RHIZOCTONIA INOCULUM AND ROTATION CROP EFFECTS ON A FOLLOWING SUGARBEET CROP

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Rhizoctonia solani (= *R. solani*) is a common, soilborne fungal pathogen of crops grown throughout the world. The fungus is composed of genetically isolated populations called anastomosis groups or AGs (4). The AG population causing Rhizoctonia root and crown rot of sugarbeet is *R. solani* AG 2-2 (4, 6). In the last decade, *R. solani* AG-2-2 has been increasing in prevalence and severity on sugarbeet in the Red River Valley (RRV) and southern Minnesota.

R. solani AG 2-2 is further divided into two intraspecific groups (ISGs): AG 2-2 IIIB and AG 2-2 IV. Rhizoctonia root and crown rot of sugarbeet can be caused by both ISGs of *R. solani* AG 2-2 (IIIB and IV) but *R. solani* AG 2-2 IIIB is the most aggressive population (5). Build-up of inoculum in the region is attributed to recent wet summers conducive to infection and disease development and also by increased production of soybean and edible bean crops, which are susceptible to stem and root rot caused by *R. solani* AG 2-2 IIIB. Presence and distribution of the two ISGs in the sugarbeet growing regions of the RRV and southern Minnesota are unknown.

Cereal crops (e.g., wheat, barley, corn) typically are recommended for rotation with broadleaf crops (e.g., sugarbeet, soybean, sunflower) in the upper Midwest because they are not susceptible to *R. solani* AG 2-2. Thus, rotation with cereal crops allows populations of *R. solani* to decrease. Reports from Europe, however, indicate *R. solani* AG 2-2 IIIB is an aggressive pathogen that causes root and stalk rot of corn and also is the primary cause of Rhizoctonia root and crown rot of sugarbeet (2). In the southeastern U.S.A., *R. solani* AG 2-2 IIIB causes a root and brace rot on corn (7) but this disease has not been reported in the upper Midwest. Although *R. solani* AG 2-2 IV is the primary cause of root and crown rot on sugarbeet (4, 6), the recent report in Europe that AG 2-2 IIIB is attacking sugarbeet raises concerns about whether increased production of corn and bean crops (especially soybean) in Minnesota and North Dakota is building up inoculum of *R. solani* AG 2-2 IIIB.

Our laboratory has identified both intraspecific groups (AG 2-2 IIIB and IV) for a few cultures of *R. solani* AG 2-2 from sugarbeet. Preliminary pathogenicity tests confirm *R. solani* AG 2-2 IIIB as very aggressive in attacking soybean, edible bean, and sugarbeet compared to *R. solani* AG 2-2 IV, which causes moderate root rot on these crops (1). With increasing acreage planted to soybean and corn in the RRV (and both of these crops commonly are grown in southern Minnesota), it is important to know the prevalence and distribution of *R. solani* AG 2-2 IIIB and AG 2-2 IV in these regions. Furthermore, it is essential to understand the influence of crops rotated with sugarbeet on build-up of Rhizoctonia inoculum, so they can be rotated to minimize Rhizoctonia root and crown rot.

OBJECTIVES

Our objectives were to conduct field trials to determine pathogenicity of *R. solani* AG-2-2 IIIB and AG 2-2 IV on (1.) rotation crops (corn, wheat, soybean) and (2.) a following sugarbeet crop. A previous report summarized effects of *R. solani* AG-2-2 IIIB, *R. solani* AG 2-2 IV, and a non-inoculated control on rotation crops (11). This report summarizes results when the trial was repeated in 2006. It also reports on the effects of growing a 2006 sugarbeet crop in plots that were inoculated with *R. solani* AG 2-2 IIIB and AG 2-2 IV and then sown to various rotation crops in 2005.

MATERIALS AND METHODS

Rotation crops: Plot establishment. Two field trials (one each in 2005 and 2006) were established at the University of Minnesota, Northwest Research and Outreach Center, Crookston in a split-plot trial of four replicates. Main plots were inoculated with *R. solani* AG 2-2 IIIB, *R. solani* AG 2-2 IV, and not inoculated. Inoculum of *R. solani* was grown on sterile barley grain for 3 weeks and then air-dried. On May 17, 2005 and May 18, 2006, barley grain inoculum (11.3 ounces) was sprinkled over each main plot (33 x 30 ft) and incorporated with a Melroe multiweeder to about a 2-inch depth. Rotation crops then were sown as subplots of main plots including spring wheat ‘Knudson’, soybean ‘GoldCountry 923RR’, and corn ‘Pioneer 39D81’ at rates of 90 lb, 60 lb, and 30,000 seed per acre, respectively. Each crop was fertilized, treated with pesticides, and maintained following recommended practices.

Rotation crops: Root rot ratings. Wheat was assessed for root disease on August 16, 2005 and August 15, 2006 by rating the subcrown internode of 25 plants per plot on a 0 to 3 scale where 0 = clean and healthy and 3 = more than 50% of the surface with lesions and discoloration (9). Subcrown internodes are easier to rate than crown roots, indicate general root health, and can be infected by several soilborne pathogens (primarily “common root rot” fungi, e.g., *Bipolaris sorokiniana* and *Fusarium* species) Soybean plants were removed August 23, 2005 and August 16, 2006 (25 plants per plot), washed, and basal stems and roots were assessed for disease with a 1 to 5 scale where 1 = no symptoms and 5 = shoot dead and more than 75% of stem girdled (1). In 2005, plants had slight discoloration and no root rot, so they were not rated; in 2006, they were rated. Corn plants (25 per plot) were dug from plots on September 4 and 7, 2005 and September 15, 2006. Roots were thoroughly washed to remove adhering soil and then rated for disease on a 1 to 5 scale where 1 = less than 2% root surface with lesions and 5 = plant dead (8).

Rotation crops: Isolation of *R. solani*. After roots were assessed for disease, attempts were made to isolate *R. solani* (a total of 100 plants per crop per soil treatment per year). For wheat, subcrown internodes were surface-disinfested in bleach, rinsed twice in sterile distilled water, and placed on potato-dextrose agar (PDA). For soybean, a 1-inch piece of each basal stem was disinfected and cultured in the same fashion. For corn, a 1-inch segment of root with lesions or discoloration was excised from each plant, or if no discoloration occurred, a piece was randomly removed from an apparently healthy root. Corn root pieces were cultured as previously described. After 14 days, PDA was examined for growth of *R. solani* and other fungi. If *R.*

solani was present, transfers were made to fresh PDA so cultures could be purified and further identified.

Rotation crops: Harvest. Wheat plots were not harvested in 2005 because of severe lodging. Wheat was harvested on September 28, 2006 with a small plot combine (Wintersteiger Seedmuch, Dimmelstrasse, Germany) that removed a swath (5 x 30 feet) per plot. Soybeans were harvested (with the same equipment as used for wheat) on September 29, 2005 and September 15, 2006. Yields were adjusted to 13% moisture and based on 60 pounds per bushel. Corn was hand-harvested on October 19, 2005 and September 28, 2006 by removing ears from plants in the two middle rows of each plot, which were dried at 105 ^{0}F for 48 hours. Kernels were removed with a corn sheller (Hocking Valley Improved AU170) and percent moisture was determined with an Infratec 1229 grain analyzer. Yields were adjusted to 15.5% moisture and based on 56 pounds per bushel.

Sugarbeet following rotation crops. Two sugarbeet varieties (Beta 1301R and Beta 1305R, resistant and susceptible to Rhizoctonia root and crown rot, respectively) were sown on May 19, 2006 as sub-subplots within each rotation crop (wheat, soybean, corn subplots) grown in main plot treatments in 2005. Sugarbeet seed of each variety was sown at a 2.6-inch spacing in rows 30 feet long and 22-inches apart (4-row plots per variety). Plots were fertilized at recommended rates and the insecticide Counter (1.0 lb a.i. per acre) was applied over the row at planting. Roundup (1 quart per acre) was applied pre-emergent and Select + MSO (12 ounce + 1 pint per acre, respectively) were applied on June 1. Microrates of the herbicides Betamix + UpBeet + Stinger + Select + MSO (0.5-0.7 pt + 0.125 oz + 35 ml + 90-120 ml + 1-1.5 pt per acre, respectively) on June 5, 12, 23, and 30. Herbicides were applied with a tractor-mounted sprayer and TeeJet 8003 flat fan nozzles at 30 psi. Stands were thinned, where needed, to the equivalent of 200 plants per 100 feet of row on June 21. Plots were cultivated on July 5. Cercospora leaf spot was controlled by an application of Eminent on August 22 and Headline on September 1 (13 and 9 oz per acre, respectively).

Stands counts were done at regular intervals after emergence and post-thinning. Two middle rows of each plot were harvested on September 27, 2006. Number of marketable roots were counted and 20 roots were randomly selected from each sub-subplot and rated for Rhizoctonia root and crown rot (0 – 7 scale, 0 = healthy and 7 = root completely rotted and foliage dead). Ten roots also were randomly selected on October 13 and analyzed for yield and sucrose quality by the American Crystal Sugar Company Quality Laboratory, East Grand Forks, MN.

Data analysis. Data were subjected to analysis of variance and if significant (P = 0.05), means were separated by Least Significant Difference (LSD).

RESULTS

Rotation crops: Root rot, isolation of *R. solani*, yields. Results are summarized in Table l for full-season crops of wheat, soybean, and corn grown in soil inoculated with *R. solani* AG 2-2 IIIB, *R. solani* AG 2-2 IV, and a non-inoculated control in 2005 and 2006. For wheat, there were no significant differences in disease ratings for common root rot. Isolation of *R. solani* from subcrown internodes was very low and statistically the same in inoculated and control plots, however, isolation was slightly higher in plots inoculated with *R. solani* AG 2-2 IIIB compared to the other soil treatments. Wheat is not a typical host of *R. solani* AG 2-2. Symptoms observed on subcrown internodes were for “common root rot” caused by *Bipolaris sorokinana* and *Fusarium* species, and these fungi were commonly isolated (data not shown). There were no differences in wheat yields in inoculated and non-inoculated plots.

For soybean, root rot ratings were low with no significant differences in *Rhizoctoni*a-inoculated and non-inoculated plots (Table 1). Percentage of basal stems infected by *R. solani*, however, was significantly higher and equal in soils inoculated with *R. solani* AG 2-2 IIIB and AG 2-2 IV compared to the non-inoculated control (which also had a low level of infection, indicating naturally occurring levels of the pathogen). The basal stem and root rot observed was typical of *R. solani*. Yet, there were no significant differences in yield among soil treatments.

Corn collected from plots inoculated with *R. solani* AG 2-2 IIIB had extensive rotting and lesions on roots compared to soil inoculated with *R. solani* AG 2-2 IV and the non-inoculated control, which had equally low root rot ratings (Table 1). Isolation of *R. solani* from corn grown in soil inoculated with *R. solani* AG 2-2 IIIB was high (33%) compared to soil inoculated with *R. solani* AG 2-2 IV (5%) and the non-inoculated control (2%). There were no significant differences in yield among inoculated and non-inoculated plots.

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Table 1. Average root rot ratings, percent isolation of *Rhizoctonia solani* from roots, and yield of wheat, soybean (soy), and corn grown in plots soil-inoculated with *R. solani* AG 2-2 IIIB or *R. solani* AG 2-2 IV compared to non-inoculated soil in 2005 and 2006.

	Wheat ‘Knutson’[V]			Soy ‘Gold Country 923RR’[V]			Corn ‘Pioneer 39D81’[V]		
Soil treatment[U]	RRR (1–3)[W]	% Isolation *R. solani*[X]	Yield (bu/A)[Y]	RRR (1-5)[W]	% Isolation *R.solani*[X]	Yield (bu/A)[Y]	RRR (1-5)[W]	% Isolation *R.solani*[X]	Yield (bu/A)[Y]
Non-inoculated control	2.0	1	43	1.4	4 a	36	1.3 a	2 a	154
R.solani AG 2-2 IV	2.0	2	39	1.6	12 b	39	1.5 a	5 a	141
R. solani AG 2-2 IIIB	2.1	5	40	1.7	16 b	33	2.8 b	33 b	155
LSD (*P* = 0.05)[Z]	NS	NS	NS	NS	8	NS	0.5	0.5	NS

[U] *R. solani* AG 2-2 IIIB and *R. solani* AG 2-2 IV were grown on sterile barley grains for 3 weeks and air-dried. Plots then were inoculated on May 16, 2005 and May 18, 2006 (plots at different locations) by sprinkling infested barley grains onto the soil surface (11.3 ounces per 990 ft^2; the control was not inoculated) and incorporated with a Melroe multiweeder. Plots were arranged in a randomized block design with four replicates.

[V] Rotation crops were sown on May 17, 2005 and May 18, 2006 as subplots of main plots.

[W] RRR = root rot rating; each value for wheat and corn is an average of 200 plants (25/replicate/soil treatment/year) and for soybean is an average of 100 plants (25/replicate/soil treatment in 2006; in 2005, all plants had slight discoloration and no root rot and were not rated). **Wheat** subcrown internodes were rated for root rot on August 16, 2005 and August 15, 2006 with a 0 – 3 scale where 0 = clean and 3 = more than 50% of the surface with lesions and discoloration (9). **Soybean** basal stems and roots were rated on August 16, 2006 with a 1 – 5 scale where 1 = no symptoms and 5 = shoot dead and more than 75% of stem girdled (1). **Corn** plants were dug from plots on September 4 and 7, 2005 and September 15, 2006; root systems were washed and rated with a 1 – 5 scale where 1 = less than 2% root surface with lesions and 5 = plant dead (8).

[X] A section of root (~ 1-inch long) of each plant was removed after disease assessment, surface-sterilized with bleach, and cultured on potato-dextrose agar for isolation of *R. solani*.

[Y] **Wheat** plots were harvested on August 9, 2006 (plots were not harvested in 2005 because of severe lodging). **Soybean** was harvested on September 29, 2005 and September 15, 2006 (yields were adjusted to 13% moisture and based on 60 pounds per bushel). **Corn** was harvested on October 19, 2005 and September 28, 2006 (yields were adjusted to 15.5% moisture and based on 56 pounds per bushel). .

[Z] LSD = Least significant difference, P = 0.05; for each column, values followed by the same letter are not significantly different; NS = not significantly different.

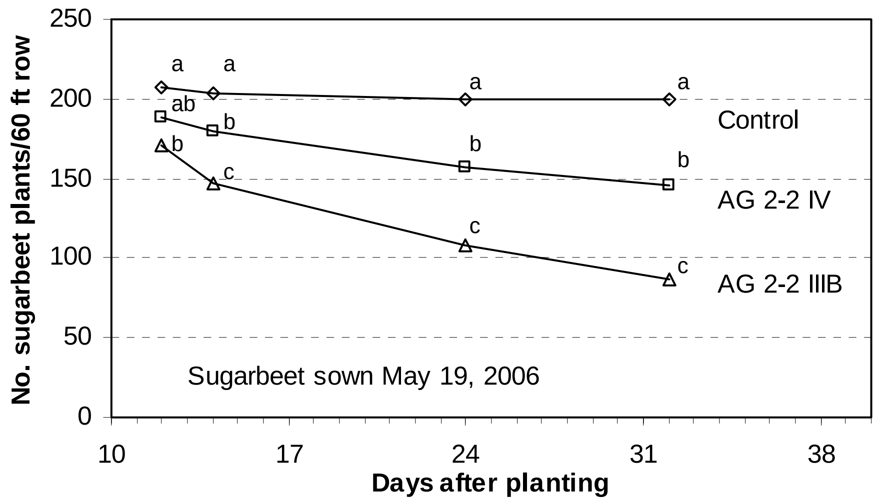

Figure 1. Sugarbeet seedling stands averaged across two varieties (Beta 1301R and 1305R, resistant and susceptible to *Rhizoctonia solani*, respectively) sown in 2006 into plots previously soil-inoculated on May 17, 2005 with *R. solani* AG 2-2 IIIB, *R. solani* AG 2-2 IV (11.3 ounces per 990 ft^2), or not inoculated (control); these main plots were arranged in a randomized block design (replicated four times) and then sown with wheat, soybean, and corn as subplots. Each value is an average of 24 plots. For each date, values followed by the same letter are not significantly different, P = 0.05).

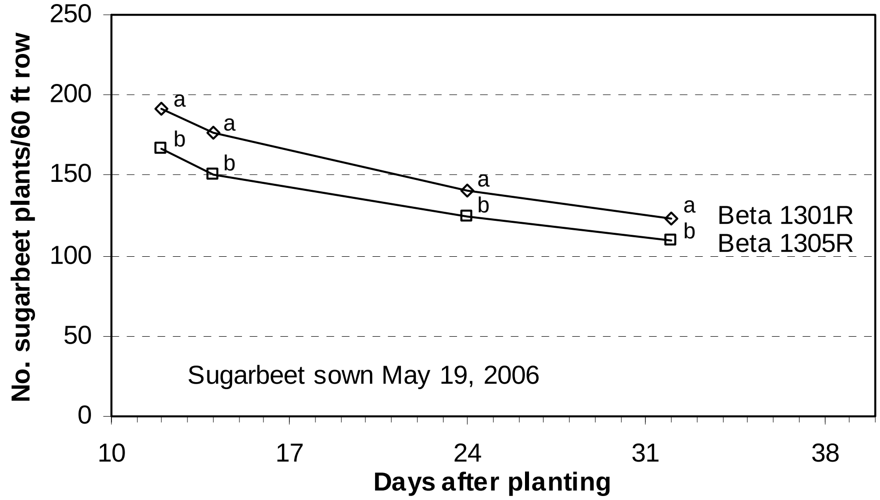

Figure 2. Sugarbeet seedling stands in 2006 of two sugarbeet varieties (Beta 1301R and 1305R, resistant and susceptible to *Rhizoctonia solani*, respectively) averaged across plots previously soil-inoculated on May 17, 2005 with *R solani* AG 2-2 IIIB or *R. solani* AG 2-2 IV (11.3 ounces per 990 ft^2); these main plots were arranged in a randomized block design (replicated four times) and then sown with wheat, soybean, and corn as subplots. Each value is based on an average of 24 plots; the non-inoculated control is excluded. For each date, values followed by the same letter are not significantly different, $P = 0.05$).

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Sugarbeet following rotation crops. *Seedling stand.* In 2006, Rhizoctonia damping-off started to occur about 2 weeks after planting in plots inoculated with *R. solani* in May, 2005 and then sown with wheat, soybean, and corn. Effects of previous soil inoculation with *R. solani* AG 2-2 IIIB, *R. solani* AG 2-2 IV, and the non-inoculated control on sugarbeet seedlings stand are shown in Figure 1 (each value is averaged across previous rotation crop and two varieties of sugarbeet). Sugarbeet seedling stands were significantly greater and stable in the non-inoculated control compared to plots inoculated with *R. solani* AG 2-2 IIIB one year earlier; stands were intermediate in plots inoculated with *R. solani* AG 2-2 IV one year earlier.

Rhizoctonia damping-off occurred in both sugarbeet varieties when averaged across previous soil inoculations with *R. solani* AG 2-2 IIIB and *R. solani* AG 2-2 IV in the spring of 2005 (Figure 2). Stands were significantly greater for the *Rhizoctonia*-resistant (Beta 1301R) than susceptible (Beta 1305R) variety.

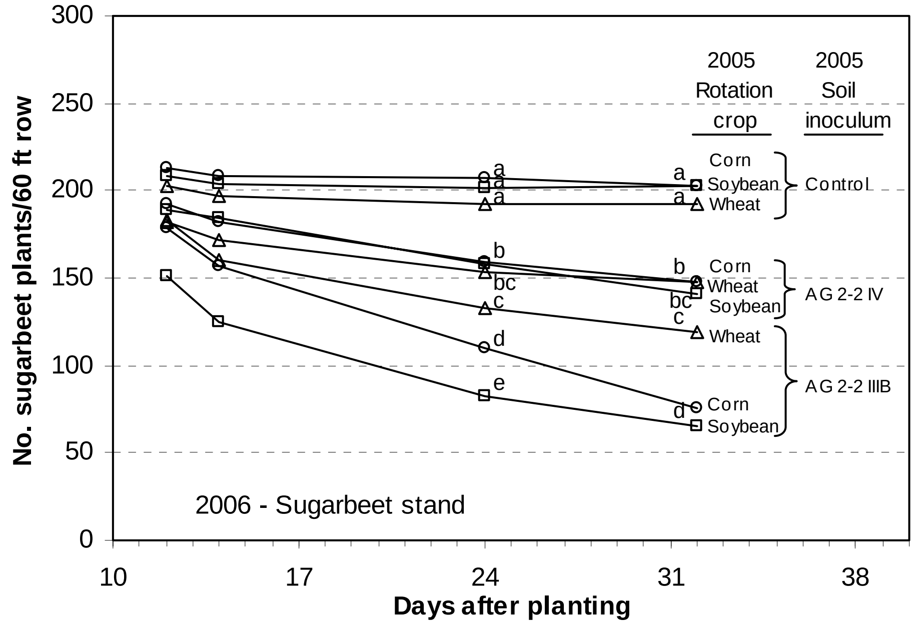

Figure 3. Sugarbeet stands in 2006 averaged across two varieties Beta 1301R and 1305R, resistant and susceptible to *Rhizoctonia solani*, respectively) sown in plots previously soil-inoculated on May 17, 2005 with *R. solani* AG 2-2 IIIB, *R. solani* AG 2-2 IV (11.3 ounces per 990 ft^2), and a non-inoculated control; these main plots were arranged in a randomized block design (replicated four times) and then sown with wheat, soybean, and corn as subplots. Each value is based on an average of eight plots. For each date, values followed by the same letter are not significantly different, *P* = 0.05).

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There were negligible losses in sugarbeet stands in the non-inoculated control plots, regardless of previous rotation crop (Figure 3). Rhizoctonia damping-off of sugarbeet was severe in plots inoculated with *R. solani* AG 2-2 IIIB the previous year and losses were significantly greater and equal when following corn and soybean compared to wheat. There were moderate losses of sugarbeet stands in plots inoculated with *R. solani* AG 2-2 IV the previous year and effects of previous rotation crop were minor, except there was a tendency for lower stands following soybean than for wheat and corn.

Harvest data. Effects of 2005 soil treatments on the following 2006 sugarbeet crop (averaged across previous rotation crop and two sugarbeet varieties) are shown in Table 2. Non-inoculated control plots in 2005 had minimal Rhizoctonia root and crown rot and a significantly greater number of harvested roots, yield, sucrose, and economic return per acre than either of the *Rhizoctonia*-inoculated plots. Plots previously inoculated with *R. solani* AG 2-2 IIIB resulted in significantly more Rhizoctonia root and crown rot and a significantly lower number of harvested roots, yield, sucrose, and gross economic return per acre than plots inoculated with *R. solani* AG 2-2 IV or the non-inoculated control. Plots previously inoculated with *R. solani* AG 2-2 IV had intermediate amounts of Rhizoctonia root and crown rot and number of marketable roots, yield, sucrose, and gross economic return per acre.

The *Rhizoctoni*a-susceptible variety (Beta 1301R) resulted in significantly higher percent sucrose and pounds of sucrose per ton compared to the resistant variety (Beta 1305R) when averaged across plots previously inoculated with *R. solani* and sown with rotation crops (Table 3). There were no significant differences, however, between the two varieties for severity of Rhizoctonia root and crown rot, number of roots harvested, or for yield (tons of roots), pounds of recoverable sucrose, and gross economic return per acre (Table 3).

Table 2. Sugarbeet harvest data for Rhizoctonia root and crown rot ratings, stand, yield and quality in 2006. Sugarbeet was grown in plots previously soil-inoculated on May 16, 2005 with *Rhizoctonia solani* AG 2-2 IIIB, *R. solani* AG 2-2 IV, or not-inoculated and then sown with wheat, soybean, and corn.

Previous year (2005) soil treatment[W]	RRR (0-7)[XY]	No. roots harvested/ 60-ft row[X]	Yield (Ton/A)[X]	Sucrose[X]			Gross return ($/A)[X]
				%	lb/T	lb recov/A	
Non-inoculated	1.4 a	105 a	24.1 a	16.5a	299 a	7213 a	803 a
R. solani AG 2-2 IV	3.5 b	63 b	18.5 b	15.6b	278 b	5213 b	536 b
R. solani AG 2-2 IIIB	6.3 c	22 c	7.5 c	13.9c	239 c	1806 c	145 c
LSD (P = 0.05)[Z]	0.8	13	4.0	0.6	14	1128	119

[W] *R. solani* AG 2-2 IIIB and *R. solani* AG 2-2 IV were grown on sterile barley grains for 3 weeks and air-dried. Plots were inoculated on May 15, 2005 by sprinkling infested barley grains onto the soil surface (11.3 ounces per 990 ft^2; the control was not inoculated) and then incorporated with a Melroe multiweeder. Plots were arranged in a randomized block design with four replicates. Rotation crops (wheat, soybean, corn) were sown on May 17, 2005 as subplots of each soil treatment.

[X] Each value is averaged across two sugarbeet varieties (Beta 1301R and Beta 1305R, resistant and susceptible to Rhizoctonia root and crown rot, respectively) and across subplots previously sown to wheat, soybean, and corn in 2005.

[Y] RRR = Rhizoctonia root and crown rot rating on a 0 to 7 scale, 0 = root clean and healthy and 7 = root completely rotted and foliage dead.

[Z] LSD = Least significant difference, P = 0.05; for each column, values followed by the same letter are not significantly different.

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Table 3. Rhizoctonia root and crown rot ratings, stand, yield and quality of two sugarbeet varieties differing in susceptibility to *Rhizoctonia solani* that were grown in 2006 in plots previously soil-inoculated in May, 2005 with *Rhizoctonia sol*ani AG 2-2 IIIB and *R. solani* AG 2-2 IV (data from the non-inoculated control is excluded) and then sown with wheat, soybean, and corn.

Sugarbeet variety	RRR (0-7)[XY]	No. roots harvested/ 60-	Yield (Ton/A)[X]	Sucrose[X]			Gross return ($/A)[X]
				%	lb/T	lb	

	ft row[X]				recov/A	
1301R (resistant)	4.9	43	13.3	14.5a	253 a	3529	333
1305R (susceptible)	4.9	42	12.7	15.0b	264 b	3489	348
LSD (*P* = 0.05)[Z]	NS	NS	NS	0.3	6	NS	NS

[X] Each value is averaged across plots inoculated with *R. solani* AG 2-2 IIIB or *R. solani* AG 2-2 IV on May 17, 2005. Inoculum was grown on sterile barley grains for 3 weeks and air-dried; plots were inoculated on May 16, 2005 by sprinkling infested barley grains onto the soil surface (11.3 ounces per 990 ft^2) and incorporated with a Melroe multiweeder. Plots were arranged in a randomized block design with four replicates. Wheat, soybean, and corn were sown on May 17, 2005 as subplots of each soil treatment.

[Y] RRR = Rhizoctonia root and crown rot rating on a 0 to 7 scale, 0 = root clean and healthy and 7 = root completely rotted and foliage dead.

[Z] LSD = Least significant difference, *P* = 0.05; for each column, values followed by the same letter are not significantly different. .

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There were significant differences for various 2006 sugarbeet yield parameters when compared to 2005 soil treatments and rotation crops. For instance, Rhizoctonia root and crown rot was significantly different among the previous 2005 soil treatments and sometimes, following certain crop rotations within each soil treatment (Figure 4A). Disease was equally low following all rotation crops in the non-inoculated control. Overall, disease was significantly highest in plots inoculated with *R. solani* AG 2-2 IIIB following corn compared to wheat (soybean was intermediate). Disease was intermediate in plots inoculated with *R. solani* AG 2-2 IV and among this soil treatment, was highest following soybean and significantly lower following wheat (corn was intermediate).

2006 SUGARBEET HARVEST DATA FOLLOWING 2005
SOIL-INOCULATION WITH *RHIZOCTONIA SOLANI* AND VARIOUS GROWING ROTATION CROPS

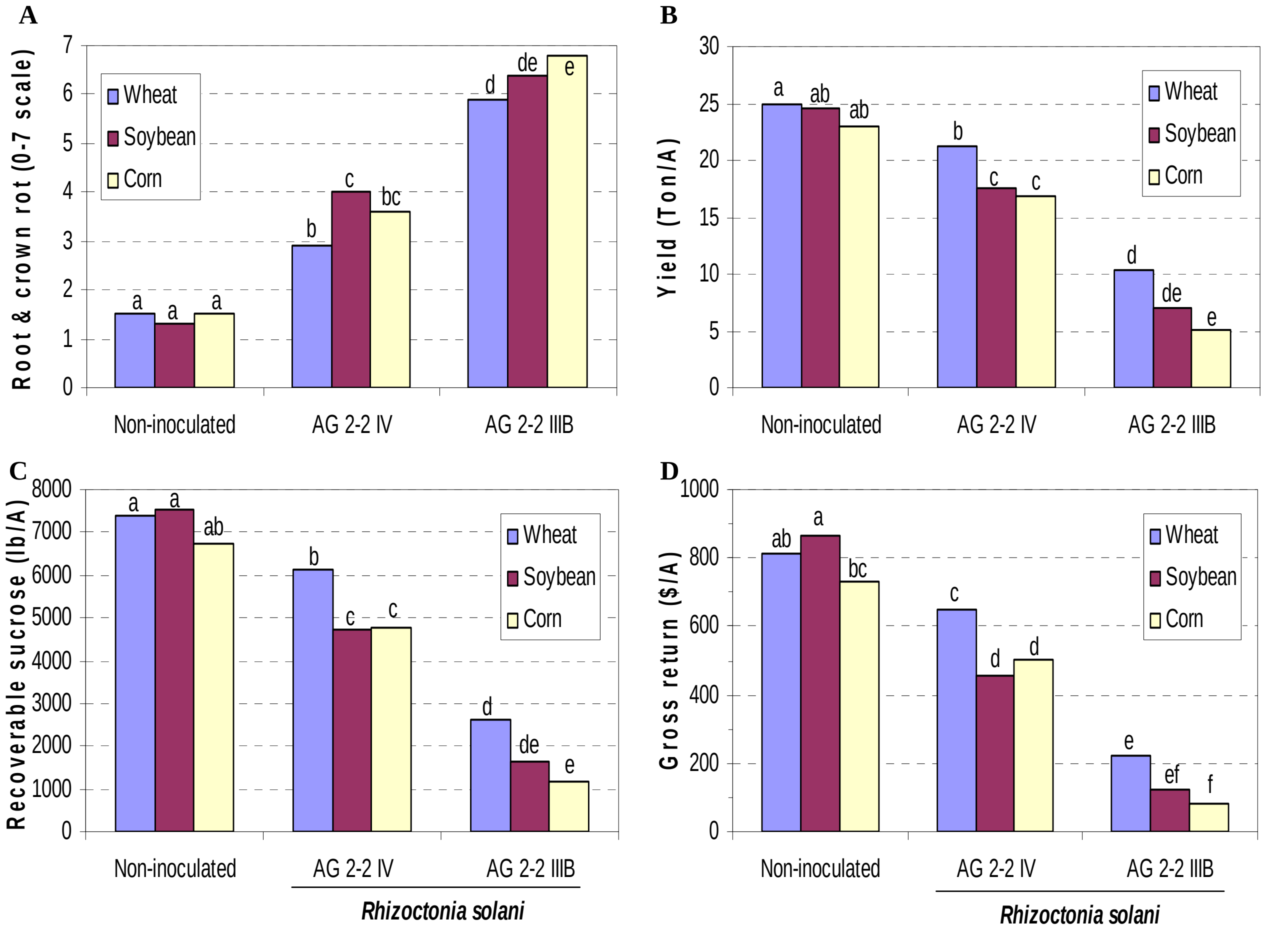

Figure 4. Sugarbeet harvest data in 2006 presented by main treatment (soil inoculated on May 16, 2005 with *Rhizoctonia solani* AG 2-2 IIIB, *R. solani* AG 2-2 IV [11.3 ounces per 990 ft^2], or not inoculated) and by previous crop (wheat, soybean, corn) sown on May 17, 2005 for: **A.)** Rhizoctonia root and crown rot ratings (0-7 scale, 0 = healthy, 7 = root completely rotted and foliage dead), **B.)** yield (tons of roots per acre), **C.)** pounds of recoverable sucrose per acre, and **D.)** gross economic return per acre. Each bar is based on an average of four replicates. For each graph, bars with the same letter are not significantly different, *P* = 0.05).

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Sugarbeet yields (tons of roots per acre) were significantly different among previous 2005 soil treatments and sometimes, following certain crop rotations within each soil treatment (Figure 4B). Yields were highest in non-inoculated plots following wheat, followed by soybean and corn. Overall, yields were significantly lowest in plots inoculated with *R. solani* AG 2-2 IIIB following corn compared to wheat (soybean was intermediate). Yields were intermediate in plots inoculated with *R. solani* AG 2-2 IV and among this soil treatment, were lowest following soybean and corn and significantly higher following wheat.

Sucrose yields (pounds of recoverable sucrose per acre) were significantly different among previous 2005 soil treatments and sometimes, following certain crop rotations within each soil treatment (Figure 4C). Sucrose yields were highest in non-inoculated plots following wheat and soybean, and lower following corn. Overall, sucrose yields were significantly lowest in plots inoculated with *R. solani* AG 2-2 IIIB following corn compared to wheat (soybean was intermediate). Sucrose yields were intermediate in plots inoculated with *R. solani* AG 2-2 IV and among this soil treatment, were lowest following soybean and corn (which were equal) and significantly higher following wheat.

Gross economic return of sugarbeet per acre also was significantly different among previous 2005 soil treatments and sometimes, following certain crop rotations within each soil treatment (Figure 4D). Gross return was highest in non-inoculated plots after soybean, followed by wheat, and corn. Overall, gross return was significantly lowest in plots inoculated with *R. solani* AG 2-2 IIIB following corn compared to wheat (soybean was intermediate). Gross return was intermediate in plots inoculated with *R. solani* AG 2-2 IV and among this soil treatment, was lowest following soybean and corn (which were equal) and significantly higher following wheat.

DISCUSSION

This research showed that soil infested with *R. solani* AG 2-2 IIIB and *R. solani* AG 2-2 IV did not result in obvious, above-ground symptoms or yield reductions of rotation crops, even when crops were susceptible to *R. solani*. Yet, there were dramatic effects on the following sugarbeet crop sown in 2006. The prevalence and severity of Rhizoctonia diseases on sugarbeet one year after soil was inoculated were unexpectedly high since the amount of inoculum applied was in the mid-range recommended for field experiments. Rhizoctonia damping-off and root and crown rot as well as reductions in yield were most severe in plots previously inoculated with *R. solani* AG 2-2 IIIB and sown with rotation crops, especially following corn. Rhizoctonia diseases and yield reductions also occurred in plots previously inoculated with *R. solani* AG 2-2 IV, but impacts were not as great as in plots inoculated with *R. solani* AG 2-2 IIIB. Panella (5) also reported cultures of *R. solani* AG 2-2 IIIB as more aggressive and pathogenic on sugarbeet compared to *R. solani* AG 2-2 IV. In plots infested with *R. solani* AG 2-2 (IIIB or IV), wheat had the most favorable impact on sugarbeet the following season compared to soybean or corn. In a related trial in 2003, Windels and Brantner (10) also did not observe aboveground symptoms of Rhizoctonia diseases on corn, soybean, or wheat in plots inoculated with *R. solani* AG 2-2 IIIB. When sugarbeet was grown the following year, however, the crop was severely infected by *R. solani* following corn, least infected when following wheat, and intermediate after soybean.

Our research provides the first evidence of *R. solani* AG 2-2 IIIB causing root rot on corn in the Upper Midwest of the U.S.A. Root infections are not easily discerned with no above-ground symptoms (such as stalk rot, which occurs in Europe). In 1996, Nelson et al. (3) reported cultures of *R. solani* AG 2-2 from soybean in the RRV caused some lesions on corn seedlings in greenhouse experiments, but cultures were not identified to intraspecific group. The significantly higher recovery of *R. solani* AG 2-2 IIIB from corn roots than from soybean and wheat further reveals the vulnerability of corn to infection by this pathogen. Although there were limited symptoms of root rot on soybean, 12 and 16% of roots were infected by *R. solani* AG 2-2 IIIB and AG 2-2 IV, respectively. This level of isolation is relatively low, but illustrates soybean also increases inoculum levels of *R. solani*. In fields with low levels of infestation by *R. solani* AG 2-2, populations can increase with continued production of susceptible crops until an economic threshold is reached, particularly when also growing sugarbeet, a very susceptible crop.

R. solani also is an excellent competitive saprophyte so results reported here for isolation from rotation crops may not represent or predict the potential of inoculum build-up or pathogen survival. Inoculum levels of the pathogen could increase in soil by several means including: causing root rot of rotation crops, infecting roots that remain symptom-free, or by saprophytically colonizing crop residue after harvest. It is unknown, however, if *R. solani* AG 2-2 colonizes crop residue after harvest. Also, it is unknown if *R. solani* AG 2-2 IIIB is more aggressive in attacking non-transgenic or transgenic varieties of corn or soybean, but investigations will be initiated in 2007.

The variety with resistance to Rhizoctonia root and crown rot performed similar to the susceptible variety in *Rhizoctonia*-inoculated plots. Disease pressure likely was too high for the resistant variety to outperform the susceptible variety.

Currently, surveys are underway to determine the presence and distribution of intraspecific groups (IIIB and IV) of *R. solani* AG 2-2 in the RRV and southern Minnesota. About 600 cultures of *R. solani* have been collected, purified, and placed in storage (400 collected in 2006, 132 in 2005, and 60 from previous years). Field histories also are being collected for each sample (typically wheat, soybean, or corn). Identifications are in progress. Each culture of *R. solani* AG 2-2 is being identified as IIIB or IV by a temperature differential test (IIIB grows at 95 ºF but IV does not) and by molecular techniques. Additional cultures from diseased sugarbeet roots will be collected in 2007 to represent distribution of populations of *R. solani* AG 2-2 throughout the region.

Crop rotation is an effective practice for managing plant diseases and improving crop production. Benefits of crop rotations are complicated and vary among regions (and fields) because of many factors including whether *R. solani* AG 2-2 IIIB or *R. solani* AG 2-2 IV are present. Surveys will continue to identify the distribution and prevalence of *R. solani* AG 2-2 IIIB and AG 2-2 IV in the RRV and southern Minnesota. This information is critical in adopting crop rotation practices that avoid or delay build-up of inoculum and to manage disease in fields where *R. solani* is established.

CONCLUSIONS

1. *R. solani* AG 2-2 IIIB increased on roots of corn and soybean while *R. solani* AG 2-2 IV increased on soybean; neither population favored infection of wheat roots. Yet, *R. solani* produced no above-ground symptoms or reduced yields of these crops.

2. Rhizoctonia diseases of sugarbeet were significantly more severe when soil was infested with *R. solani* AG 2-2 IIIB than with *R. solani* AG 2-2 IV.

3. In 2006, Rhizoctonia diseases of sugarbeet in plots inoculated in 2005 with *R. solani* AG 2-2 IIIB (and then planted to rotation crops) were most severe following corn; intermediate after soybean; and lowest following wheat. Although sugarbeet diseases were less severe in plots inoculated with *R. solani* AG 2-2 IV, previous cropping history followed the same trends.

4. If *R. solani* AG 2-2 IIIB is present in fields, corn is a host contributing to the build-up of inoculum, followed by soybean.

5. Wheat has the least effect on inoculum build-up of *R. solani* AG 2-2 compared to corn and soybean. When inoculum levels of *R. solani* AG 2-2 IIIB are high, however, wheat has little effect in minimizing damage to a subsequent sugarbeet crop.

6. Surveys are underway to determine the prevalence and distribution of *R. solani* AG 2-2 IIIB and *R. solani* AG 2-2 IV in the RRV and southern Minnesota. Interested sugarbeet growers should contact their agriculturist to include samples from their fields in the survey.

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