SEED AND IN-FURROW FUNGICIDES 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 (1-2). 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 either in-furrow (IF) or postemergence. Several new fungicides are being developed by companies for use as seed treatments. Some are already registered for use on sugarbeet seed (Dynasty and Stamina), while others are being tested for their potential use.

OBJECTIVES

A field trial was established to compare seed treatment fungicides and 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 two locations, one at the University of Minnesota, Northwest Research and Outreach Center, Crookston, the other near St. Thomas, ND. Both locations were fertilized for optimal yield and quality. At each location, two plots of each fungicide seed treatment (applied by Germains Seed Technology, Fargo, ND) and in-furrow treatments shown in Table 1 were planted in four replicates in a randomized complete block design. At 4 to 5 weeks after planting, one plot of each treatment received a postemergence 7-inch band application of Quadris (14.3 fl oz A^{-1}). Controls included no fungicide at planting with and without postemergence Quadris. Counter 20G (6.8 lb A^{-1}) was applied at planting for control of sugarbeet root maggot and no starter fertilizer was applied.

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, 25-ft rows) on May 4 at 4.5-inch seed spacing. Glyphosate (4.5 lb product ae/gallon) was applied on May 22, June 4, and June 25 (22 oz A^{-1}) for control of weeds. Because of dry conditions, plots were irrigated on May 21 and June 5 (17 and 32 days after planting, respectively). Postemergence application of Quadris was made on June7 (34 days after planting). Cercospora leafspot was controlled by Super Tin 80WP + Topsin M 4.5F (6 oz + 7.6 fl oz 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 July 27 and August 17, respectively.

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 May 7 at a 4.5-inch seed spacing. Glyphosate (Power Max, 28 fl oz A^{-1} + Border, 1 gallon/100) was applied May 23, June 13, and July 19 by the grower cooperator for control of weeds. For additional root maggot control, chlorpyrifos (Govern 4E, 24 fl oz A^{-1}) was applied June 2 and 11 by the grower cooperator. Postemergence application of Quadris was made on June 6. Cercospora leafspot was controlled by Super Tin 80WP + Inspire XT (6 oz + 7 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 9 and Headline (9.6 fl oz A^{-1} + Wetcit, 32 fl oz/100 gallons) applied by the grower cooperator on August 27.

Stand counts were done beginning 2 wk after planting through 7 wk after planting at the NWROC and 5 wk after planting at St. Thomas. The trial was harvested October 1 at the NWROC and September 19 at St. Thomas. 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).

Data were subjected to analysis of variance using SAS Proc GLM (SAS Institute, Cary, NC) for main effects of at-plant treatment, postemergence Quadris application, and at-plant by postemergence interactions.

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. All treatments 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	0.2 g a.i. + 0.034 fl oz product/unit seed
Seed	Penthiopyrad	Penthiopyrad	14 g a.i./unit seed
Seed	Stamina	Pyraclostrobin	30 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}

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 10 kg ground infested barley ha^{-1} (≈10 mg/600 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

Field trials. There were no interactions between at-planting treatments and the postemergence Quadris treatment (Tables 2 and 3, bottom), so main effects of at-planting and postemergence treatments will be shown separately.

NWROC site: Emergence was slow due to dry soil conditions, but following irrigation of plots 17 days after planting and 0.6 inch of rain 26 days after planting, stands were excellent by 28 days after planting (Fig. 1A). Stand began to decline slowly in the untreated control at 28 days after planting and for other plots, around 34 days after planting. By 34 days after planting there were significant differences in plant stand among at-planting treatments and at 49 days after planting, all treatments except penthiopyrad-treated seed had significantly higher stand than the untreated control (Fig. 1A).

Application of postemergence Quadris did not affect stand loss (Fig. 1B). Data shown in Fig. 1B for postemergence Quadris application and no Quadris represent mean of 28 plots averaged across at-planting treatments.

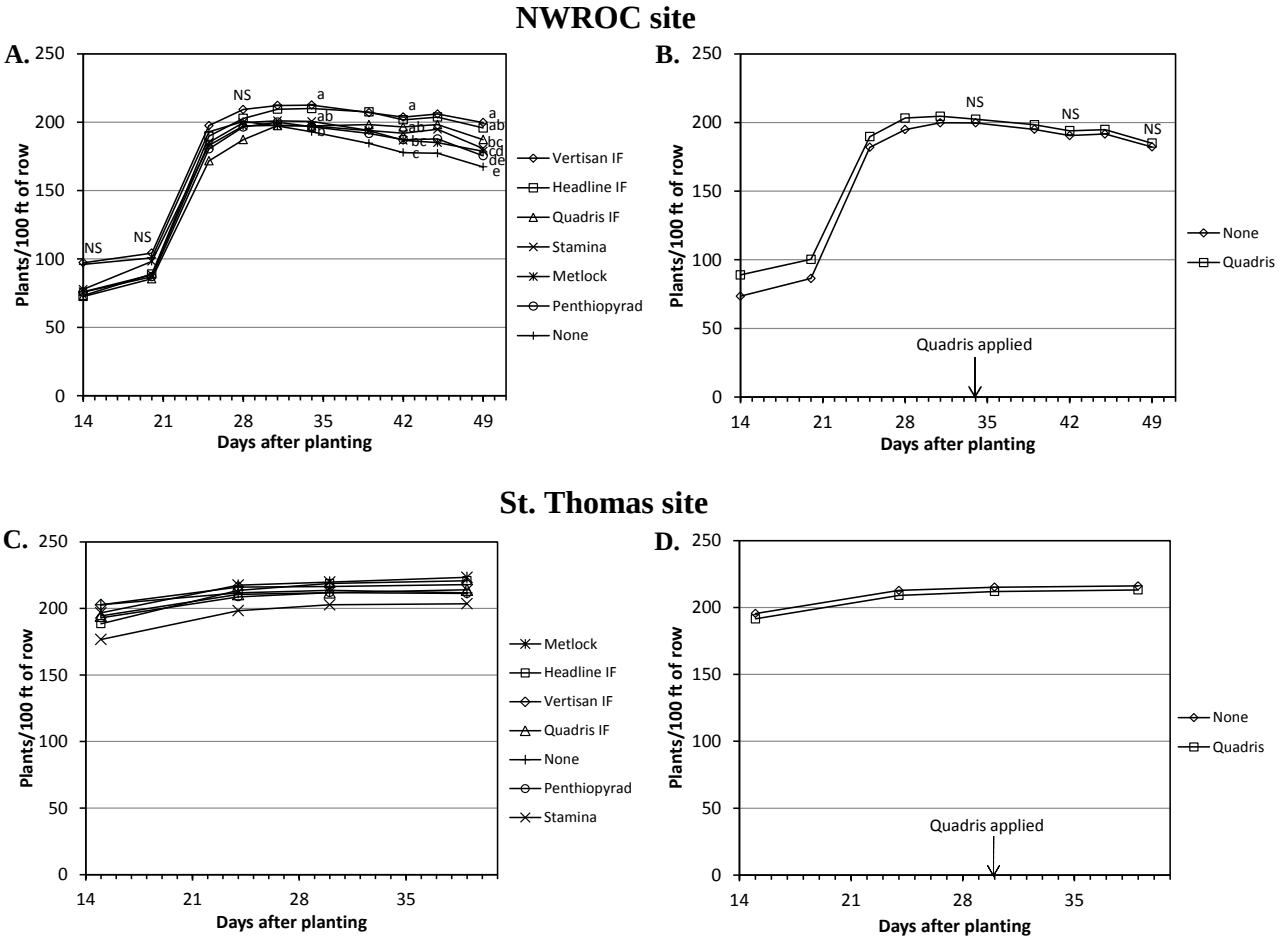

Fig. 1. Stand from field trials in two sites for sugarbeet **A**. and **C**.) treated with various fungicides for control of *Rhizoctonia solani* either on seed or in-furrow (IF) and **B**. and **D**.) treated with a postemergence band application of Quadris or untreated. For **A**, stands at 34, 42, and 49 days after planting followed by the same letter are not significantly different (P = 0.05). Stands for **B**, **C**, and **D** were not significantly different. Data shown in B and D represent mean of 28 plots averaged across at-planting treatments.

Dry conditions persisted throughout the growing season, resulting in very low disease pressure. At harvest, there were significant differences among at-planting treatments for number of harvested roots and RCRR ratings but not for yield and quality variables, and revenue (Table 2, top half). Number of harvested roots was highest for the three IF fungicides, lowest for Metlock-treated seed and the untreated control, and intermediate for penthiopyrad- and Stamina-treated seed. RCRR ratings were lowest for IF fungicides, highest for Metlock-treated seed and the untreated control, and intermediate for penthiopyrad- and Stamina-treated seed.

There were no significant differences for number harvested, RCRR, or yield parameters for postemergence Quadris treated vs. untreated plots (Table 2, bottom half). Data represent mean of 28 plots averaged across at-planting treatments.

St. Thomas site. Disease pressure was mild and occurred very late in the growing season. As a result, emergence and stand establishment were excellent for all at-plant treatments (Fig. 1C) and postemergence application of Quadris (Fig. 1D).

Table 2. **NWROC:** Efficacy of at-planting (seed or in-furrow) and post-emergence fungicide treatments in controlling Rhizoctonia damping-off and crown and root rot of sugarbeet compared to an untreated control.

Treatment and rate (Apron + Thiram on all)	No. harv. root/100 ft[z]	RCRR (0-7)[z]	Yield[z] T A^{-1}	Sucrose[z] %	Sucrose[z] lb ton^{-1}	Sucrose[z] lb recov. A^{-1}	Revenue ($A^{-1})[z]
At-plant treatments							
Untreated control	126 e	3.2 a	29.5	19.4	358	10526	1922
Seed treatments							
Metlock @ 0.2 g a.i./unit	132 de	3.2 a	31.2	19.6	362	11326	2094
Penthiopyrad @ 14 g a.i. /unit	142 bcd	2.6 ab	30.7	19.3	355	10897	1978
Stamina @ 30 g a.i./unit	140 cd	2.8 ab	30.7	19.3	355	10897	1974
In-furrow treatments							
Headline @ 12 fl oz A^{-1}	152 abc	2.4 bc	31.0	19.6	362	11242	2074
Quadris @ 14.3 fl oz A^{-1}	155 ab	1.9 c	31.3	19.2	354	11046	1996
Vertisan @ 28.5 fl oz A^{-1}	157 a	2.3 bc	30.0	19.5	360	10787	1979
ANOVA p-value	<0.0001	0.0008	0.824	0.916	0.919	0.893	0.911
LSD (P = 0.05)[Z]	13.2	0.63	NS	NS	NS	NS	NS
Post-emergence							
None	143	2.8	30.9	19.3	355	10967	1990
Quadris @ 14.3 fl oz A^{-1}	143	2.5	30.3	19.5	361	10953	2015
ANOVA p-value	1.00	0.055	0.455	0.329	0.237	0.969	0.756
Interaction p-value	0.584	0.249	0.059	0.630	0.601	0.191	0.321

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

Table 3. **St. Thomas:** Efficacy of at-planting (seed or in-furrow) and post-emergence fungicide treatments in controlling Rhizoctonia damping-off and crown and root rot of sugarbeet compared to an untreated control.

Treatment and rate (Apron + Thiram on all)	No. harv. root/100 ft[z]	RCRR (0-7)[z]	Yield[z] T A^{-1}	Sucrose[z] %	Sucrose[z] lb ton^{-1}	Sucrose[z] lb recov. A^{-1}	Revenue ($A^{-1})[z]
At-plant treatments							
Untreated control	130	2.9	18.5	18.6	347	6402 cd	1137 cd
Seed treatments							
Metlock @ 0.2 g a.i./unit	131	3.2	19.4	18.4	343	6672 bcd	1177 bcd
Penthiopyrad @ 14 g a.i. /unit	147	2.2	20.7	19.1	357	7415 abcd	1354 abc
Stamina @ 30 g a.i./unit	118	3.2	17.8	18.2	339	6017 d	1047 d
In-furrow treatments							
Headline @ 12 fl oz A^{-1}	152	2.6	22.7	18.9	352	7954 ab	1429 ab
Quadris @ 14.3 fl oz A^{-1}	157	2.0	23.1	19.1	356	8217 a	1495 a
Vertisan @ 28.5 fl oz A^{-1}	157	2.1	22.6	18.6	346	7769 abc	1373 abc
ANOVA p-value	0.084	0.111	0.100	0.104	0.177	0.037	0.018
LSD (P = 0.05)[Z]	NS	NS	NS	NS	NS	1524	278
Post-emergence							
None	140	2.7	20.5	18.5	344	7047	1246
Quadris @ 14.3 fl oz A^{-1}	147	2.2	20.9	18.9	353	7366	1329
ANOVA p-value	0.745	0.629	0.713	0.031	0.032	0.433	0.267
Interaction p-value	0.505	0.637	0.935	0.072	0.056	0.924	0.800

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

Disease was patchy in this naturally infested field at St. Thomas, resulting in high variability. As a result, at harvest there were no significant (P = 0.05) differences among at-planting treatments for number of harvested roots, RCRR, root yield or percent sugar (Table 3, top half). There were, however, significant differences among at-planting treatments for recoverable sucrose and revenue A^{-1}. Recoverable sucrose and revenue A^{-1} were highest for plots treated with Quadris IF, intermediate for Headline and Vertisan IF and penthiopyrad-treated seed, and lowest for Metlock- and Stamina-treated seed and the untreated control.

Postemergence application of Quadris had no effect on number of harvested roots, RCRR rating or root and sucrose yields, and revenue (Table 3, bottom half). Postemergence application of Quadris did result in a small, but statistically significant (P = 0.05) increase in percent sugar and pounds of sucrose ton^{-1}.

Growth room trials. Emergence was excellent for treated seed and the untreated control (Fig. 2). Stand began declining for the untreated control seed by 10 days after planting. By 14 days after planting, stands were significantly higher for fungicide-treated seed compared to the untreated control. By 28 days after planting, stand for the untreated control had dropped to 36%, indicating moderate disease pressure. All three fungicide seed treatments protected stand throughout the 4-wk assay. Root rot indices were significantly lower for fungicide-treated seed compared to the untreated control and averaged 25, 20, and 16 for Metlock-, Stamina-, and penthiopyrad-treated seed, respectively, compared to 68 for the untreated control.

DISCUSSION

The 2012 growing season at the NWROC was extremely dry. Total rainfall at the NWROC for the 5 months of May-September was 8.2 inches compared to the 30-year average of 15.3 inches. Plots were irrigated two times with trickle-tape, providing some low, early-season disease pressure that resulted in significant differences in stand among at-planting treatments. However, plants that survived were able to compensate and produced high yields and sugars in all treatments, including the untreated control. While Rhizoctonia does not require high soil moisture, clearly disease was limited by low soil moisture at this site.

Similarly, at St. Thomas, the 2012 growing season was drier than normal. Total rainfall for the 5 months of May-September was 7.4 inches compared to the North Dakota Agricultural Weather Network normal of 13.8 inches. Despite these dry conditions, there was disease pressure beginning later in the season, but it was very patchy. For example, yields in the four replicated plots for the untreated control (no at-planting treatment, no postemergence Quadris) were 12.8, 19.6, 16.1, and 18.5 ton A^{-1}. These results point out the difficulty of obtaining consistent results with small plots in fields naturally infested with soilborne pathogens. Two at-planting treatments, Quadris and Headline IF, resulted in significantly increased recoverable sucrose and revenue A^{-1} compared with the untreated control, while there was no effect of postemergence Quadris application. Postemergence Quadris was applied on June 6 when plants were at the 4- to 6-leaf stage and average 4-inch soil temperature had been 65 °F or higher for 10 days (including June 2-6). Considering disease pressure was not observed until August, the June 6 application date was too early. In-furrow fungicide applications eliminate uncertainty in timing postemergence applications and have provided consistent disease control in our trials.

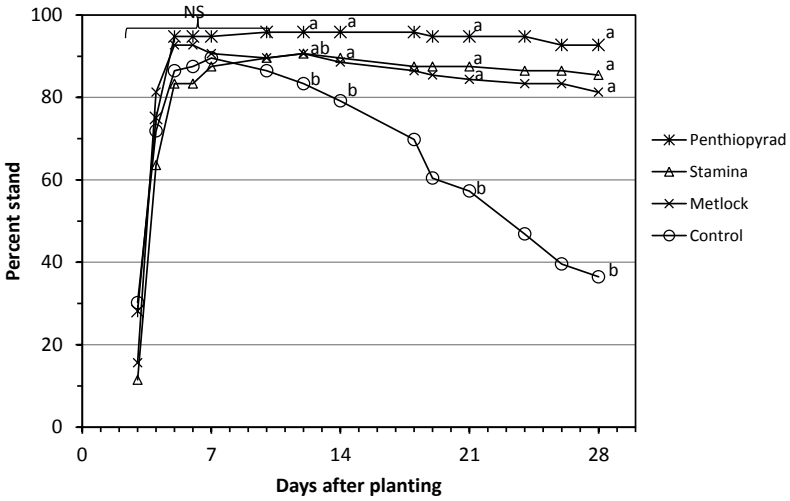

Fig. 2. Percent stand of sugarbeet for seed treated with various fungicides compared to an untreated control (all seed was treated with metalaxyl + Thiram). Seed was planted into a natural field soil infested with *Rhizoctonia solani* AG 2-2 ground barley grain at 10 kg ha^{-1} (≈10 mg/ 600 cc soil/pot) and incubated at ≈77 °F for 4 wk. Stands at each day after planting that are followed by the same letter are not significantly different ($P = 0.05$); NS = not significantly different.

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