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 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 sites at the University of Minnesota, Northwest Research and Outreach Center, Crookston and fertilized for optimal yield and quality. **Site one** was infested with *R. solani* (grown on whole barley grain) at 35 kg ha^{-1} and incorporated into the top 4 inches on July 1, 2010. Soybeans then were planted to obtain infected soybean roots, which were incorporated into soil in the fall for increased inoculum in 2011. **Site two** was infested with *R. solani* (grown on whole barley grain) at 35 kg ha^{-1} and incorporated into the top 4 inches in spring 2011 prior to planting. Both sites were planted May 19, 2011with a *Rhizoctonia*-susceptible conventional sugarbeet variety at 4.5-inch spacing. Two plots (6 rows, 22 inches apart and 25 ft long) 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 weeks after planting (June 17), one plot of each treatment received a postemergence 7-inch band application of Quadris (14.3 fl oz/A). 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 <u>no</u> starter fertilizer was applied. Microrates of Betamix + Upbeet + Stinger + Select + MSO (0.5-0.7pt + 0.125 oz + 50 ml + 300 ml + 1-2 pt A^{-1}, respectively) were applied on June 6, 9, 20, and July 1 for control of weeds. Stinger was not included in the third application. Cercospora leaf spot was controlled by application of Inspire XT (7 oz product), Super Tin 80WP + Topsin M 4.5F (5 oz + 10 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 29, August 18, and September 7, respectively.

At site one, stand counts were taken in the center two rows for each treatment at 13, 18, 28, 33, 43, 50, 57, and 71 days after planting. At site two, stand counts were taken at 13, 15, 19, 28, 33, 41, and 49 days after planting. The center two rows at both sites were harvested on September 29 and data were collected for the number of roots harvested, 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 (General Linear Model) 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).

Application	Product	Active ingredient	Rate
None	-	-	-
Seed	Dynasty	Azoxystrobin	0.25 g a.i./unit seed
Seed	Penthiopyrad	Penthiopyrad	14 g a.i./unit seed
Seed	Sedaxane	Sedaxane	0.05 g a.i./unit seed
Seed	Stamina	Pyraclostrobin	30 g a.i./unit seed
In-furrow	Headline	Pyraclostrobin	12 fl oz product/A
In-furrow	Quadris	Azoxystrobin	14.3 fl oz product/A
In-furrow	Vertisan	Penthiopyrad	38 fl oz product/A

Growth room trial. 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 trial. 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.

Site one: Disease pressure from *R. solani* began very early and by 18-28 days after planting, damping-off was occurring in many treatments (Fig. 1A). Stands for seed treated with penthiopyrad and all three in-furrow (IF) fungicides remained stable through 56 days after planting, although stands treated with Quadris IF were lower to begin with (Fig. 1A). Stands for seed treated with sedaxane, Dynasty, and the untreated control showed similar stand losses from 18 to 71 days after planting and were significantly lower than all other treatments (Fig. 1A). By 71 days after planting, stands in plots treated with Vertisan IF were the highest, followed by seed treated with penthiopyrad, Headline IF and Quadris IF, and Stamina-treated seed, which were intermediate.

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 32 plots averaged across at-planting treatments.

At harvest in site 1, there were significant differences among at-planting treatments for number of harvested roots, RCRR ratings, all yield and quality variables, and revenue (Table 2, top half). Number of harvested roots was highest for Vertisan IF, lowest for Dynasty- and sedaxane-treated seed and the untreated control, and intermediate for penthiopyrad- and Stamina-treated seed and Headline IF and Quadris IF. RCRR ratings were lowest for Quadris

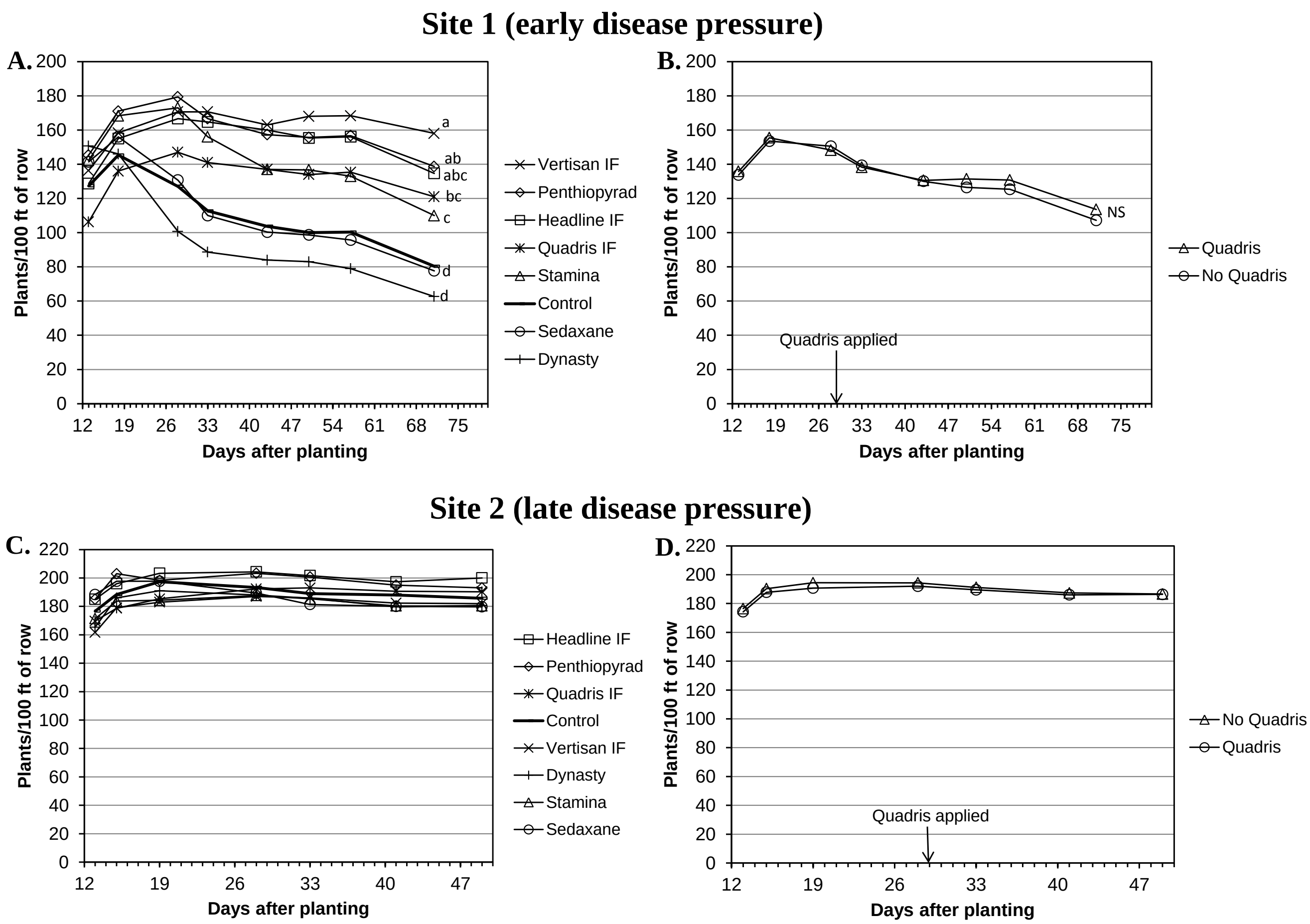

Fig. 1. Stand from field trials in two sites for sugarbeet **A**. and **C**.) treated with various fungicides for control of *Rhizoctonia solani* either on seed or in-furrow (IF) and **B**. and **D**.) treated with a postemergence band application of Quadris or untreated. For **A**, stands at 70 days 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 32 plots averaged across at-planting treatments.

IF and Vertisan IF, highest for Dynasty- and sedaxane-treated seed and the untreated control, and intermediate for Headline IF and penthiopyrad- and Stamina-treated seed. Root and sucrose yields showed similar trends (Table 2). Recoverable sucrose A^{-1} was highest for the three IF fungicides and penthiopyrad-treated seed, lowest for Dynasty-treated seed, and intermediate for Stamina- and sedaxane-treated seed and the untreated control. Similarly, revenue was highest for the three IF fungicides and penthiopyrad treated seed, lowest for Dynasty- and sedaxane- treated seed and the untreated control, and intermediate for 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 32 plots averaged across at-planting treatments.

Site two. 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 (Fig. 1C) and postemergence treatments (Fig. 1D).

At harvest in site 2, there were significant differences among at planting treatments for number of harvested roots, RCRR, root and sucrose yields, and revenue (Table 3, top half). Number of harvested roots was highest for Headline IF and Quadris IF, lowest for the untreated control and Dynasty-, sedaxane-, and Stamina-treated seed, and intermediate for Vertisan IF and penthiopyrad-treated seed. RCRR ratings were lower for the three IF fungicides compared to all other treatments. Root yields were highest for Quadris IF, lowest for Stamina- and Dynasty-treated

Table 2. **Site 1:** 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 T/A[z]	Sucrose[z] %	Sucrose[z] lb/ton	Sucrose[z] lb recov./A	Revenue ($/A)[z]
At-plant treatments							
Untreated control	71 c	4.9 ab	16.8 bc	16.7 c	298 d	5081 bc	803 c
Seed treatments							
Dynasty @ 0.25 g a.i/unit	52 c	5.5 a	13.4 c	17.1 bc	309 bcd	4196 c	687 c
Penthiopyrad @ 14 g a.i. /unit	120 ab	3.8 cd	23.0 a	17.3 bc	317 bc	7317 a	1220 ab
Sedaxane @ 0.05 g a.i./unit	66 c	5.1 ab	16.7 bc	16.7 c	302 cd	5094 bc	812 c
Stamina @ 30 g a.i./unit	99 b	4.5 bc	19.9 ab	17.2 bc	312 bcd	6207 ab	1015 bc
In-furrow treatments							
Headline @ 12 fl oz/A	116 b	3.6 d	22.1 a	17.6 ab	320 abc	7108 a	1199 ab
Quadris @ 14.3 fl oz/A	114 b	2.7 e	21.5 ab	17.6 ab	321 ab	6926 a	1169 ab
Vertisan @ 38 fl oz/A	139 a	2.8 e	23.6 a	18.2 a	337 a	7942 a	1404 a
ANOVA p-value	<0.0001	<0.0001	0.007	0.010	0.014	0.005	0.004
LSD (P = 0.05)[Z]	22.4	0.8	5.1	0.75	18.9	1785	333
Post-emergence							
None	96	4.1	19.6	17.2	312	6167	1020
Quadris @ 14.3 fl oz/A	98	4.1	19.7	17.4	317	6301	1057
ANOVA p-value	0.719	1.00	0.903	0.299	0.370	0.774	0.670
Interaction p-value	0.432	0.903	0.480	0.524	0.772	0.600	0.704

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

Table 3. **Site 2:** 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 T/A[z]	Sucrose[z] %	Sucrose[z] lb/ton	Sucrose[z] lb recov./A	Revenue ($/A)[z]
At-plant treatments							
Untreated control	140 b	3.0 a	22.8 abc	16.7	299	6818 b	1062 b
Seed treatments							
Dynasty @ 0.25 g a.i/unit	141 b	3.2 a	22.0 c	16.9	302	6660 b	1051 b
Penthiopyrad @ 14 g a.i. /unit	154 ab	3.0 a	23.3 abc	17.3	313	7253 ab	1184 ab
Sedaxane @ 0.05 g a.i./unit	142 b	3.4 a	22.6 bc	17.1	308	6950 b	1117 ab
Stamina @ 30 g a.i./unit	142 b	3.0 a	21.1 c	17.7	320	6718 b	1124 ab
In-furrow treatments							
Headline @ 12 fl oz/A	171 a	2.2 b	24.9 ab	17.3	312	7746 a	1261 a
Quadris @ 14.3 fl oz/A	163 a	1.5 b	25.2 a	17.3	312	7824 a	1275 a
Vertisan @ 38 fl oz/A	157 ab	2.0 b	24.6 ab	17.3	313	7718 a	1267 a
ANOVA p-value	0.012	0.0001	0.026	0.318	0.431	0.008	0.027
LSD (P = 0.05)[Z]	18.4	0.7	2.5	NS	NS	742	159
Post-emergence							
None	147	3.2	22.4	17.2	310	6932	1121
Quadris band @	156	2.1	24.2	17.2	310	7490	1214
ANOVA p-value	0.127	<0.0001	0.009	0.688	0.878	0.007	0.017
Interaction p-value	0.814	0.126	0.163	0.380	0.320	0.115	0.112

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

seed, and intermediate for Headline IF and Vertisan IF, penthiopyrad- and sedaxane-treated seed, and the untreated control. Percent sugar and pounds of sucrose ton^{-1} were not significantly different (P = 0.05) among at-planting treatments. Recoverable sucrose A^{-1} was highest for the three IF fungicides, lowest for Dynasty-, sedaxane-, and Stamina-treated seed and the untreated control, and intermediate for penthiopyrad-treated seed. Revenue was highest for the three IF fungicides, lowest for the untreated control and Dynasty-treated seed, and intermediate for penthiopyrad-, Stamina-, and sedaxane treated seed.

Plots treated with a postemergence application of Quadris had significantly lower (P = 0.05) RCRR rating and higher root and sucrose yields, and revenue than plots that did not receive postemergence application of Quadris (Table 3, bottom half).

Growth room trial. Emergence was good and statistically equal for all fungicide-treated seed under controlled environment conditions (Fig. 2). By 7 days after planting, damping-off was beginning to occur in the untreated control. At 2 weeks after planting, seed treatments were beginning to separate. Seedlings from penthiopyrad- and Stamina-treated seed were maintaining healthy stands, while stand was rapidly declining and statistically lower (P= 0.05) for Dynasty- and sedaxane-treated seed and the untreated control (Fig. 2). By 3 weeks after planting, stands from penthiopyrad-treated seed still had not begun to decline, while stands from seed treated with Stamina had begun to decline, but were not significantly lower. Stands from other treatments continued to decline rapidly with Dynasty having intermediate stand and sedaxane-treated seed and the control being the lowest (Fig. 2). Stand for all seed treatments declined between 3 and 4 weeks after planting (Fig. 2). At the end of the 4 week assay, seed treated with penthiopyrad had the highest stand (60%), significantly higher than seed treated with Dynasty (15%), sedaxane (7%), and the untreated control (3%). Stand from seed treated with Stamina was intermediate with 40%.

DISCUSSION

In two very different disease pressure situations, in-furrow fungicides followed by penthiopyrad seed treatment provided the best control of RCRR and sugar yields compared to other seed treatments and the untreated control. In one case (site 1) disease pressure was very high early in the season, most likely due to high populations of *R. solani* on soybean residue. At the time plants began to die from *R. solani*, 4-inch soil temperature maximum had not been above 64.5 °F. On the other hand, at site 2, disease pressure was low all season and damping-off did not occur even though plots had been inoculated prior to planting and soil temperatures were similar at both sites. These results suggest that both inoculum density and soil temperature are important in determining the onset of disease.

Although at-planting treatment results were similar at both sites, results with postemergence application of Quadris were very different. In site 1, where disease started early, infections had already occurred by June 17 when Quadris was applied. At this time plants were at the 4-leaf stage, and 4-inch soil temperature maximum still had not been above 64.5 °F. As a result, plants were already infected and there was no significant effect of postemergence Quadris application. At site 2, however, where disease did not start early, there was a significant effect of postemergence Quadris application (applied on the same date, with similar 4-inch soil temperature).

Interestingly, penthiopyrad, the only seed treatment to provide results similar to in-furrow fungicides in the field trial, also was the most effective in controlling damping-off in the growth room trial. Stamina seed treatment also had good activity in the growth room trial and tended to give intermediate results in the field trial. Sedaxane and Dynasty seed treatments likely were applied at rates that were too low for activity against *R. solani* in natural field soil.

In this trial we used a *Rhizoctonia*-susceptible variety to increase the likelihood of having good disease pressure to test fungicides. Under heavy disease pressure, the best combination of strategies for full-season control of *Rhizoctonia* is a partially resistant variety, early planting, an effective seed treatment or in-furrow fungicide, and a timely application of Quadris postemergence.

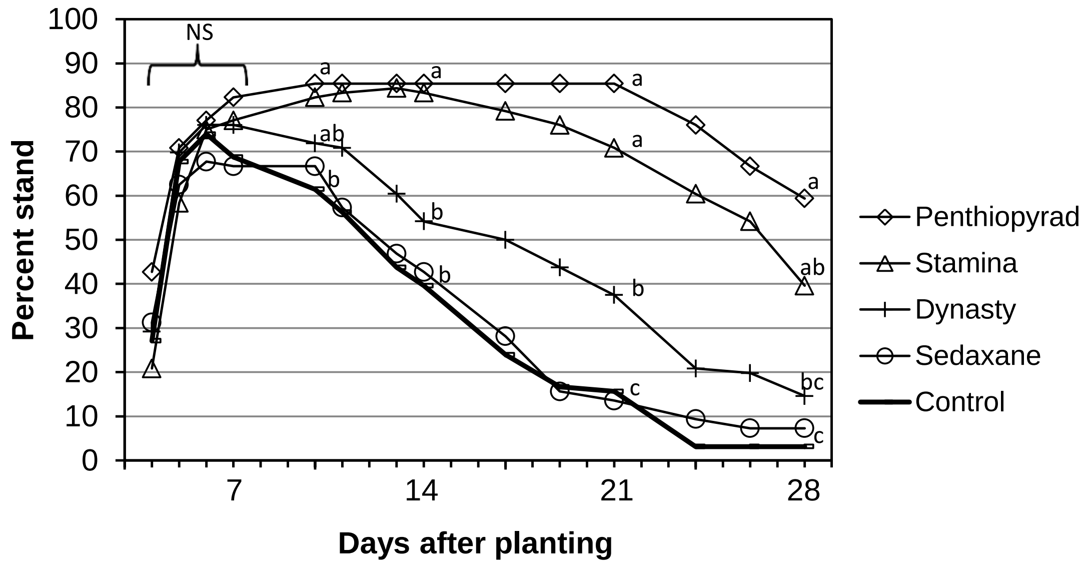

Fig. 2. Percent stand of sugarbeet for seed treated with various fungicides compared to an untreated control (all seed was treated with metalaxyl + Thiram). Seed was planted into a natural field soil infested with *Rhizoctonia solani* AG 2-2 at 10 kg ha^{-1} ground barley grain (≈10 mg/600 cc soil /pot) and incubated at ≈77 °F for 4 wk. Stands at 10, 14, 21, and 28 days after planting that are followed by the same letter are not significantly different (P = 0.05).

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