INTEGRATED MANAGEMENT OF RHIZOCTONIA ON SUGARBEET WITH VARIETAL RESISTANCE, 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, 4-6). Disease can occur throughout the growing season and reduces plant stand, root yield, and quality. 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), moderately resistant (MR) and a susceptible (S) variety with new available seed treatments compared with in-furrow azoxystrobin alone and in combination with a postemergence azoxystrobin application 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, ND and one at Raymond, MN. All locations were fertilized for optimal yield and quality. At each location, a combination of a R, MR, and S variety treated with penthiopyrad (Kabina ST), sedaxane (Vibrance), or untreated or azoxystrobin in-furrow was planted in four replicate plots in a randomized complete block design. Seed treatments and rates are summarized in Table 1 and were applied by Germains Seed Technology, Fargo, ND. In-furrow azoxystrobin was applied down the drip tube in 6 gallons total volume A^{-1}. Each variety by at-planting treatment combination was planted in duplicate, so that at 5 weeks after planting, one plot of each variety by at-planting fungicide 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 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 R, MR, and S varieties were 3.4, 4.0 and 5.3, respectively (7).

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 08 at 4.5-inch seed spacing. Counter 20G (8 lb A^{-1}) was applied at planting for control of sugarbeet root maggot. Glyphosate (4.5 lb product ae/gallon) was applied on May 28, June 5 and 23, and August 17 (22 oz A^{-1}) for control of weeds. Postemergence azoxystrobin was applied in a 7-inch band in 10 gallon/A using 4002 nozzles and 39 psi on June 15 (5 weeks after planting). 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.

MDFC 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 20 at 4.5-inch seed spacing. Glyphosate (4.5 lb product ae/gallon) tank-mixed with AMS (8.5 lbs A^{-1}) was applied on May 23, June 09 and June 30. Postemergence azoxystrobin was applied in a 7-inch band on June 23 (about 4 weeks after planting). Cercospora leafspot was controlled by separate applications of TPTH/Topsin (5 & 7.6 oz A^{-1}, respectively) on July 21, Inspire (7 oz A^{-1})

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 (2014 rating = 3.4), moderately resistant (2014 rating = 4.0) and susceptible (2014 rating = 5.3) variety, and all treatment combinations were duplicated, with one set receiving a postemergence 7-inch band application of azoxystrobin (14.3 fl oz A^{-1}). Standard rates of Apron + Maxim and 45 g/unit Tachigaren were on all seed. In-furrow Quadris was applied down the drip tube in a total volume of 6 gal/A.

Application	Product	Active ingredient	Rate
None	-	-	-
Seed	Kabina ST	Penthiopyrad	14 g a.i./unit seed
Seed	Vibrance	Sedaxane	2 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 2015 crop season based on weather stations.

	Precipitation in inches		
Month	NWROC	MDFC	SMBSC
May	2.56	6.03	4.60
June	3.70	2.43	3.49
July	4.96	2.76	2.46
August	1.10	1.03	4.70
September	0.27	0.43	0.86
Total	12.59	12.68	16.11

on August 4 and Headline (9 oz A^{-1}) on August 25. 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.

SMBSC 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 5 at 4.9-inch seed spacing. Preemergence herbicide (Dual Magnum) was applied on May 06 for control of weeds. Glyphosate was applied on May 21, June 02, and June 16 for control of weeds. Postemergence azoxystrobin was applied on June 18 (6 weeks after planting). Fungicides were applied for controlling Cercospora leaf spot on July 10, July 26, Aug 05, and Aug 28.

At NWROC stand counts were done beginning 3 weeks after planting through 9 weeks after planting. The trial was harvested September 16 at the NWROC, September 15 at Wahpeton, and September 30 at Raymond. 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 azoxystrobin application, and all possible interactions.

RESULTS

NWROC site: There were no significant (P = 0.05) interactions for stand data. Emergence was higher for the moderately resistant variety at 3 weeks after planting (WAP) compared to the resistant and the susceptible varieties. By 5 WAP, the resistant variety had highest stands, followed by the moderately resistant, and lowest for the susceptible variety (Fig. 1A). In all varieties, seed treated with Kabina or Vibrance, or with in-furrow Quadris application resulted in higher emergence and stand establishment over 9 weeks than the untreated control (Fig. 1B). Postemergence Quadris application did not significantly affect stand data. There were significant (P = 0.05) variety by at-planting treatment interactions on yield and significant (P = 0.05) variety by at-planting by postemergence treatment interactions on root rot rating and recoverable sugar A^{-1}. Resistant and moderately resistant varieties had higher number of harvested roots and low root rot rating compared to the susceptible variety (Tab. 3). Yield was highest for the moderately resistant variety compared to the resistant and susceptible varieties. RSA was highest for the moderately resistant variety followed by the resistant variety and lowest for the susceptible variety. Root rot ratings were significantly lower for Quadris in-furrow compared to untreated control and 14 g Kabina. Root rot rating was intermediate for 2 g Vibrance between 14 g kabina and Quadris in-furrow (Tab. 3). Yield was high and

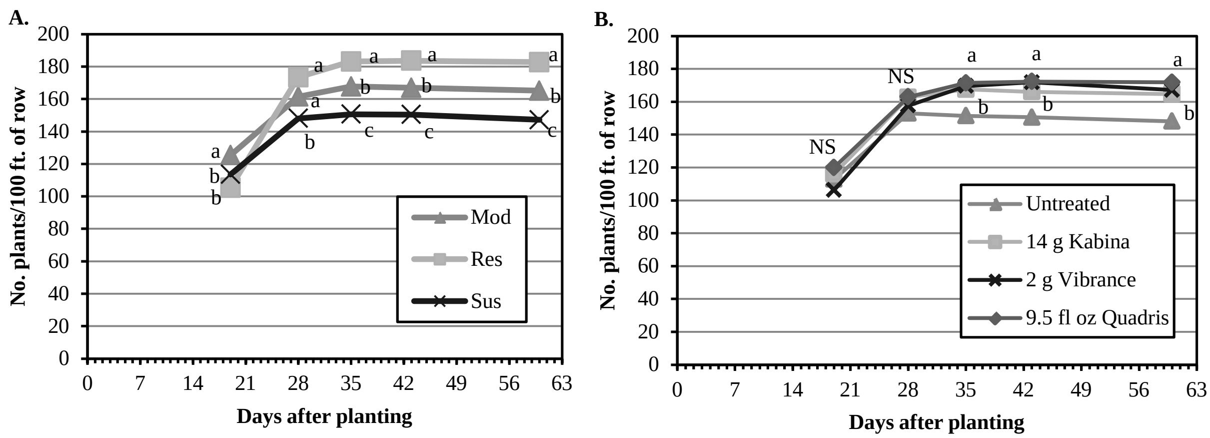

Fig. 1. Emergence and stand establishment for **A**) resistant, moderately resistant, and susceptible sugarbeet varieties and **B**) fungicide treatments on seed, or Quadris in-furrow, or untreated control. For each stand count date, values sharing the same letter are not significantly different (*P* = 0.05); NS = not significantly different. Data shown in **A** represent mean of 32 plots averaged across at-planting and postemergence treatments and in **B** represent mean of 24 plots averaged across varieties and postemergence treatments.

Table 3. NWROC site: Main effects of variety, at-planting (seed or in-furrow), and postemergence fungicide treatments on Rhizoctonia crown and root rot and sugarbeet yield and quality in a field trial sown May 8, 2015.

Main effect (Apron + Maxim on all seed)	No. harv. roots/100 ft[U]	RCRR (0-7)[UV]	Yield ton A^{-1U}	Sucrose %	Sucrose lb ton^{-1}	Sucrose lb A^{-1U}
Variety[W]						
Resistant	143 a	0.5 b	22.8 b	15.9	296	6730 b
Moderate	137 a	0.8 b	24.6 a	15.9	296	7275 a
Susceptible	114 b	2.0 a	21.5 b	15.5	287	6180 c
ANOVA p-value	<0.0001	<0.0001	0.0003	0.2631	0.2579	<0.0001
LSD (*P* = 0.05)	9.0	0.5	1.4	NS	NS	450
At-planting treatments[X]						
Untreated control	123 b	1.3 a	22.1 b	15.9	296	6536 b
Kabina ST @14 g a.i./unit	128 b	1.4 a	22.8 ab	15.3	282	6451 b
Vibrance @ 2.0 g a.i./unit	131 ab	1.1 ab	22.6 b	15.9	294	6648 b
Quadris @ 9.5 fl. oz./A	141 a	0.5 b	24.4 a	16.1	298	7278 a
ANOVA p-value	0.0116	0.0165	0.0347	0.0859	0.1020	0.0102
LSD (*P* = 0.05)	10.4	0.54	1.6	NS	NS	520
Postemergence fungicide[Y]						
None	131	1.1	22.9	15.8	293	6709
Quadris @ 14.3 fl. oz./A	131	1.0	23.0	15.8	293	6748
ANOVA p-value	0.9820	0.3954	0.7760	0.9808	0.9914	0.8316
Interactions[Z]						
Vty. x At-plant trmt.	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	*

[U] Numbers followed by the same letter are not significantly different; LSD = Least Significant Difference, *P* = 0.05
[V] RCRR = Rhizoctonia crown and root rot; 0-7 scale (adjusted rating), 0 = root clean, no disease, 7 = root completely rotted and plant dead
[W] Values represent mean of 24 plots (3 replicate plots across 4 at-planting treatments and 2 postemergence treatments)
[X] Values represent mean of 18 plots (3 replicate plots across 3 varieties and 2 postemergence treatments)
[Y] Values represent mean of 36 plots (3 replicate plots across 3 varieties and 4 at-planting treatments)
[Z] * = significant at *P* = 0.05, ** = significant at *P* = 0.01, NS = not significantly different

not significantly different for Quadris in-furrow and 14 g Kabina. Percent sucrose and recoverable sucrose T^{-1} (RST) were not significantly different between treatments. Recoverable sugar A^{-1} (RSA) was highest for Quadris in-furrow compared to Kabina, Vibrance, and untreated control (Tab. 3). There was no significant difference between untreated control and postemergence Quadris application on any harvest parameters. This very well could be because of the low overall development of root rot during the season.

MDFC site: There were no significant (P = 0.05) interactions for stand or harvest data. Seed treated with Kabina or Vibrance, or with in-furrow Quadris application resulted in higher stands at 4 weeks after planting than the untreated control (data not shown). The resistant variety had significantly lower root rot than the moderately resistant and susceptible varieties (Tab. 4). The susceptible variety had significantly lower yield and RSA than the moderately resistant and resistant varieties. Percent sucrose and RST were significantly higher for the resistant variety than the moderately resistant and susceptible varieties (Tab. 4). Overall root rot rating was very low, and there was no significant difference between treatments for root rot rating, percent sucrose and RST (Tab. 4). Yield and RSA were significantly lower for untreated control compared to all other treatments. There was no significant difference between untreated control and postemergence Quadris application on any harvest parameters (Tab. 4). This very well could be because of the low overall development of root rot during the season.

SMBSC site: There were no significant (P = 0.05) interactions for stand or harvest data. At 4 and 8 weeks after planting, the susceptible variety had lowest stands compared to moderately resistant and resistant varieties (data not shown). At 4 weeks after planting Kabina or Vibrance had higher stands and by 8 weeks Vibrance had highest

Table 4. **MDFC site:** Main effects of variety, at-planting (seed or in-furrow), and postemergence fungicide treatments on Rhizoctonia crown and root rot and sugarbeet yield and quality in a field trial sown May 21, 2015.

Main effect (Apron + Maxim on all seed)	RCRR (0-7)[TU]	RCRR % Incidence[TV]	Yield ton A^{-1}[T]	Sucrose %[T]	Sucrose lb ton^{-1}[T]	Sucrose lb A^{-1}[T]
Variety[W]						
Resistant	0.4 b	6 b	13.5 a	17.7 a	287 a	3871 a
Moderate	0.7 a	10 b	12.8 a	16.9 b	274 b	3508 a
Susceptible	0.9 a	16 a	10.3 b	17.0 b	268 b	2778 b
ANOVA p-value	0.0005	0.0008	0.0005	0.0052	0.0016	<0.0001
LSD (P = 0.05)	0.2	4.8	1.6	0.5	9.8	455
At-planting treatments[X]						
Untreated control	0.7	11	10.8 b	17.3	277	3009 b
Kabina ST @14 g a.i./unit	0.6	13	13.3 a	17.3	280	3725 a
Vibrance @ 2.0 g a.i./unit	0.8	13	11.8 ab	16.9	273	3238 ab
Quadris @ 9.5 fl. oz./A	0.5	7	13.0 a	17.2	275	3570 a
ANOVA p-value	0.1290	0.1196	0.0375	0.4545	0.7384	0.0374
LSD (P = 0.05)	NS	NS	1.9	NS	NS	525
Postemergence fungicide[Y]						
None	0.7	12	12.2	17.2	277	3396
Quadris @ 14.3 fl. oz./A	0.6	10	12.2	17.2	276	3375
ANOVA p-value	0.7342	0.5283	0.9933	0.9463	0.7491	0.9074
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	NS	NS

[T] Numbers followed by the same letter are not significantly different; LSD = Least Significant Difference, P = 0.05
[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 24 plots (3 replicate plots across 4 at-planting treatments and 2 postemergence treatments)
[X] Values represent mean of 18 plots (3 replicate plots across 3 varieties and 2 postemergence treatments)
[Y] Values represent mean of 36 plots (3 replicate plots across 3 varieties and 4 at-planting treatments)
[Z] * = significant at P = 0.05, ** = significant at P = 0.01, NS = not significantly different

Table 5. **SMBSC site:** Main effects of variety, at-planting (seed or in-furrow), and postemergence fungicide treatments on Rhizoctonia crown and root rot and sugarbeet yield and quality in a field trial sown May 5, 2015.

Main effect (Apron + Maxim on all seed)	RCRR (0-7)[TU]	RCRR % Incidence[TV]	Yield ton A^{-1T}	Sucrose %[T]	Sucrose lb ton^{-1T}	Sucrose lb A^{-1T}
Variety[W]						
Resistant	0.1 b	2 b	25.4 a	16.7 a	293 a	7420 a
Moderate	0.3 b	4 b	27.4 a	16.2 b	283 b	7730 a
Susceptible	1.0 a	17 a	21.6 b	15.7 c	268 c	5797 b
ANOVA p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
LSD (*P* = 0.05)	0.2	3.8	2.0	0.3	8.7	605
At-planting treatments[X]						
Untreated control	0.4	6	24.7	16.2	283	6995
Kabina ST @14 g a.i./unit	0.5	7	25.2	16.3	283	7110
Vibrance @ 2.0 g a.i./unit	0.6	9	24.3	16.0	276	6740
Quadris @ 9.5 fl. oz./A	0.5	8	24.9	16.3	284	7085
ANOVA p-value	0.7373	0.5046	0.9167	0.4570	0.4616	0.7071
LSD (*P* = 0.05)	NS	NS	NS	NS	NS	NS
Postemergence fungicide[Y]						
None	0.6 a	10 a	24.2	16.1	279	6772
Quadris @ 14.3 fl. oz./A	0.3 b	5 b	25.3	16.3	284	7192
ANOVA p-value	0.0019	0.0062	0.1744	0.2675	0.2338	0.0942
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	NS	NS

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

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 24 plots (3 replicate plots across 4 at-planting treatments and 2 postemergence treatments)

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

Z * = significant at *P* = 0.05, ** = significant at *P* = 0.01, NS = not significantly different

stands, followed by Kabina and Quadris, and lowest for untreated controls (data not shown). Root rot rating was significantly higher for the susceptible variety compared to the moderately resistant and resistant varieties (Tab. 5). Yield and RSA were significantly lower for the susceptible variety compared to the resistant and moderately resistant varieties. Percent sucrose and RST were highest for the resistant variety, intermediate for the moderately resistant variety, and lowest for the susceptible variety (Tab. 5). Overall root rot rating was very low, and there was no significant difference between treatments for root rot rating, yield, percent sucrose, RST, and RSA (Tab. 5). Quadris postemergence application had significantly lower root rot rating compared to untreated control (Tab. 5).

DISCUSSION

NWROC site: At the NWROC site, early planting (May 08) into cool and dry soils that had been inoculated with *R. solani* along with average rainfall (Tab. 2) and cool weather in May accounted for light early-season disease pressure. Four inch soil temperatures reached 65 °F by June 07 and rainfall in June was average. Most of the damage to the crop was from mid-season infections beginning in July. Rainfall in July was 4.96 inches which is above average and also 4-inch soil temperatures remained above 70 °F. Overall, the best disease control and sugar yield was with a combination of resistant or a moderately resistant variety with an effective at-planting seed treatment or Quadris in-furrow. Under severe disease pressure, growers cannot expect to protect a susceptible variety, even with the best control options (3). Among at-planting treatments, seed treatments containing penthiopyrad (Kabina) or sedaxane (Vibrance) or Quadris in-furrow resulted in the best stand compared with untreated control. The months of August and September were very dry with very low rainfall, 1.1 and 0.27 in, respectively, which is way below the average for these months (Tab. 2). The dry conditions significantly impacted the development of late season Rhizoctonia root rot and as a result there was no benefit from postemergence application in 2015 which was very similar to observations in 2014 (2).

MDFC site: Overall, the best sugar yield was obtained with a moderately resistant or a resistant variety compared to a susceptible variety. Among at-planting treatments, seed treatments containing penthiopyrad (Kabina) or sedaxane (Vibrance) or Quadris in-furrow resulted in the best stand compared with untreated control. For Yield and RSA, penthiopyrad (Kabina) or Quadris in-furrow was highest followed by intermediate for sedaxane (Vibrance) and lowest for untreated control. The months of August and September were very dry with very low rainfall, 1.03 and 0.43 in., respectively, which is below the average for these months (Tab. 2). The dry conditions significantly impacted the development of late season Rhizoctonia root rot and as a result there was no additional benefit from postemergence application.

SMBSC site: Overall, the best disease control and sugar yield was obtained with a moderately resistant or a resistant variety compared to a susceptible variety. The rainfall in August was conducive for development of disease (Tab. 2) and as a result postemergence Quadris application helped in managing root rot compared to the untreated control.

Based on results from this study and an earlier study (3), one common observation is that selection of a sugarbeet variety with good resistance to Rhizoctonia should be the first choice that the growers should make to manage Rhizoctonia root rot and ultimately to keep the disease levels low in the following seasons.

ACKNOWLEDGEMENTS

We thank the Sugarbeet Research and Education Board of Minnesota and North Dakota for funding this research; Mitsui Chemicals Agro, Inc., and Syngenta for providing products; Hilleshog 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 Raymond 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, Brandon Kasprick, Tim Cymbaluk, Katie Sheetz, and Irwin Sylvah 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 Raymond site sugarbeet quality analysis and American Crystal Sugar Company, East Grand Forks, MN for NWROC site sugarbeet quality analysis.

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