctonia root rot severity (0-7 scale (adjusted rating), 0 = root clean, no disease, 7 = root completely rotted and plant dead). Incidence only includes percent of roots with rating greater than two.

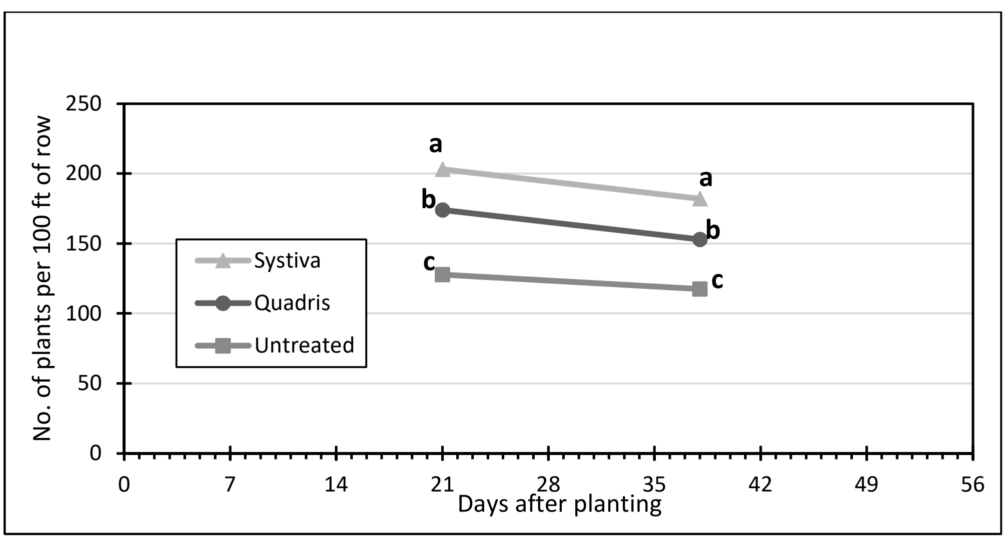

Fig. 5. SMBSC site: Emergence and stand establishment for fungicide treatments at planting or untreated control. For each stand count date, values sharing the same letter are not significantly different ($P = 0.05$); NS = not significantly different. Data shown represents mean of 24 plots averaged across varieties and postemergence treatments.

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 16, 2018.

Main effect	RCRR	RCRR %	Yield	Sucrose[T]		
(Apron + Maxim on all seed)	(0-7) [TU]	incidence[TV]	ton A^{-1T}	%	lb ton^{-1}	lb A^{-1}
Variety[W]						
Resistant	0.1	3.1	28.0	14.8	240	6710
Moderately Susceptible	1.6	32.4	30.4	13.2	205	6255
ANOVA p-value	0.02	0.03	0.003	0.02	0.01	0.07
LSD (*P* = 0.05)	0.9	23.5	0.5	1.0	18.0	NS
At-planting treatments[X]						
Untreated control	1.0	19.7	29.4	13.8	219	6458
Systiva @ 5 g a.i /unit	1.1	23.9	28.8	13.9	221	6326
Quadris In-Furrow	0.5	9.7	29.3	14.2	228	6663
ANOVA p-value	0.003	0.007	0.72	0.32	0.31	0.40
LSD (*P* = 0.05)	0.31	7.7	NS	NS	NS	NS
Postemergence fungicide[Y]						
None	1.2	24.7	29.0	14.1	225	6513
4-leaf Quadris @ 14.3 fl. oz./A	0.9	18.9	28.9	14.0	221	6393
8-leaf Quadris @ 14.3 fl. oz./A	0.5	9.7	29.6	13.9	222	6542
ANOVA p-value	0.0007	0.0002	0.51	0.68	0.67	0.66
LSD (*P* = 0.05)	0.32	6.4	NS	NS	NS	NS
Vty x at-plant	**0.0016**	**0.0053**	NS	NS	NS	NS
Vty x Post	**0.0213**	**0.0176**	NS	NS	NS	NS
At-plant x Post	NS	NS	NS	NS	NS	NS
Vty x at-plant x Post	**0.003**	**0.006**	NS	NS	NS	NS

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, 7 = 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 27 plots (3 replicate plots across 3 at-planting treatments and 3 postemergence treatments)

X Values represent mean of 18 plots (3 replicate plots across 2 varieties and 3 postemergence treatments)

Y Values represent mean of 18 plots (3 replicate plots across 2 varieties and 3 at-planting treatments)

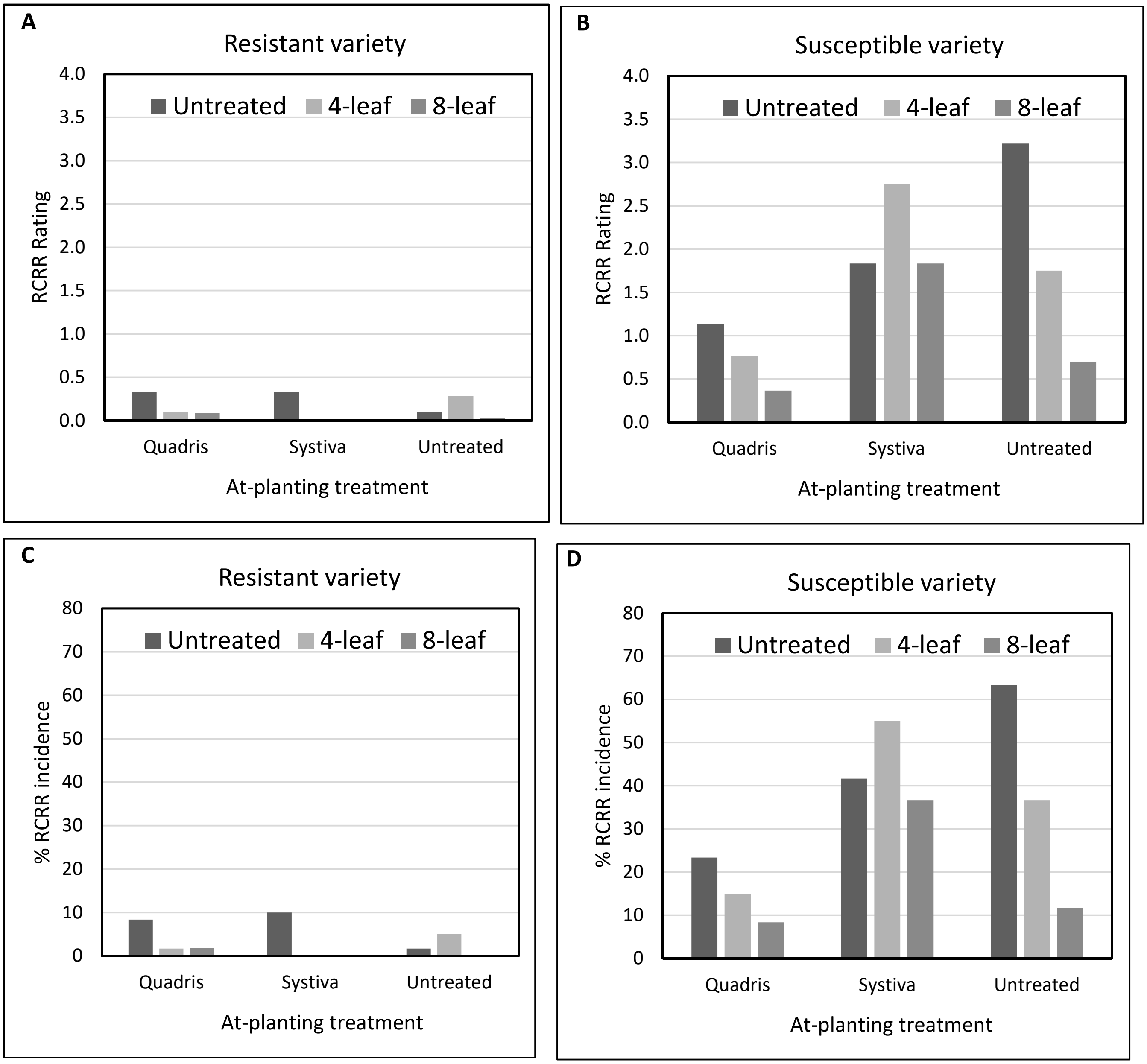

Fig. 6. SMBSC site: Effect of variety, at-planting and postemergence treatments on RCRR rating on **A)** Resistant and **B)** Susceptible variety and RCRR incidence on **C)** Resistant and **D)** Susceptible variety. Rhizoctonia root rot severity (0-7 scale (adjusted rating), 0 = root clean, no disease, 7 = root completely rotted and plant dead). Incidence only includes percent of roots with rating greater than two.

SMBSC site: This site received high rainfall and soil conditions were highly favorable for Rhizoctonia diseases immediately after planting. Resistant variety had higher stands at 3 WAP and both varieties had similar stands at 7 WAP. Systiva treatment had highest stands at 3 and 7 WAP, intermediate for Quadris in-furrow and lowest for control plots (Fig. 5). Control plants had 128 and 118 plants/100 ft. row at 3 and 7 WAP respectively, indicating very high early season disease pressure at this site (Fig. 5). Excess rainfall during the season resulted in significant stunting in one of the replications and for harvest parameters data from only 3 replications was used. There were significant variety x at-planting and variety x postemergence treatment interactions for disease severity and incidence. There was also a significant variety x at-planting x postemrgence treatment interaction for disease severity and incidence. Resistant variety had lower root rot severity and incidence and higher percent sucrose, purity, and RST than moderately resistant (Table 5). Susceptible variety had higher yield than the resistant variety, so that RSA was similar (Table 5). Quadris in-furrow had significantly lower root rot severity and incidence compared to Systiva and control treatments (Table 5). Despite the lower number of roots in control plots at 7 WAP, final harvest parameters such as yield, RSA and RST were not significantly different between control, Systiva and Quadris in-furrow treatments (Table 5). Postemergence application (8-leaf) significantly reduced root rot severity and incidence compared to 4-leaf and no postemergence application (Table 5). RCRR rating and incidence was lower in the resistant variety compared to susceptible variety and hence 4- or 8-leaf Quadris application was effective on the susceptible variety to lower root rot rating and incidence; 8-leaf application was better compared to 4-leaf application (Fig. 6A-D). Similar benefit from postemergence Quadris application at this location was also evident in 2016 and 2017 (4,5). This clearly demonstrates the importance of choosing a resistant variety for managing Rhizoctonia diseases. In fields with heavy Rhizoctonia pressure, in-furrow application provide better protection compared to seed treatment as observed in this trial especially when using a susceptible variety for Rhizoctonia.

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, Alec Boike, Karen Soi Choi, Brandon Kasprick, and Muira MacRae 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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