EFFICACY OF IN-FURROW AND POSTEMERGENCE FUNGICIDES IN CONTROLLING RHIZOCTONIA ON SUGARBEET

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Rhizoctonia damping-off and crown and root rot (RCRR) caused by *Rhizoctonia solani* AG 2-2 are increasing on sugarbeet in Minnesota and North Dakota. This soil-borne fungal pathogen can cause disease throughout the growing season and reduces stands and sucrose yield and quality. Several control options, when combined, help to reduce disease and include planting partially resistant varieties, cultural practices (e.g., early planting, rotation with cereal crops), and application of fungicides.

OBJECTIVES

A field trial was established to compare application of in-furrow and post-emergence fungicides for 1.) control of early-season damping-off and RCRR and 2.) yield and quality of sugarbeet.

MATERIALS AND METHODS

In-furrow trial. A trial was established at the University of Minnesota, Northwest Research and Outreach Center, Crookston and fertilized for optimal yield and quality. Soil was infested with *R. solani* (grown on whole barley grains) at 35 kg ha^{-1} and incorporated into the top 4 inches. On May 19, 2010, sugarbeet seed of a susceptible variety (disease rating = 5.76) was sown (2.4-inch spacing) and in-furrow fungicides were applied in a 4-inch band with a nozzle placed directly behind the disk opener. Fungicides included Headline (pyraclostrobin, BASF), Vertisan (penthiopyrad, DuPont), Aproach (picoxystrobin, DuPont), Q8Y78 (2:1 premix of penthiopyrad + picoxystrobin, DuPont), and Quadris (azoxystrobin, Syngenta) at label rates (Table 1). In-furrow fungicides were applied in all rows of six-row plots (rows 22 inches apart and 30 ft long) in a randomized block design of four replicates. There were two controls: non-inoculated and inoculated (both with no fungicide). Counter 15 G (9 lb product A^{-1}) was applied at planting for control of root maggot and glyphosate (4.5 lb product ae/gallon) was applied on June 3 and 29 (24 and 28 oz A^{-1}, respectively) for control of weeds. Cercospora leaf spot was controlled by Super Tin 80WP + Topsin M (5 oz + 0.5 lb product) and 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 14 and September 4, respectively.

Stand counts were taken in the two center rows for each treatment at 13, 14, 16, 19, 22 and 28 days after planting and then plots were thinned to the equivalent of 160 plants per 100 ft row on June 23. The two centers rows were harvested on September 21 and data were collected for number of harvested roots, 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).

Postemergence trial. A trial was established next to the in-furrow trial and sown with the same sugarbeet variety (2.4-inch spacing) on May 17. The trial was managed throughout the growing season in the same manner as the in-furrow trial. Plots were thinned on June 9. When plants reached the 6- to 8-leaf stage (June 24), treatments were assigned to plots (6 rows wide, 30 ft long) arranged in a randomized block design with four replicates. The same fungicides and rates (Table 1) used for the in-furrow trial, plus Proline (prothioconazole, 5.7 fl oz product A^{-1}, Bayer CropScience), were applied in a 7-inch band in the four center rows of plots. Later in the day, *R. solani*-infested ground barley inoculum (28 g/30 ft row) was deposited in sugarbeet crowns with a Gandy granule applicator. Plots then were cultivated to throw soil into crowns and cover inoculum. Two controls were included: non-inoculated and inoculated (both with no fungicide). Plots were harvested on September 22 and disease assessed, as previously described.

Statistical analysis. Data were subjected to analysis of variance (General Linear Model) and if significantly different ($P = 0.05$), means were separated by Fisher's protected Least Significant Difference.

Table 1. Product names, active ingredients, and rates for fungicides used in in-furrow and band trials for control of *Rhizoctonia solani*.

Fungicide	Active ingredient	Product rate	
		fl oz/1000 ft row	fl oz/A
Aproach	Picoxystrobin	1.3	31
Headline[Y]	Pyraclostrobin	0.5	12
Proline[YZ]	Prothioconazole	0.24	5.7
Q8Y78 (Vertisan + Aproach)	2:1 premix of penthiopyrad + picoxystrobin	1.6	38
Quadris	Azoxystrobin	0.6	14.3
Vertisan	Penthiopyrad	1.6	38

[Y] In the band trial, Headline and Proline treatments included Induce at 0.125%.
[Z] Proline was included in the band trial only.

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RESULTS

In-furrow trial. About 2 weeks after planting, seedling stands were excellent for Vertisan and Headline and were comparable to the non-inoculated control; Quadris also resulted in excellent stands but were slightly lower (Fig. 1). Stand loss started to occur in the inoculated control about 2 weeks after planting and continued over the next couple of weeks, but stands in plots treated with Vertisan, Headline, and Quadris and the non-inoculated control did not decline (Fig. 1). In-furrow applications of Aproach and Q8Y78 were phytotoxic (Fig. 1) and plants were severely stunted and populations were low. During the first month after planting, populations gradually increased in the Aproach and Q8Y78 plots but stands were inferior to the other three fungicides and comparable to the inoculated, no fungicide control (Fig. 1). Similar trends occurred at the end of the growing season for numbers of harvested roots (Table 2). Root numbers were highest in the non-inoculated control and lowest in the inoculated, no fungicide control (which lost stand throughout the season) (Table 2). Root numbers in plots treated with all in-furrow fungicides were significantly higher compared to the inoculated, no fungicide control; Quadris, Headline, and Vertisan were almost as high as the non-inoculated control and were significantly higher than Aproach, while Q8Y78 was intermediate (Table 2).

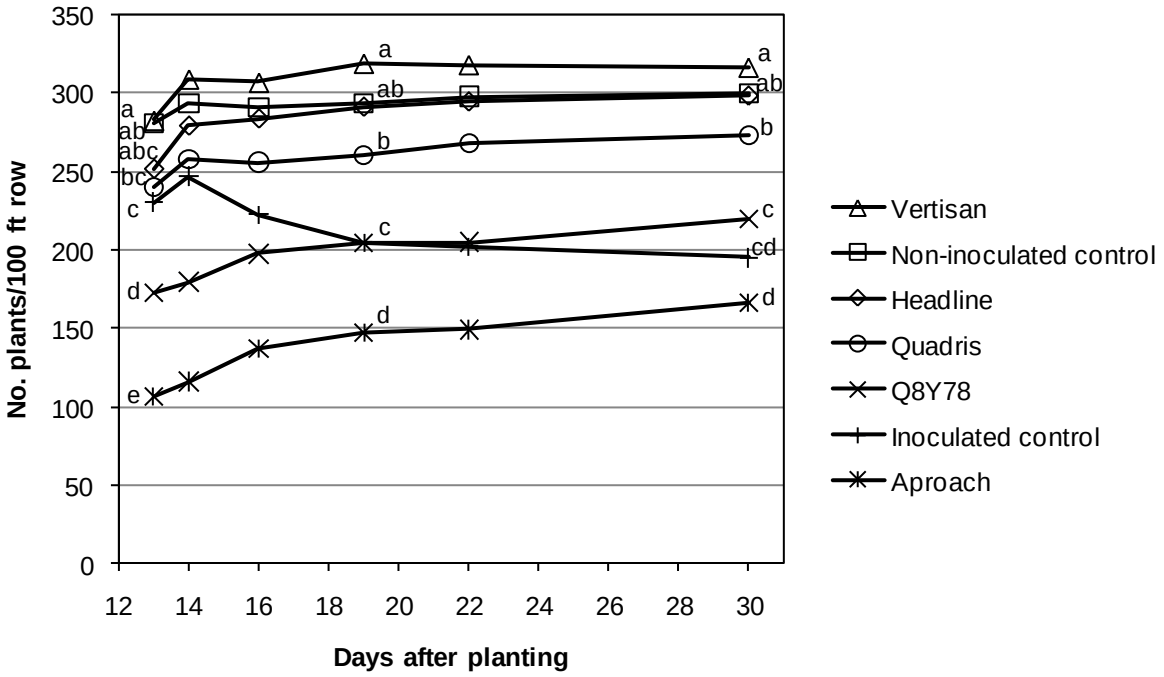

Fig. 1. Percent stand of sugarbeet seedlings in a field inoculated with *Rhizoctonia solani* and treated with various in-furrow fungicides compared to two controls (non-inoculated, no fungicide and inoculated, no fungicide).

Table 2. Efficacy of in-furrow fungicides in controlling Rhizoctonia crown and root rot and sugarbeet yield and quality compared to two controls (non-inoculated, no fungicide and inoculated, no fungicide).

Treatment and rate (in-furrow)	No. harv. root/100 ft[z]	RCRR (0-7)[z]	Yield T/A[z]	Sucrose[z] %	Sucrose[z] lb/ton	Sucrose[z] lb recov./A	Revenue ($/A)[z]
Non-inoculated control	157 a	1.8 a	27.2 a	16.9	318	8635 a	1353 a
Rhizoctonia inoculated							
No fungicide control	85 d	3.8 d	17.7 c	16.8	312	5540 c	855 c
Quadris @ 0.6 fl oz/1000 ft	143 ab	2.2 ab	23.9 ab	17.0	319	7614 ab	1200 ab
Headline @ 0.5 fl oz/1000 ft	142 ab	2.3 abc	24.3 ab	16.7	313	7599 ab	1171 ab
Vertisan @ 1.6 fl oz/1000 ft	138 ab	3.0 c	22.7 b	16.6	310	7043 b	1081 bc
Q8Y78 @ 1.6 fl oz/1000 ft	127 bc	2.7 bc	21.3 bc	17.0	318	6769 bc	1063 bc
Aproach @ 1.3 fl oz/1000 ft	113 c	2.6 abc	20.1 bc	16.9	314	6318 bc	979 bc
P-value	<0.0001	0.001	0.007	0.647	0.657	0.006	0.007
LSD (*P* = 0.05)	20.5	0.77	4.39	NS	NS	1395	228

[z] For each column, values followed by the same letter are not significantly different; LSD = Least Significant Difference, *P* = 0.05; NS = not significantly different

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At harvest, ratings for RCRR were lowest in the non-inoculated control (=1.8) and highest in the inoculated, no fungicide control (3.8) (Table 2). All in-furrow fungicides significantly reduced RCRR compared to the inoculated, no fungicide control with Quadris resulting in the lowest disease severity (= 2.2), followed by increasing RCRR ratings for Headline (= 2.3), Aproach (=2.6), Q8Y78 (= 2.7), and Vertisan (= 3) (Table 2). Correspondingly, yields (root and sucrose) were significantly higher in the non-inoculated control compared to the inoculated, no fungicide control (Table 2). Quadris and Headline applied in-furrow significantly increased yields (tons of roots, recoverable sucrose) nearly as effectively as in the non-inoculated control (Table 2). Yields in plots treated with in-furrow applications of Q8Y78 and Aproach were lowest and statistically similar to the inoculated, no fungicide control; yields were intermediate for Vertisan (Table 2). None of the in-furrow fungicides or controls affected percent sucrose or pounds of sucrose per ton (Table 2). Revenue per acre was significantly highest in the non-inoculated control compared to the inoculated control and plots treated with Vertisan, Q8Y78, and Aproach; revenues from Quadris and Headline plots were nearly equal to the non-inoculated control (Table 2).

Postemergence trial. At harvest, ratings for RCRR were significantly lowest in plots treated with Quadris (=1.5; less than 5% of the root surface rotted) compared to both controls (Table 3). The non-inoculated control had an average rating of 2.8 (6 to 25% of root surface rotted), which revealed a residual, natural population of *R. solani* in the field. The inoculated, no fungicide control average a rating of 5.7 (50 to 75% of the root surface rotted). The other band-applied fungicides significantly reduced RCRR and ratings ranged from a low of 1.6 for Proline to 2.6 for Headline (Table 3).

Numbers of harvested roots and yields (root and recoverable sucrose) were statistically equal for all band-applied fungicides (Quadris, Headline, Vertisan, Q8Y78, Aproach, Proline) and the non-inoculated control and significantly greater than the inoculated, no fungicide control (Table 3). Percent sucrose and pounds of sucrose per ton were significantly highest for Quadris compared to both controls and Headline; Quadris was similar to plots treated with Vertisan, Q8Y78, Aproach, and Proline (Table 3). Revenue per acre was significantly higher for Quadris compared to Headline and the inoculated control; the other fungicides and non-inoculated control resulted in revenues similar to Quadris (Table 3).

Table 3. Efficacy of band-applied fungicides applied at the 6- to 8-leaf stage and then inoculated with *Rhizoctonia solani* for control of crown and root rot and sugarbeet yield and quality compared to two controls (non-inoculated, no fungicide and inoculated, no fungicide).

Treatment and rate (7-inch band)	No. harv. root/100 ft[z]	RCRR (0-7)[z]	Yield T/A[z]	Sucrose[z]			Revenue ($/A)[z]
				%	lb/ton	lb recov./A	
Non-inoculated control	142 a	2.8 c	23.8 a	16.8 bc	311 b	7537 a	1011 ab
Rhizoctonia inoculated							
No fungicide control	73 b	5.7 d	9.5 b	15.6 d	286 c	2780 b	342 c
Quadris @ 0.6 fl oz/1000 ft	162 a	1.5 a	24.5 a	18.0 a	338 a	8295 a	1184 a
Headline @ 0.5 fl oz/1000 ft	147 a	2.6 bc	23.7 a	16.6 cd	308 bc	7228 a	931 b
Vertisan @ 1.6 fl oz/1000 ft	157 a	2.1 abc	25.3 a	17.3 abc	323 ab	8196 a	1126 ab
Q8Y78 @ 1.6 fl oz/1000 ft	163 a	2.0 abc	24.0 a	17.5 abc	327 ab	7863 a	1089 ab
Aproach @ 1.3 fl oz/1000ft	163 a	2.0 abc	25.5 a	17.7 ab	331 ab	8429 a	1176 ab
Proline @ 5.7 fl oz/A	160 a	1.6 ab	24.7 a	17.5 abc	327 ab	8064 a	1115 ab
P-value	<0.0001	<0.0001	<0.0001	0.005	0.004	<0.0001	<0.0001
LSD (*P* = 0.05)	30.5	1.1	5.3	1.1	23.7	1693	247

[z] For each column, values followed by the same letter are not significantly different; LSD = Least Significant Difference, *P* = 0.05

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DISCUSSION

Fungicides applied in-furrow and postemergence reduced Rhizoctonia diseases but differed in control of seedling damping-off and Rhizoctonia crown and root rot (RCRR) under moderate disease pressure. Single in-furrow applications of Quadris, Headline, and Vertisan controlled damping-off and RCRR, but Q8Y78 and Aproach were phytotoxic to seedlings and reduced emergence. Had the trial been space-planted, these two treatments would have resulted in even lower yields. After thinning the in-furrow trial, plant populations were uniform; by the end of the season, all fungicides protected against RCRR compared to the inoculated, no fungicide control but Quadris, Headline, and Aproach reduced RCRR more than Q8Y78 and Vertisan. On the other hand, when the same fungicides were applied when plants were in the 6- to 8-leaf stage (and inoculated with *R. solani* a few hours later), all fungicides significantly reduced RCRR compared to the inoculated, no fungicide control and there was no apparent phytotoxicity. The duration of exposure of sugarbeet plants to *R. solani* differed in both trials and likely affected efficacy of fungicides differently. The in-furrow trials exposed sugarbeet to *R. solani* from planting to harvest, but in the postemergence trial, plants were exposed from the 6- to 8-leaf stage until harvest. Furthermore, seeds inoculated with *R. solani* and treated with in-furrow fungicides were in contact with both the fungus and fungicide at a time when germinating seeds and emerging seedlings are most susceptible to infection (especially in warm, wet soil) and also are most vulnerable to phytotoxic affects of fungicides (i.e., Q8Y78 and Aproach). Quadris also tended to delay emergence of seedlings, which has been previously observed. Remarkably, a single, in-furrow application of Quadris, Headline, and Vertisan had season-long benefits and resulted in significantly higher yields (roots and sucrose) than the inoculated, no-fungicide control.

Based on our results, optimal disease control and sugarbeet yields are attained when the fungicide is applied before *R. solani* infects plants. Application of in-furrow fungicides can be beneficial, especially in fields where infections from *R. solani* are likely to occur early (e.g., where *Rhizoctonia* populations are high and/or late planted fields, when soil temperature is favorable for infections) but caution is warranted because of delayed/reduced emergence with some fungicides. In addition, in-furrow fungicides were applied alone in this trial - and not in combination with starter fertilizer; mixtures of some fungicides with starter fertilizer can result in emergence problems

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