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TIMING APPLICATIONS OF QUADRIS FOR CONTROL OF RHIZOCTONIA ON SUGARBEET

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Rhizoctonia solani AG 2-2 (= *R. solani*) is a soilborne fungus that causes diseases on sugarbeet throughout the growing season. Warm, wet weather is especially favorable for disease development. Depending upon when these conditions occur, the pathogen causes seed rot, damping-off, and root and crown rot of older plants throughout the season. In recent years, Rhizoctonia diseases, especially mid- to late-season root and crown rot, have been an increasing problem in sugarbeet fields in Minnesota and North Dakota. This trend is attributed to unusually wet weather and buildup of inoculum by close rotations of sugarbeet with bean crops (*R. solani* AG 2-2 also causes stem rot and root rot on soybean and edible beans). Fungicides were not available for control of Rhizoctonia root and crown rot until late in 2000, when Quadris (azoxystrobin) was registered for control of *R. solani* as well as Cercospora leaf spot caused by *Cercospora beticola* (= *C. beticola*).

In previous studies, Quadris has been shown to reduce Rhizoctonia diseases on sugarbeet (See Sugarbeet Research and Extension Reports 28:298-300 (1998); 29:275-277 (1999); 30:266-270 (2000); 32:282-286 (2002). These trials were conducted in a Rhizoctonia Nursery at the University of Minnesota, Northwest Research and Outreach Center (NWROC), Crookston. Epidemics were initiated by application of inoculum of *R. solani* at various stages of plant development. Overall, in-furrow applications of Quadris were very effective in controlling seed rot and damping-off, but these trials were not taken to harvest. When *R. solani* was inoculated on sugarbeet plants at the five- to eight-leaf stage and environmental conditions were favorable for disease, as many as three band applications of Quadris were inadequate to control root and crown rot. A broadcast application of Quadris at row closure (before disease developed), with a second application 2 to 3 weeks later, however, provided excellent protection through harvest. With so many options for timing treatment of sugarbeet with Quadris, and because of conflicting reports from other sugarbeet regions about when Quadris should be applied, questions continue to be raised about when this fungicide should be applied for optimal control of *R. solani*.

Quadris is in the strobilurin class of fungicides, which also includes Stratego, Gem, and Headline (a highly effective fungicide for control of Cercospora leaf spot on sugarbeet). Only one application of a strobilurin fungicide is recommended for control of Cercospora leaf spot per season. This is done to avoid buildup of resistance in populations of *C. beticola* to the strobilurin class of fungicides. Thus, questions have been raised about whether Quadris should be applied near time of row closure for control of late-season Rhizoctonia root and crown rot (Quadris provides inadequate control of Cercospora leaf spot) – or if a single application of Headline for control of Cercospora leaf spot also suppresses Rhizoctonia root and crown rot.

OBJECTIVES

The purpose of our experiments were to evaluate effectiveness of: 1) Quadris in controlling *R. solani* infections initiated at various stages of sugarbeet development and 2) Quadris and Headline in controlling Rhizoctonia root and crown rot initiated near row closure.

MATERIALS AND METHODS

Duplicate trials were conducted in Rhizoctonia nurseries located at the University of Minnesota, NWROC, Crookston. Site 1 was located about 1 mile south of Site 2. Both sites were used to evaluate Quadris applied on seed and in-furrow (with a postemergence band application at the four-leaf stage), as a band treatment applied at the 8 to 10-leaf and 12-leaf stages, and as a broadcast application around row closure. Headline was evaluated as a broadcast treatment only at Site 2.

Both sites were fertilized on May 16, 2002 to obtain optimal yields. Seed of ACH 817 treated with standard rates of Apron + Thiram was sown on May 28 for seed and in-furrow trials and on May 17 for band and broadcast trials. Each trial was arranged in a randomized block design of four replicates. Seed and in-furrow trials and band application trials had four-row plots and broadcast trials had six-row plots. Rows were 22 inches apart and 30 feet long. Counter was applied over the row in a 7-inch band at planting (1.8 lb active ingredient [a.i.]/A) for control of root maggot. Seed and in-furrow trials were treated with microrates of herbicides on June 21 (0.5 pint Betanex, 1/8 oz Upbeet, 40 ml Stinger, 60 ml Select, 1½ pint Scoil) and June 27 (0.5 pint Betanex, 1/8 oz Upbeet, 40 ml Stinger, 5.3 oz Poast, 1 ½ pint Scoil [product/A]). Band and broadcast trials were treated with microrates of herbicides on June 7 (0.5 pint Betamix, 1/8 oz Upbeet, 40 ml Stinger, 60 ml Select, 1 ¾ pint Scoil [product/A]) and applications on June 21 and 27 were the same as described for seed and in-furrow trials. All trials were thinned on, or a few days before, July 1. Cultivation of seed and in-furrow trials was on July 2 and 24 and for band and broadcast trials was on July 1. Fungicides applied for control of Cercospora leaf spot did not include strobilurin chemistry. All trials at both sites were treated on August 2, August 20 (August 18 for Site 2) and September 4 with 5 oz SuperTin, 13 oz Eminent, and 5 oz SuperTin (product/A), respectively.

All data were collected on the two middle rows of each plot. Stand data were collected throughout the summer until harvest. Trials were harvested on September 25 Plots were assessed for number of harvested roots and 20 roots were selected at random and rated for Rhizoctonia root and crown rot (0-7 scale, 0 = root clean and healthy, 7 = root completely rotted and foliage dead). Ten of these roots per plot were analyzed by the American Crystal Sugar Co. Quality Laboratory, East Grand Forks, MN for determination of sucrose yield and quality.

Seed and In-furrow Treatments. Treatments included two rates of Quadris applied to seed (0.025 and 0.05g a.i./kg), two rates of Quadris applied in-furrow at planting (0.1 and 0.15 oz a.i./1000 ft row = 0.4 and 0.6 fluid oz product/1000 ft row, respectively), two rates of Quadris applied in-furrow (0.1 and 0.15 oz a.i./1000 ft row) with a second application at the same rate when plants reached the four-leaf stage, and two controls (*R. solani*-inoculated plots not treated with Quadris and an untreated control).

Inoculum of *R. solani* was grown on sterile barley grains and air-dried. Plots were inoculated on May 28 by sprinkling 1 Liter of *R. solani*-infested barley grains uniformly within a 3.7 ft wide area over the 30 ft length of each plot. Inoculum was hand raked into soil and averaged 0.2% volume of soil to a 2-inch depth. Later in the day, plots were sown with a cone planter; seed (250/30 ft row) and Quadris (2 middle rows only) were simultaneously placed in-furrow. To encourage disease, Site 1 was irrigated on May 29 and 31 and on June 5 and 7 at rates of 60, 48, 54, and 60 gallons/plot, respectively. A tank truck transported water to Site 2 and was irrigated on May 31 and June 4 at 24 and 30 gallons/plot, respectively. Postemergence applications of Quadris were made at about the four-leaf stage on June 12.

Band Treatments. Plots were inoculated by sprinkling 16 g of *R. solani*-infested barley grains along a 30 ft row (two middle rows/plot) when plants were at the 8 to 10-leaf stage on July 9. Soil was lightly raked into the crowns and then Quadris was applied at two rates (0.1 and 0.15 oz a.i./1000 ft row = 0.4 and 0.6 fluid oz product/1000 ft row, respectively) with a second application at the same rate 10 days later when plants were at the 12-leaf stage. On July 15, additional plots also were inoculated with *R. solani* (as previously described) when plants reached the 12-leaf stage and treated with a single application of Quadris (0.15 oz a.i./1000 ft row = 0.6 fluid oz product/1000 ft row). Applications of Quadris were made in a 7-inch band with a three-nozzle row applicator at 30 psi (one center nozzle was directly over the row and two side nozzles were at 45 degrees and angled toward the crown). Controls consisted of plots inoculated with *R. solani* at the 8 to 10-leaf stage (no Quadris), plots inoculated with *R. solani* at the 12-leaf stage (no Quadris), and untreated plots. No irrigation was necessary because of abundant rainfall after plots were inoculated in July (total of 3.3 inches, including 1.2 inches later in the same day plants were inoculated and treated and 1.1 inches the following day) and in August (total of 9.2 inches).

Broadcast Treatments. Quadris was broadcast-applied to plots at 0.15 lb a.i./A (= 9.2 fluid oz product/A) in 20 gallons of water at 100 psi on July 9 (about 8 to 10-leaf stage); Headline (0.15 lb a.i./A = 9 fluid oz product/A) also was applied to other plots in the same manner. On July 15 (6 days later), plants were near the 12-leaf stage and inoculated with *R. solani* by sprinkling 16g of infested barley grains along each of two middle rows and soil was lightly hand raked into crowns. On July 15, additional plots were co-treated with *R. solani* (as previously described) and Quadris (0.15 lb a.i./A) or Headline (0.15 lb a.i/A), which were applied about 1 hour later. Headline was evaluated only at Site 2. Controls included plots inoculated with *R. solani* and no Quadris on July 15 and an untreated control.

RESULTS

Seed and In-furrow Treatments. On June 5 (8 days after planting), stands at Site 1 (Fig. 1A) were statistically highest for the untreated control, lowest where Quadris (0.1 oz a.i/1000 ft row) had been applied in-furrow, and other treatments were intermediate. On this same date at Site 2 (Fig. 1B), stands were statistically highest for Quadris-treated seed at the 0.05g/kg rate, lowest for the untreated control, and other treatments were intermediate. These initial stand counts, however, were not indicative of trends for the remainder of June (Fig. 1) or after thinning on July 1 (Fig. 2).

Similar trends tended to occurred at both sites (Fig. 1 and 2) from about mid-June through late August, although stand loss from *R. solani* was greatest at Site 2 and this factor tended to result in greater separation of treatments. The untreated control at both sites also sustained some stand loss, which was caused by naturally occurring inoculum of *R. solani*. At Site 1, the highest stands occurred in the untreated control and in plots treated with one (in-furrow) or two treatments (in-furrow and at the four-leaf stage) of Quadris at 0.15 or 0.1 oz a.i/1000 ft row per application (Fig. 1A and Fig. 2A). These treatments resulted in stands that were statistically higher than plants from seed treated with 0.025 or 0.05g/kg of Quadris and the *R. solani*-inoculated control, which usually were nearly equal and averaged between five to 10 plants/60 ft row by August 20 (Fig. 2A). Stands at Site 2 were highest in plots with two treatments (in-furrow and at the four-leaf stage) of Quadris at 0.1 or 0.15 oz a.i./1000 ft per application and the untreated control (Fig. 1B and 2B). Stands were intermediate for plots treated with one application of Quadris at either rate, but were higher for 0.15 oz than 0.1 oz a.i/1000 ft. Stands from seed treated with both rates of Quadris and the *R. solani*-inoculated control declined equally rapidly and plants were dead by August 20 (Fig. 2B).

Harvest data are summarized in Table 1. Overall, Rhizoctonia diseases were severe in all plots throughout the season because of wet weather so even the best Quadris treatments and the untreated control had low yields. At Site 1, plots sown with Quadris-treated seed at both rates had no stand at harvest and this missing data were excluded from statistical analyses. When Quadris was applied in-furrow or in-furrow plus at the four-leaf stage (0.1 or 0.15 oz a.i./1000 ft row/application), root rot was significantly reduced and stands, root yield, and recoverable sucrose were significantly higher compared to the *R. solani*-inoculated control. The best treatment was two applications of Quadris at 0.15 oz a.i./1000 ft row (in-furrow and at the four-leaf stage). This treatment resulted in more roots, less disease, and higher root yield and recoverable sucrose than the untreated control, although these benefits were not statistically different. Data on percent sucrose, loss to molasses, and sucrose per ton were not statistically different among treatments.

At Site 2, there were no surviving plants at harvest in plots sown with seed treated with either rate of Quadris, treated in-furrow with Quadris at 0.1 oz a.i./1000 ft row, and the *R. solani*-inoculated control. Plants survived in the remaining treatments, but not necessarily in all replicates. Hence, data for Site 2 (Table 1) are based on averages of treatments that provided yield in at least two replicates and are not analyzed statistically. Stand, root yields, and sucrose quality were best in the untreated control, followed in decreasing order by plots treated with two treatments of Quadris at 0.15 or 0.1 oz a.i./application (in-furrow and at the four-leaf stage), and one treatment of Quadris at 0.15 oz a.i./1000 ft row.

Band Treatments. When Quadris was applied on July 9, baseline stands were 80 ± 5 and 75 ± 5 plants/60 ft row at Site 1 (Fig. 3A) and Site 2 (Fig. 3B), respectively. At Site 1, stands declined within the next 20 days and all treatments were equal and significantly higher than the control where plants were inoculated with *R. solani* at the 8 to 10-leaf stage (Fig. 3A). The untreated control sustained some stand loss because of infections from naturally occurring inoculum of *R. solani*. Stands continued to decline in all plots and by harvest they were highest for the untreated control, which was closely followed in descending order by plots inoculated with *R. solani* at the 8 to 10-leaf stage and then treated with Quadris at the 8 to 10- and 12-leaf stages (0.15 oz a.i./1000 ft row/application), plots inoculated with *R. solani* at the 8 to 10-leaf stage and then treated with Quadris at the 8 to 10- and 12-leaf stages (0.1 oz a.i./1000 ft row/application), and plots co-treated with *R. solani* and Quadris at the 12-leaf stage (0.15 oz a.i./1000 ft row). These treatments resulted in significantly higher stands than control plots inoculated with *R. solani* at the 8 to 10- or 12-leaf stages.

Within 20 days after treatments were applied at Site 2, stand losses were minimal and statistically the same for all treatments compared to the control where plants were inoculated with *R. solani* at the 8 to 10-leaf stage (Fig. 3B).

A

B

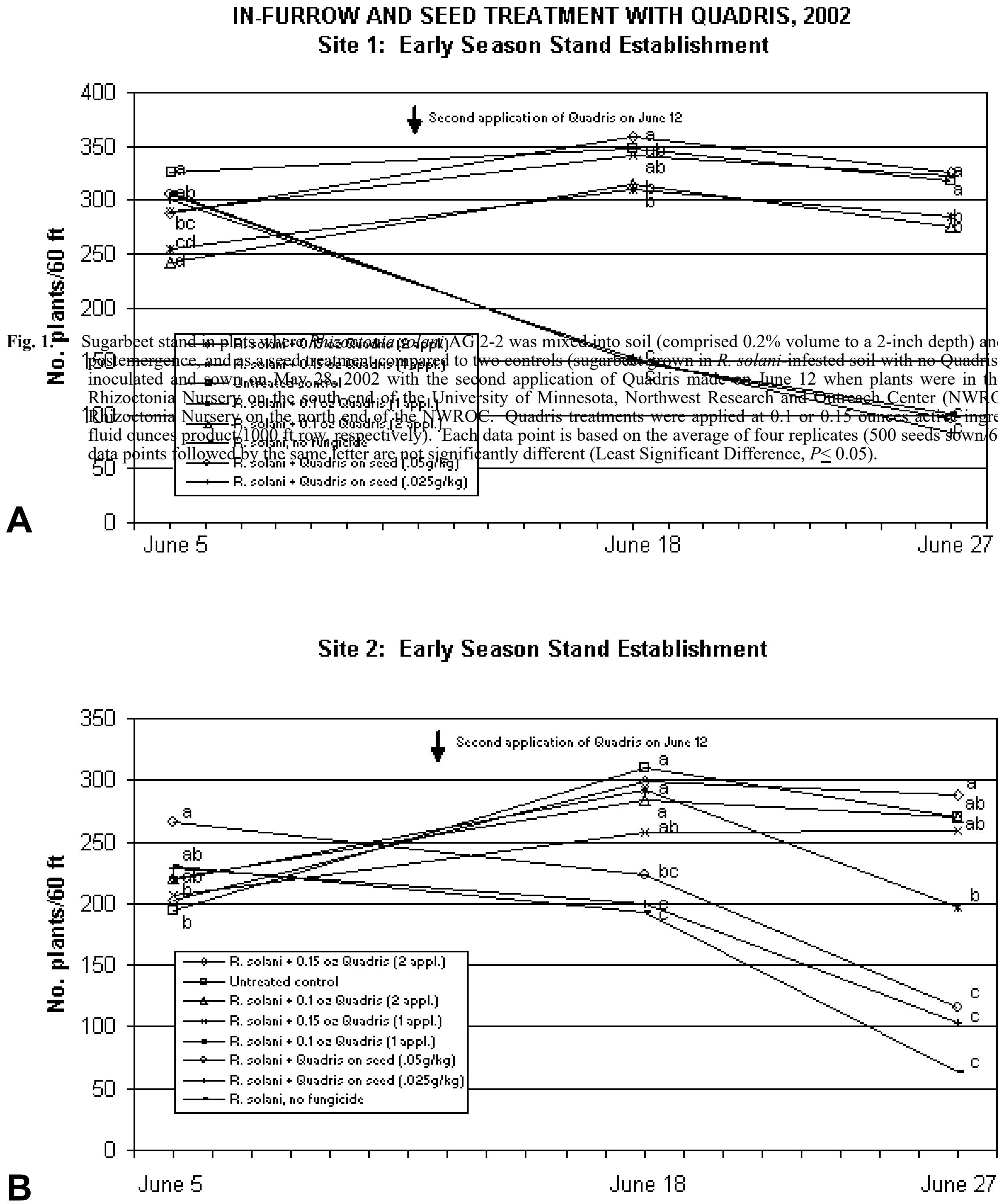
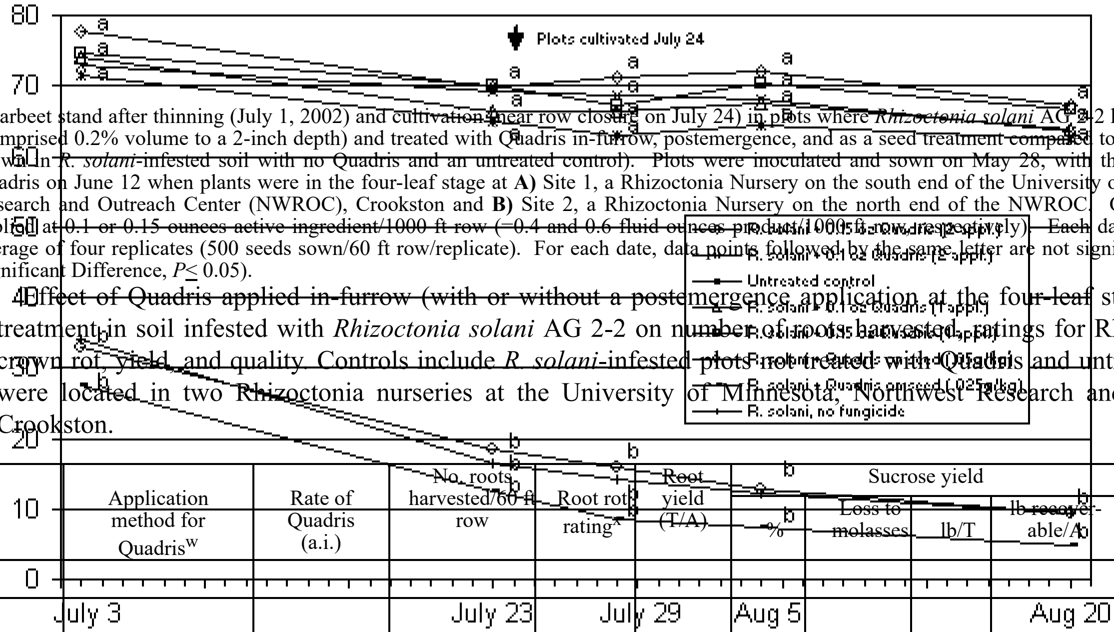


Fig. 1. Sugarbeet stand in plots where *Rhizoctonia solani* AG 2-2 was mixed into soil (comprised 0.2% volume to a 2-inch depth) and treated with Quadris in-furrow, postemergence, and as a seed treatment compared to two controls (sugarbeet grown in *R. solani*-infested soil with no Quadris and untreated plots). Plots were inoculated and sown on May 28, 2002 with the second application of Quadris made on June 12 when plants were in the four-leaf stage at **A)** Site 1, a Rhizoctonia Nursery on the south end of the University of Minnesota, Northwest Research and Outreach Center (NWROC), Crookston and **B)** Site 2, a Rhizoctonia Nursery on the north end of the NWROC. Quadris treatments were applied at 0.1 or 0.15 ounces active ingredient/1000 ft row (=0.4 and 0.6 fluid ounces product/1000 ft row, respectively). Each data point is based on the average of four replicates (500 seeds sown/60 ft row/replicate); for each date, data points followed by the same letter are not significantly different (Least Significant Difference, $P \leq 0.05$).

IN-FURROW AND SEED TREATMENT WITH QUADRIS, 2002

Site 1: Post-thinning



Site 2: Post-thinning

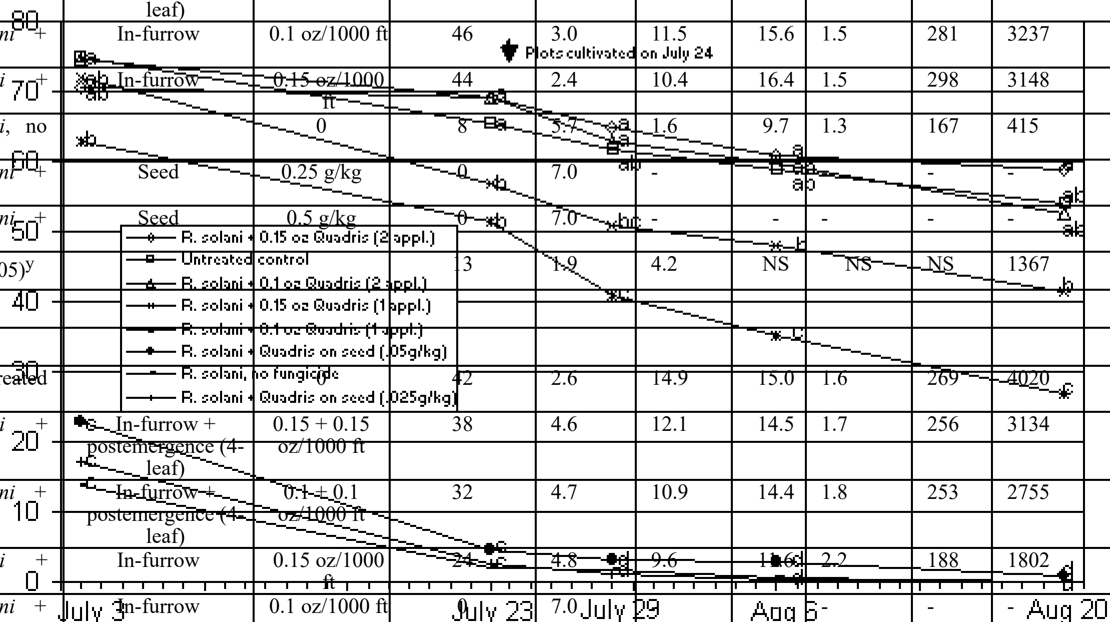


Fig. 2. Sugarbeet stand after thinning (July 1, 2002) and cultivation (near row closing on July 24) in plots where *Rhizoctonia solani* AG 2-2 had been mixed into soil (comprised 0.2% volume to a 2-inch depth) and treated with Quadris in-furrow, postemergence, and as a seed treatment compared to two controls (sugarbeet grown in *R. solani*-infested soil with no Quadris and an untreated control). Plots were inoculated and sown on May 28, with the second application of Quadris on June 12 when plants were in the four-leaf stage at **A)** Site 1, a Rhizoctonia Nursery on the south end of the University of Minnesota, Northwest Research and Outreach Center (NWROC), Crookston and **B)** Site 2, a Rhizoctonia Nursery on the north end of the NWROC. Quadris treatments were applied at 0.1 or 0.15 ounces active ingredient/1000 ft row (=0.4 and 0.6 fluid ounces product/1000 ft row, respectively). Each data point is based on the average of four replicates (500 seeds sown/60 ft row/replicate). For each date, data points followed by the same letter are not significantly different (Least Significant Difference, $P \leq 0.05$).

Table 1. Effect of Quadris applied in-furrow (with or without a postemergence application at the four-leaf stage) and as a seed treatment in soil infested with *Rhizoctonia solani* AG 2-2 on number of roots harvested, ratings for Rhizoctonia root and crown rot, yield, and quality. Controls include *R. solani*-infested plots not treated with Quadris and untreated plots. Trials were located in two Rhizoctonia nurseries at the University of Minnesota, Northwest Research and Outreach Center, Crookston.

Treatment[v]	Application method for Quadris[w]	Rate of Quadris (a.i.)	No. roots harvested/60 ft row	Root rot rating[x]	Root yield (T/A)	Sucrose yield			
						%	Loss to molasses	lb/T	lb recoverable/A
Site 1									
R. solani + Quadris	In-furrow + postemergence (4-leaf)	0.15 + 0.15 oz/1000 ft	60	1.6	16.3	16.9	1.5	308	5051
Untreated control		0	49	2.4	14.2	15.4	1.5	278	3961
R. solani + Quadris	In-furrow + postemergence (4-leaf)	0.1 + 0.1 oz/1000 ft	49	2.7	12.7	16.4	1.4	301	3884
R. solani + Quadris	In-furrow	0.1 oz/1000 ft	46	3.0	11.5	15.6	1.5	281	3237
R. solani + Quadris	In-furrow	0.15 oz/1000 ft	44	2.4	10.4	16.4	1.5	298	3148
R. solani, no Quadris		0	8	5.7	1.6	9.7	1.3	167	415
R. solani + Quadris	Seed	0.25 g/kg	0	7.0	-			-	-
R. solani + Quadris	Seed	0.5 g/kg	0	7.0	-	-	-	-	-
LSD ($P \leq 0.05$)[y]			13	1.9	4.2	NS	NS	NS	1367
Site 2[z]									
Untreated control		0	42	2.6	14.9	15.0	1.6	269	4020
R. solani + Quadris	In-furrow + postemergence (4-leaf)	0.15 + 0.15 oz/1000 ft	38	4.6	12.1	14.5	1.7	256	3134
R. solani + Quadris	In-furrow + postemergence (4-leaf)	0.1 + 0.1 oz/1000 ft	32	4.7	10.9	14.4	1.8	253	2755
R. solani + Quadris	In-furrow	0.15 oz/1000 ft	24	4.8	9.6	11.6	2.2	188	1802
R. solani + Quadris	In-furrow	0.1 oz/1000 ft	0	7.0			-	-	-
R. solani, no Quadris		0	0	7.0	-	-	-	-	-
R. solani + Quadris	Seed	0.25 g/kg	0	7.0	-	-	-	-	-
R. solani + Quadris	Seed	0.5 g/kg	0	7.0	-	-	-	-	-

v Soil was infested with 1 Liter of *R. solani*-infested barley grains by spreading over a 3.7 ft wide band in the center of each plot (30 ft long) and then gently raking to mix into soil (0.2% volume, 2-inch depth) on May 28, 2002. Plots were sown with variety Crystal 817 on May 28 (500 seeds/60 ft row, 4 rows/plot, 4 replicates/treatment). Plots were thinned on July 1.

w Seed and in-furrow applications of Quadris were simultaneously made directly into the furrow at about a 1-inch depth; Quadris-treated sugarbeet seed was pretreated before sowing; and postemergence applications of Quadris were made at the four-leaf stage over the row in a 7-inch band. Quadris was applied at 0.1 or 0.15 ounces active ingredient/1000 ft of row (=0.4 and 0.6 fluid ounces product/1000 ft row).

x Root rot rating = 0-7 scale, 0 = root healthy, 7 = root completely rotted and foliage dead.

y LSD = Least Significant Difference; if significant, LSD value provided for mean separations; NS = not significant; - = no data (because of no stand).

z Means provided based on variable number of replicates because of severe disease caused by *R. solani.*

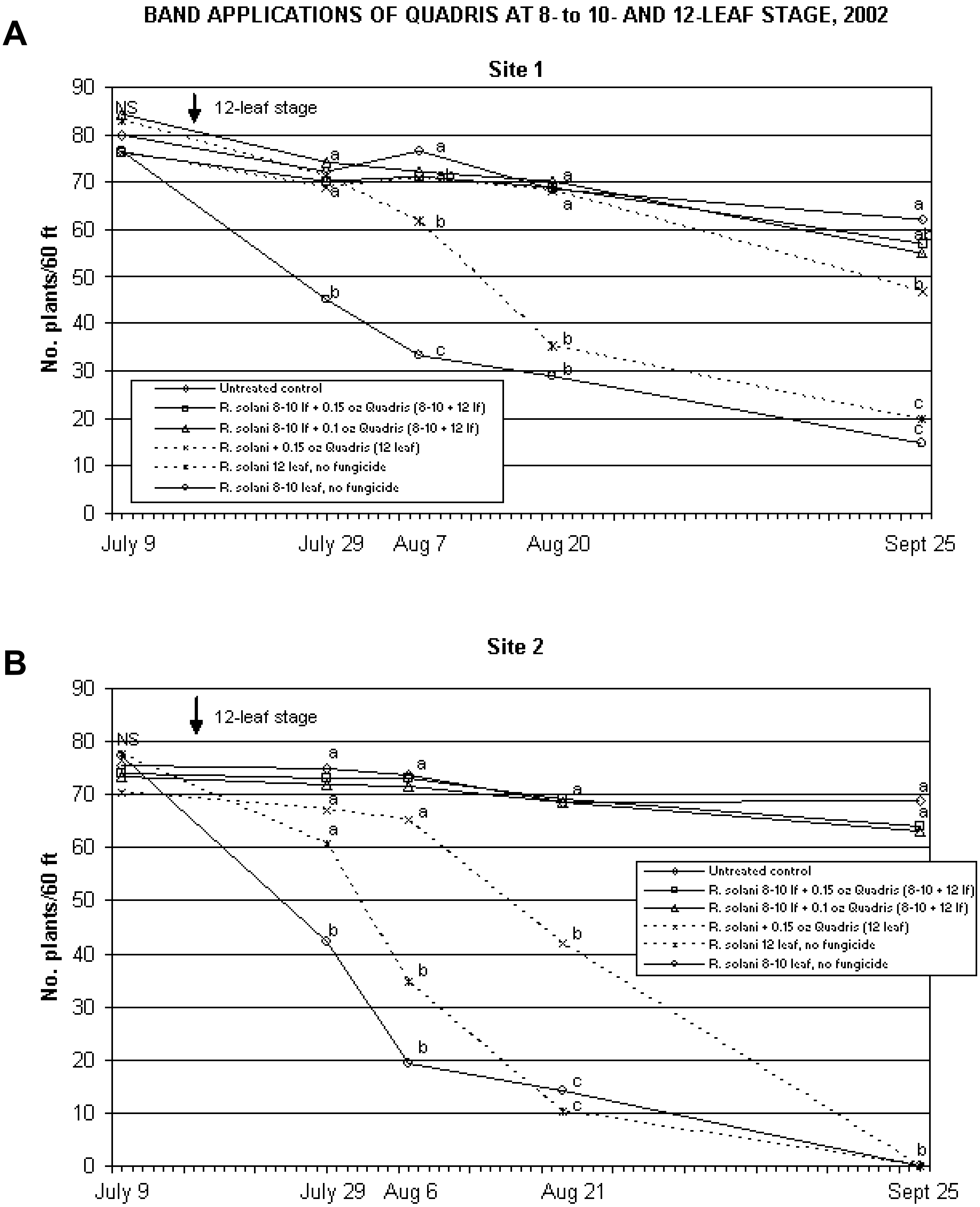


Fig. 3. Sugarbeet stand in plots where *Rhizoctonia solani* AG 2-2 and Quadris were applied in a 7-inch band at the 8 to 10-leaf stage (July 9, 2002), with a second application of Quadris at the 12-leaf stage (July 19), compared to plots co-treated with *R. solani* and Quadris at the 12-leaf stage and controls (plants inoculated with *R. solani* at the 8 to 10- or 12-leaf stage that were not treated with Quadris and untreated plots) at **A)** Site 1, a Rhizoctonia Nursery on the south end of the University of Minnesota, Northwest Research and Outreach Center (NWROC), Crookston and **B)** Site 2, a Rhizoctonia Nursery on the north end of the NWROC. Quadris was applied at 0.1 or 0.15 ounces active ingredient/1000 ft row (=0.4 and 0.6 fluid ounces product/1000 ft row). Each data point is based on the average of four replicates; for each date, data points followed by the same letter are not significantly different (Least Significant Difference, $P \leq 0.05$).

Table 2. Effect of band applications of Quadris on number of sugarbeet roots harvested, ratings for Rhizoctonia root and crown rot, yield, and quality. Plants in the 8 to 10-leaf stage (July 9, 2002) were co-treated with *Rhizoctonia solani* AG 2-2 and Quadris with a second application of Quadris when plants were in the 12-leaf stage (July 19) and compared to plots co-treated with *R. solani* and Quadris at the 12-leaf stage and controls (plants inoculated with *R. solani* in the 8 to 10- or 12-leaf stages that were not treated with Quadris and untreated plots). Sites 1 and 2 are Rhizoctonia nurseries located about 1 mile apart at the University of Minnesota, Northwest Research and Outreach Center, Crookston.

Treatment[w,x]	Plant stage @ application	Rate of Quadris (a.i./1000 ft, 7-inch band)	No. roots harvested/60 ft row	Root rot rating[y]	Root yield (T/A)	Sucrose yield			
						%	Loss to molasses	lb/T	lb recover-able/A
Site 1									
Untreated control		0	62	1.7	21.0	16.0	1.6	289	6066
R. solani + Quadris	8-10 + 12 leaf	0.15 + 0.15 oz	57	1.7	20.0	16.1	1.5	292	5843
R. solani + Quadris	8-10 + 12 leaf	0.1 + 0.1 oz.	56	1.8	21.1	15.0	1.7	267	5594
R. solani + Quadris	12 leaf	0.15 oz	47	2.8	17.0	15.6	1.5	281	4718
R. solani, no Quadris	12 leaf	0	20	5.8	4.1	12.8	2.3	211	864
R. solani, no Quadris	8-10 leaf	0	15	5.7	4.4	10.7	1.4	187	1025
LSD ($P \le 0.05$)[z]			15	1.2	3.6	NS	NS	NS	947
Site 2									
Untreated control		0	69	1.6	26.3	15.1	1.6	269	7058
R. solani + Quadris	8-10 + 12 leaf	0.15 + 0.15 oz	64	1.4	26.0	15.5	1.6	278	7226
R. solani + Quadris	8-10 + 12 leaf	0.1 + 0.1 oz.	63	1.6	26.2	16.0	1.4	292	7650
R. solani + Quadris	12 leaf	0.15 oz	-	7.0	-	-	-	-	-
R. solani, no Quadris	8-10 leaf	0	-	7.0	-	-	-	-	-
R. solani, no Quadris	12 leaf	0	-	7.0	-	-	-	-	-

W Inoculum of *R. solani* was applied along the row (16 g/30 ft row) and then soil was lightly raked into the crown to cover inoculum before the first application of Quadris. Quadris was applied in a 7-inch band at 0.1 or 0.15 ounces active ingredient/1000 ft row (=0.4 and 0.6 fluid ounces product/1000 ft row, respectively).

X Each value for Site 1 based on four replicates and for Site 2, based on three replicates.

y Root rot rating at harvest (September 25, 2002) on a 0 – 7 scale, 0 = roots healthy, 7 = root completely rotted and foliage dead.

z LSD = Least Significant Difference; if significant, LSD value is provided for mean separations; NS = not significant; - = no data presented because all plants were dead; data for Site 2 not analyzed statistically because all plants were dead in three treatments and surviving plants in other treatments provided yield in only two or three replicates.

Stand continued to decline across all treatments but was especially severe in plots co-treated with *R. solani* and Quadris at the 12-leaf stage and controls where plants were inoculated with *R. solani* at the 8 to 10- or 12-leaf stages. By harvest, stands were highest and statistically the same in the untreated control and in plots inoculated with *R. solani* at the 8 to 10-leaf stage and then treated with Quadris at the 8 to 10- and 12-leaf stages (0.1 or 0.15 oz a.i./1000 ft row/ application). All plants were dead in plots co-treated with *R. solani* and Quadris (0.15 oz a.i./1000 ft row) at the 12-leaf stage and in controls where plants were inoculated with *R. solani* at the 8 to 10- or 12-leaf stages.

Overall, yields were lower than expected because weather was extremely favorable for Rhizoctonia root and crown rot. Harvest data for both sites are shown in Table 2. The untreated control and plots inoculated with *R. solani* at the 8 to 10-leaf stage and then treated with Quadris at the 8 to 10- and 12-leaf stages (0.1 or 0.15 oz a.i./1000 ft row/ application) consistently resulted in more harvested roots, lower root rot ratings, and higher root yields and recoverable sucrose compared to the other treatments at both sites. At Site 1, harvest data were intermediate for plants co-treated with *R. solani* and Quadris at the 12-leaf stage compared to inoculated plots treated twice with Quadris and the *R. solani*-inoculated controls. At Site 2, no plants survived in plots co-treated with *R. solani* and Quadris at the 12-leaf stage. At Site 1, control plots inoculated with *R. solani* at the eight- or 12-leaf stages had more disease, lower stands, yield, and quality compared to all other treatments and at Site 2, no plants survived in these controls.

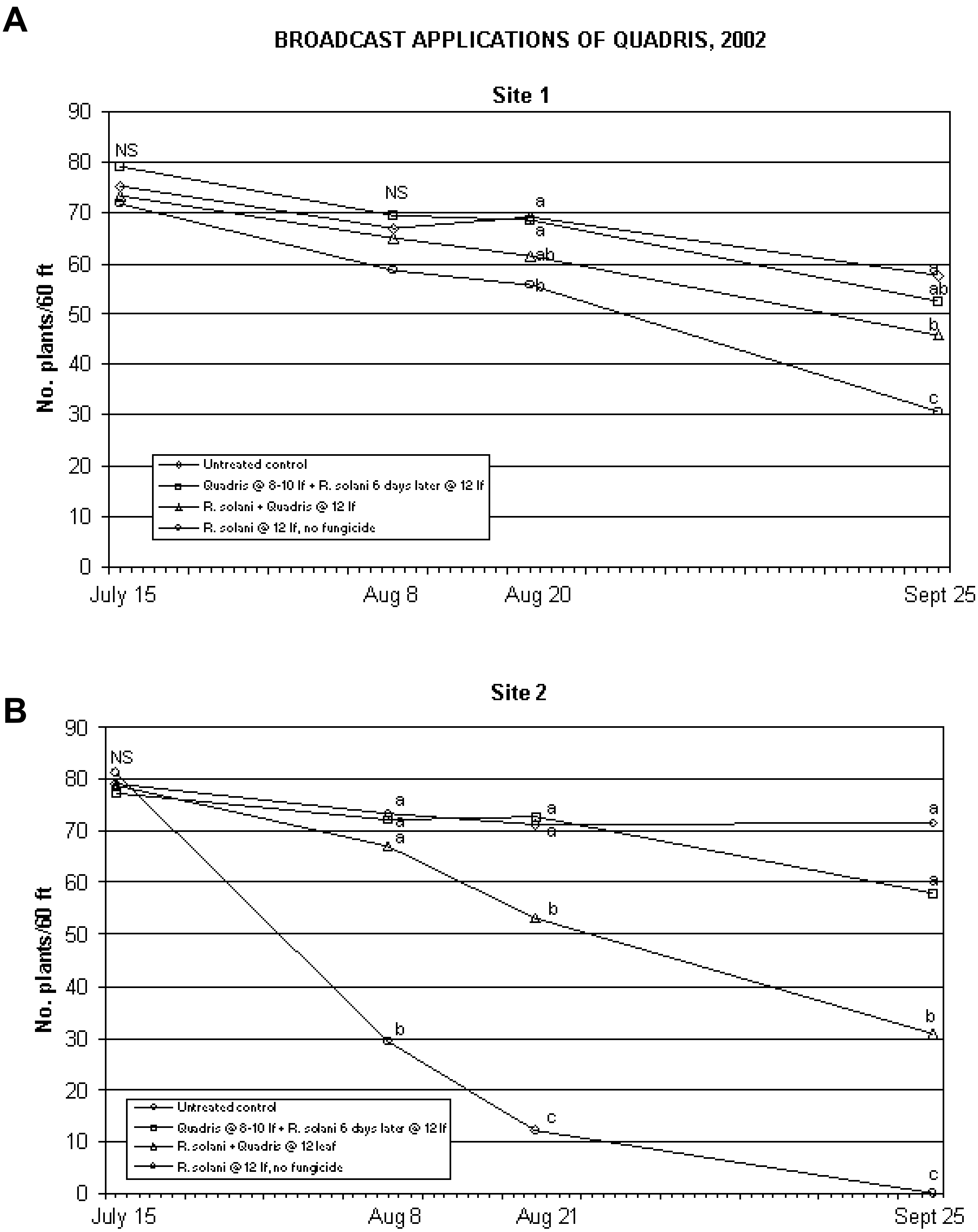


Fig. 4. Sugarbeet stand in plots where Quadris was broadcast (July 9, 2002) at the 8 to 10-leaf stage 6 days before inoculation of plants with *Rhizoctonia solani* AG 2-2 (July 15) compared to co-application of *R. solani* and Quadris (broadcast) at row closure (July 15) and two controls (plants inoculated with *R. solani* on July 15 and untreated plants) at **A)** Site 1, a Rhizoctonia Nursery on the south end of the University of Minnesota, Northwest Research and Outreach Center (NWROC), Crookston and **B)** Site 2, a Rhizoctonia nursery on the north end of the NWROC. Quadris was applied at 0.15 pounds active ingredient/A (=9.2 fluid ounces product/A). Each data point is based on the average of four replicates for Site 1 and three replicates for Site 2; for each date, data points followed by the same letter are not significantly different (Least Significant Difference, $P \leq 0.05$).

Table 3. Effect of broadcast applications of Quadris on number of sugarbeet roots harvested, ratings for Rhizoctonia root and crown rot, yield, and quality. Quadris was applied (July 9) at the 8 to 10-leaf stage 6 days before inoculation with *Rhizoctonia solani* AG 2-2 (12-leaf stage on July 15) and compared to Quadris and *R. solani* co-applied at the 12-leaf stage and controls (plants inoculated with *R. solani* at the 12-leaf stage that were not treated with Quadris and untreated plots). Sites 1 and 2 are

Rhizoctonia nurseries located about 1 mile apart at the University of Minnesota, Northwest Research and Outreach Center, Crookston.

Treatment[w,x]	No. roots harvested/60 ft row	Root rot rating[y]	Root yield (T/A)	Sucrose yield			
				%	Loss to molasses	lb/T	lb recover-able/A
Site 1							
Untreated control	58	2.3	19.9	15.8	1.5	285	5612
Quadris (0.15 lb a.i./A) + *R. solani* 6 days later @ 12-leaf stage	53	2.7	17.3	15.8	1.6	284	4951
R. solani + Quadris (0.15 lb a.i./A) @ 12-leaf stage	46	4.0	14.0	15.0	1.7	267	3694
R. solani @ 12-leaf stage, no Quadris	31	5.7	6.5	14.7	1.7	261	1622
LSD ($P \leq 0.05$)[z]	11	1.1	6.3	NS	NS	NS	1813
Site 2							
Untreated control	72	1.2	26.3	16.4	1.7	294	7723
Quadris (0.15 lb a.i./A) + *R. solani* 6 days later @ 12-leaf stage	58	3.7	19.7	15.3	1.6	273	5309
R. solani + Quadris (0.15 lb a.i./A) @ 12-leaf stage	31	6.3	7.5	10.7	2.0	1.73	1195
R. solani @ 12-leaf stage, no Quadris	-	7.0	-	-	-	-	-
LSD ($P \leq 0.05$)[z]	13	0.6	6.1	2.3	0.5	53	753

[w] Inoculum of *R. solani* was applied along the row (16 g/30 ft row) and then soil was lightly raked into the crown to cover inoculum before the first application of Quadris. Quadris applied at 0.15 pounds of active ingredient/A (= 9.2 fluid ounces product/A).

[x] Each value provided based on four replicates for Site 1 and three replicates for Site 2.

[y] Root rot ratings at harvest (September 25, 2002) based on a 0 – 7 scale, 0 = roots healthy, 7 = root completely rotted and foliage dead.

[z] LSD = Least Significant Difference; if significant, LSD value provided for mean separations; NS = not significant; - = no data (because of no stand).

Broadcast Treatments. Baseline stand counts were the same at both sites when plants were pretreated with Quadris (0.15 lb a.i./A) at the 8 to 10-leaf stage on July 9 and then inoculated with *R. solani* 6 days later when plants were at the 12-leaf stage (Fig. 4). Stand loss occurred throughout the summer across all treatments at both sites until harvest, but was especially severe in the *R. solani*-inoculated control at Site 2 (Fig. 4B). Untreated controls at both sites also suffered some stand loss from infection by naturally occurring inoculum of *R. solani*. Throughout the summer, both sites maintained the highest stands in the untreated control, followed closely by plots pretreated with Quadris at the 8 to 10-leaf stage and inoculated with *R. solani* 6 days later compared to plots co-treated with *R. solani* and Quadris at the 12-leaf stage. By harvest, stands were lowest in the *R. solani*-inoculated controls at both sites (all plants were dead at Site 2).

Yield and quality data for broadcast treatments were low because of severe Rhizoctonia root and crown rot (Table 3). At Site 1, the untreated control resulted in the most roots harvested, lowest root rot ratings, and highest root yields and recoverable sucrose compared to all treatments, followed in descending order by plots pre-treated with Quadris 6 days before inoculation with *R. solani* when plants were at the 12-leaf stage, and plots co-treated with *R. solani* and Quadris at the 12-leaf stage. All treatments were significantly better than the *R. solani*-inoculated control for all variables measured, except for percent sucrose, loss to molasses, and pounds of sucrose per ton, which were the same.

At Site 2, the untreated control performed statistically better for most yield variables than plots pre-treated with Quadris and inoculated with *R. solani* 6 days later; both of these treatments were statistically better compared to plots co-treated with *R. solani* and Quadris in the 12-leaf stage (Table 3). All treatments were significantly better than the *R. solani*-inoculated control, which had no surviving plants.

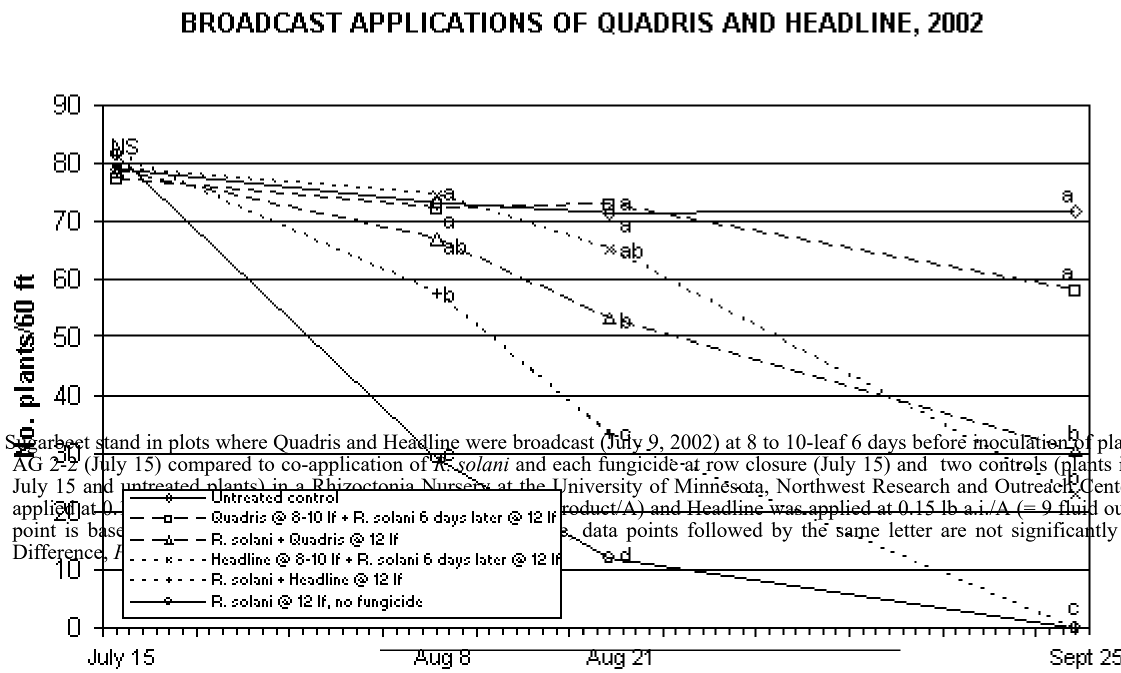


Fig. 5. Sugarbeet stand in plots where Quadris and Headline were broadcast (July 9, 2002) at 8 to 10-leaf 6 days before inoculation of plants with *Rhizoctonia solani* AG 2-2 (July 15) compared to co-application of *R. solani* and each fungicide at row closure (July 15) and two controls (plants inoculated with *R. solani* on July 15 and untreated plants) in a Rhizoctonia Nursery at the University of Minnesota, Northwest Research and Outreach Center, Crookston. Quadris was applied at 0.[illegible] product/A) and Headline was applied at 0.15 lb a.i./A (= 9 fluid ounces product/A). Each data point is base[illegible], data points followed by the same letter are not significantly different (Least Significant Difference, *P* [illegible]

Broadcast applications of Quadris and Headline at the 8 to 10-leaf stage (6 days before inoculation with *R. solani* at the 12-leaf stage) initially resulted in equal and better stands than co-treatment of plants with *R. solani* and application of either fungicide (Fig. 5). As the season progressed, higher stands were maintained in plots treated with Quadris 6 days before inoculation with *R. solani* compared to plots where Headline was applied 6 days before inoculation with *R. solani*. Pre-treatment with Headline 6 days before inoculation with *R. solani*, however, slowed down the rate of stand loss compared to plots co-treated with *R. solani* and Headline and also in the *R. solani*-inoculated control.

The untreated control resulted in the highest retention of stands during the growing season (Fig. 5) and had significantly higher root yields and sucrose quality (Table 4) compared to all other treatments. Application of Quadris 6 days before inoculation with *R. solani* when plants were at the 12-leaf stage was the next best treatment and resulted in statistically lower root rot ratings and higher root yields and recoverable sucrose compared to plots co-treated with *R. solani* and Quadris at the 12-leaf stage. Yields and sugar quality were low in plots where Headline had been applied 6 days before inoculation with *R. solani*, but these results were better than in plots co-treated with *R. solani* and Headline at the 12-leaf stage and the *R. solani*-inoculated control, which had no stand at harvest.

DISCUSSION

Quadris is an effective fungicide for reducing Rhizoctonia diseases throughout the growing season but timing and rate of application must be considered in conjunction with when infections occur. An understanding of when infections are initiated is dependent on inoculum density of *R. solani* (based on previous field history), cultivation practices, and weather conditions (temperature and moisture). Our 2002 field trials sustained more severe Rhizoctonia diseases compared to previous years where the same amounts of inoculum (16 g/30 ft row) were applied because of very favorable soil moisture and warm temperatures (75-85°F are optimal).

Table 4. Effect of broadcast applications of Quadris and Headline on number of sugarbeet roots harvested, ratings for Rhizoctonia root and crown rot, yield, and quality compared to controls. Quadris and Headline were applied (on July 9) at the 8 to 10-leaf stage 6 days before inoculation with *Rhizoctonia solani* AG 2-2 (12-leaf stage on July 15) and each fungicide also was co-applied with *R. solani* at the 12-leaf stage; controls included plants inoculated with *R. solani* at the 12-leaf stage that were not treated with either fungicide and an untreated control. Plots located in a Rhizoctonia Nursery at the University of Minnesota, Northwest Research and Outreach Center, Crookston.

Treatment[w,x]	No. roots harvested/60 ft row	Root rot rating[y]	Root yield (T/A)	Sucrose yield			
				%	Loss to molasses	lb/T	lb recover-able/A
Untreated control	72	1.2	26.3	16.4	1.7	294	7712
Quadris (0.15 lb ai/A) + *R. solani* 6 days later @ 12-leaf stage	58	3.7	19.7	15.3	1.6	273	5302
R. solani + Quadris (0.15 lb ai/A) @ 12-leaf stage	31	6.3	7.5	10.7	2.0	173	1187
Headline (0.15 lb ai/A) + *R. solani* 6 days later @	23	6.4	5.7	4.6	0.5	82	747

12-leaf stage							
R. solani + Headline (0.15 lb ai/A) @ 12-leaf stage	-	7.0	-	-	-	-	-
R. solani @ 12-leaf stage, no fungicides	-	7.0	-	-	-	-	-
LSD ($P \leq 0.05$)[z]	16	0.6	5.7	4.8	0.7	88	968

[w] Inoculum of *R. solani* was applied along the row (16 g/30 ft row) and then soil was lightly raked into the crown. Quadris was applied at 0.15 pounds active ingredient/A (= 9.2 fluid ounces product/A), and Headline was applied at 0.15 pounds active ingredient/A (= 9 fluid ounces of product/A).

[x] Each value provided based on an average of three replicates.

[y] Root rot ratings at harvest (September 25, 2002) based on a 0 – 7 scale, 0 = roots healthy, 7 = root completely rotted and foliage dead.

[z] LSD = Least Significant Difference; if significant, LSD value provided for mean separations; NS = not significant; - = no data (because of no stand).

Fields with high inoculum densities of *R. solani* tend to have early-season infections that result in damping-off and root rot of seedlings and young plants, provided soils are warm and moist to wet. As seeds germinate and roots grow through soils with high inoculum concentrations of *R. solani*, the odds of encountering overwintering propagules of the pathogen are high. If producers have severe early-season problems on sugarbeet they should send samples to a reputable diagnostic laboratory to confirm if the problem is caused by *R. solani* or another factors. If *R. solani* is confirmed in a high percentage of diseased plants, this is an indication that the field (or an affected portion of the field) can benefit by in-furrow treatment with Quadris supplement by a band treatment when plants reach the four-leaf stage (0.1 or 0.15 oz a.i./1000 ft row/application). Trials conducted in 2002 also were cultivated at row closure on July 24 and this practice threw *R. solani*-infested soil into crowns, which resulted in additional stand loss (Quadris also was decomposing and less active than earlier in the season). For soils with high concentrations of inoculum, avoidance of cultivation may not significantly reduce number of infected plants or disease severity because roots growing through soil encounter soilborne inoculum of *R. solani* throughout the season. Fortunately, roots of both susceptible and resistant varieties tend to develop increasing resistance to *R. solani* as they mature.

Seed treatment with Quadris may hold promise in controlling early-season infections by *R. solani* but both rates tested in our trials were inadequate to protect seeds and seedlings. Rates of Quadris applied to sugarbeet seed sown in these trials should have been ten times higher to be equivalent to rates currently applied to control *R. solani* on other crops. Future trials to evaluate seed treatment with Quadris are expected to be promising, especially for controlling *R. solani* AG-4, which typically causes seed rot on sugarbeet (the AG 2-2 population can infect throughout the field season).

Two postemergence band treatments of Quadris (0.1 or 0.15 oz a.i./1000 ft row) applied at the 8 to 10- and 12-leaf stages were very effective when plants were inoculated with *R. solani* and conditions were very favorable for disease in 2002. Jacobsen et al. also reported good control of *R. solani* of Quadris (0.075 oz a.i./1000 ft row) was applied at the four- and eight-leaf stage (2001 Sugarbeet Research and Extension Reports 32:293-295). In previous trials (Sugarbeet Research and Extension Reports 30:266-270 [2000]; 32:282-286 [2002]) to evaluate postemergence band treatments of Quadris (0.15 oz a.i./1000 ft row), control of Rhizoctonia root and crown rot was poor compared to the 2002 trials. There may be several reasons for different results in our earlier studies and the 2002 trials. In previous trials, *R. solani* was inoculated on sugarbeet when plants were between the five- to eight-leaf stage but in 2002, plants were inoculated at the 8 to 10-leaf stage. In earlier trials, Quadris was applied in a band over the row but in 2000, it was applied with a three-nozzle row applicator (one center nozzle was directly over the row and two side nozzles were at 45 degrees and angled into the crown), so application likely was more thorough. In 2002, there was a 1.2-inch rainfall later in the day after the first band application of Quadris, but the fungicide apparently remained intact and protected plants. In earlier trials, Quadris was applied at about 2-week intervals and plots were treated two or three times (early disease symptoms sometimes were observed by the second application) compared to 2002 where applications were 10 days apart and disease symptoms were not observed by the second application. Thus, application of Quadris at a 10-day interval is advisable in fields that typically have mid-season Rhizoctonia problems, especially when weather conditions are very favorable for disease. Cultivation that throws *R. solani*-infested soil into sugarbeet crowns in these fields will increase numbers of diseased plants, but is unlikely to affect root infections initiated below the crown. Since cultivation can increase disease in moderately infested fields, Quadris should be applied before cultivation (or at least at the time of cultivation). Quadris must be applied <u>before</u> disease symptoms occur because infected plants will not be “cured” or recover.

Trials conducted in 2002 showed that a single broadcast application of Quadris around the time of row closure was effective when applied a few days before inoculation with *R. solani* but it was not as effective when applied on the same day plants were inoculated with *R. solani*. Fields with low inoculum densities of *R. solani* can experience some root and crown rot after row closure. Plants likely are inoculated during the last cultivation (shortly before row closure) when infested soil is thrown into the crown. Thus, for the most effective control of *R. solani* in these fields, Quadris should be applied near row closure (before the last cultivation and/or the field should not be cultivated). In previous trials, good control of *R. solani* occurred when Quadris was applied twice (at canopy closure and about 2½ weeks later). Two applications of strobilurin fungicides, however, are not recommended in order to avoid development of resistance to these fungicides by *C. beticola*.

One broadcast application of Headline at row closure was fairly effective when applied a few days before inoculation with *R. solani* but was not as effective when applied on the same day plants were inoculated with *R. solani*. Reduction of *R solani* by Headline was not as effective as Quadris but did retard rate of disease development, which was unusually severe in 2002 compared to previous seasons. Under less severe disease pressure, Headline likely would have looked more promising for reducing Rhizoctonia root and crown rot. Producers who apply Headline as the first fungicide for control of Cercospora leaf spot may also gain some additional benefit for control of *R. solani*, provided infections have not already occurred.

Application of one strobilurin treatment for control of Cercospora leaf spot is recommended to avoid the development of populations of *C. beticola* that are resistant to this class of fungicides. If Quadris (a strobilurin) is applied before row closure to control early- and mid-season infections by *R. solani*, it is unknown if this fungicide creates selection pressure on the overwintering populations of *C. beticola* that would result in build-up of resistance to Headline and other strobilurin fungicides. Thus, applications of Quadris should be made only in fields, or in portions of fields, that have a documented history of Rhizoctonia root and crown rot.

CONCLUSIONS

1. Reduction of Rhizoctonia diseases by Quadris is best achieved when the fungicide is applied <u>before</u> infections occur.

2. Timing of Quadris applications and their effectiveness depend upon inoculum density, cultivation practices, and weather conditions.

3. Applications of Quadris are not advised unless a producer has a substantial and <u>confirmed</u> problem with Rhizoctonia diseases.

4. In-furrow and early band applications of Quadris reduce seed rot, damping-off, and root rot but yield returns may not be economic. Fields with a confirmed history of early-season stand loss caused by *R. solani* have high inoculum levels; infections can continue throughout the season (and may be increased by cultivation that throws soil into crowns).

5. Band treatments of Quadris at the 8 to 10- and 12-leaf stages reduce root and crown rot and increase yield and quality of sugarbeet. Fields with a confirmed history of Rhizoctonia root rot occurrence at early- to mid-season (with moderate inoculum densities of *R. solani*) can benefit by Quadris treatments, provided both applications are made before infections and disease symptoms occur. Thus, the first application may need to be made before the 8 to 10-leaf stage. Cultivation practices that throw soil in crowns (e.g., inoculates plants) should be avoided.

6. A broadcast application of Quadris 1 week before row closure and infection by *R. solani* (or 1 week before the last cultivation), reduces root and crown rot and increases yield and quality.

7. Growers may have to sacrifice some control of *R. solani* to preserve other strobilurin products for control of Cercospora leaf spot. Resistance management of the strobilurin fungicides e.g., Quadris (and especially Headline for control of Cercospora leaf spot) is critical to avoid development of strains of *C. beticola* with resistance to strobilurin fungicides.

8. A broadcast treatment of Headline 1 week before row closure and infection by *R. solani* retards development of root rot and may be a beneficial "side-effect" of applying this fungicide for control of Cercospora leaf spot.

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