ROTATION CROP EFFECTS ON RHIZOCTONIA DISEASES OF SUGARBEET IN INFESTED FIELDS

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Rhizoctonia solani AG 2-2 (= *R. solani*) survives in soil on infected crop residue. Populations of the fungus decrease as residue decomposes. Thus, planting non-host crops allows *R. solani* to die over time so the soil is "safe" to plant to sugarbeet. *R. solani* infects many crops, however, so populations of the pathogen may increase or decrease, depending upon susceptibility of rotation crops, length of time between sugarbeet crops, presence of weed species (also susceptible), and weather conditions (that affect whether or not disease will develop).

Rhizoctonia crown and root (RCRR), caused by *R. solani* AG 2-2, is increasingly common in sugarbeet fields in Minnesota and North Dakota. Two populations within AG 2-2 cause RCRR and these are the intraspecific groups (ISGs) AG 2-2 IV and AG 2-2 IIIB. Both ISGs occur in the region and cause identical symptoms of RCRR. Infections begin at the crown (from deposits of infested soil by cultivation, splashing rain), below the soil line, or root tip, depending on where the fungus occurs in the soil profile and if soil moisture and temperature are suitable for infection. Foliar symptoms include sudden, permanent wilting with yellowing of foliage and dark brown to black lesions at the base of petioles; leaves collapse on the soil surface and die, but remain attached to the crown. Belowground, dark brown lesions spread (in a ladder-like pattern) and coalesce over the root surface. Diseased crowns and roots may develop deep fissures and cracks that deform the root. Rot initially is restricted to external layers of the root but as disease advances, moves into the interior. By harvest, plants are dead or have symptoms of RCRR ranging from mild to severe.

R. solani AG 2-2 IIIB tends to be more aggressive and has a wider host range than AG 2-2 IV. Since the mid 1990s there has been a shift in crops grown in the Red River Valley (RRV) that favor build-up of the pathogen. Spring wheat (a non-host) has been decreasing in the 3-yr rotation between sugarbeet crops, while planting of *Rhizoctonia*-susceptible crops has increased. From 1995 to 2007 in the RRV, hard red spring wheat production decreased 33% (from 3,045,230 to 2,032,030 acres) while soybean increased 141% (from 823,020 to 1,983,225 acres) and corn increased 189% (from 398,000 to 1,149,200 acres). Other factors contributing to increases in RCRR include widespread planting of susceptible sugarbeet varieties and favorable soil moisture during the growing season. Since crops susceptible to *R. solani* now are commonly grown in rotation with sugarbeet, growers have many questions about the sequence of crops that can be grown to reduce populations of the pathogen.

OBJECTIVES

Experiments were conducted to determine effects of several crop rotation sequences on 1.) populations of *R. solani* AG 2-2 IV and AG 2-2 IIB and 2.) RCRR and effects on sugarbeet yield and quality.

MATERIALS AND METHODS

Sugarbeet. A field trial was established at the University of Minnesota, Northwest Research and Outreach Center, Crookston in mid May, 2005. Main plots (33 x 30 ft) were inoculated with *R. solani* AG 2-2 IV, AG 2-2 IIIB, and not inoculated (control) in a randomized block design with four replications. Within 24 hr, each plot was divided into subplots and sown with wheat, soybean, and corn. The following year, all subplots were planted to sugarbeet. The original purpose of this trial was to determine the pathogenicity and survival of *R. solani* AG 2-2 IV and AG 2-2 IIIB on 1.) rotation crops (wheat, soybean, corn) and 2.) a subsequent sugarbeet crop. Results have been reported (2-4). Establishment of the trial also presented an opportunity to assess long-term effects of various crop rotations on *R. solani* AG 2-2 in plots where both ISGs are present. Rotation sequences from 2005 to 2009 are shown in Table 1. All crops were grown following standard production practices.

Table 1. Crop sequences from 2005 to 2009 in plots inoculated with *Rhizoctonia solani* AG 2-2 IV, AG 2-2 IIIB, and the non-inoculated control. Main plots were inoculated in May, 2005 and crops were sown as subplots within 24 hours.

	Plot treatments in 2005 and crop grown each consecutive year								
Year	Non-inoculated control			AG 2-2 IV			AG 2-2 IIIB		
2005	Wheat	Soybean	Corn	Wheat	Soybean	Corn	Wheat	Soybean	Corn
2006	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet
2007	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat
2008	Wheat	Soybean	Corn	Wheat	Soybean	Corn	Wheat	Soybean	Corn
2009	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet

Plots inoculated in May, 2005.

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On May 20, 2009 (five years after plots were inoculated with *R. solani* AG 2-2), a Roundup Ready sugarbeet variety susceptible to RCRR (rating of 4.3) was sown in each subplot (Table 1). Data were collected on seedling emergence at 14, 21, 29, and 36 days after planting. Plots then were thinned to the equivalent of 150 plants per 100-ft row. The two middle rows of each subplot were harvested on October 12 and number of marketable roots were counted; 20 roots were selected and rated for RCRR (0 to 7 scale, where 0 = healthy and 7 = root completely rotted and foliage dead). Ten of these roots were analyzed for yield and sucrose quality by the American Crystal Sugar Company Quality Laboratory, East Grand Forks, MN.

Rhizoctonia soil index values. One day after planting sugarbeet in 2009, six soil cores (2.5-inch diameter) were collected to a 6-inch depth and combined for each subplot. Assays to determine Rhizoctonia soil index values (SIVs, which indicate potential for *Rhizoctonia* diseases when soil is warm and wet) were done by planting 25 sugarbeet seed of 'ACH 261' per 4 x 4 x 4-inch plastic pot (four pots per soil sample) to "bait" *R. solani* from soil. Pots were placed in a controlled environment chamber in a randomized block design at 70 $\pm$ 2^0F for 1 week for optimal emergence. Temperatures then were increased to 79 $\pm$ 2^0F (14 hour photoperiod) and soil was kept moist to favor disease. Stand counts were made three times weekly starting at emergence and dying seedlings were removed to prevent disease from spreading to adjacent plants. At 4 weeks after planting, surviving seedlings were rated for root rot. These ratings and numbers of dead seedlings during the 4-week assay were used to calculate a Rhizoctonia SIV (0 to 100 scale, 0 = *Rhizoctonia*-free and 100 = all seedlings dead and soil severely infested with *Rhizoctonia)*.

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

RESULTS

Sugarbeet. In 2009, there were no interactions for any variable measured on sugarbeet between *R. solani*-inoculated and non-inoculated treatments and sequence of crops (data not shown). Consequently, data for these main treatments are presented separately in Table 2. The trial was nearly symptom-free of *Rhizoctonia* diseases; seedling stands were excellent and RCRR was minimal. There were no differences in *Rhizoctonia* diseases or sugarbeet yield, quality, and economic return among plots inoculated in 2005 with either ISG of *R. solani* AG 2-2 and the non-inoculated control or among sequences of crops from 2005 to 2008 (Table 2).

Rhizoctonia soil index values. In both 2006 and 2009 (years sugarbeet was grown), there were significant interactions of SIVs between main soil treatments (*R. solani*-inoculated and non-inoculated) and sequence of crops (Table 3). In 2006, SIV's were significantly highest in plots inoculated in 2005 with *R. solani* AG 2-2 IIIB compared to plots inoculated with AG 2-2 IV and the non-inoculated control, which were the same; SIVs also were highest and equal when sugarbeet was grown after soybean and corn compared to following wheat. Figure 1A illustrates the interaction between main soil treatment and previous crop. Plots inoculated with *R. solani* AG 2-2 IIIB in 2005 and sown with corn (SIV = 55) or soybean (SIV = 65) had much higher SIVs compared to wheat (SIV = 25); all plots inoculated with AG 2-2 IV and control plots sown with wheat, soybean, and corn had SIVs $\leq$ 20.

Table 2. Sugarbeet yield and quality in 2009, four years after plots were inoculated with *Rhizoctonia solani* AG 2-2 IV, AG 2-2 IIIB, and not inoculated (control) in May, 2005. Inoculated and control plots were rotated to the same crops from 2005 to 2009.

		No. beets	RCRR Rating	Yield	Sugar			Revenue
Effect	29 DAP[w]	harvested	(0-7)[x]	(ton/A)	%	lb/ton	Recov. lb/A	($/A)
Inoculum								
Non-inoculated	198	78	2	25.3	16.3	3.5	7697	954
R. solani AG 2-2 IV	200	74	1.9	24.6	16.6	311	7677	976
R. solani AG 2-2 IIIB	203	76	2.2	25.3	16.4	306	7748	964
LSD (P=0.05)[y]	NS	NS	NS	NS	NS	NS	NS	NS
Crop Sequences (2005-2009)[z]								
W-SB-W-W-SB	207	76	2.1	24.5	16.6	311	7613	965
Soy-SB-W-Soy-SB	197	74	2.0	25.2	16.4	308	7770	976
C-SB-W-C-SB	200	78	2.0	25.6	16.2	303	7739	952
LSD (P=0.05)[y]	NS	NS	NS	NS	NS	NS	NS	NS

[w] DAP=Days after planting.

[x] RCRR=Rhizoctonia crown and root rot, 0-7 scale, where 0=root healthy and 7=root completely rotted and foliage dead.

[y] NS=Not significant at P=0.05.

[z] W=wheat, Soy=soybean, C=corn, SB=sugarbeet.

Table 3. Rhizoctonia soil index values (SIVs) from soil samples collected in May, 2006 and 2009 after sugarbeet was sown; main plots included inoculation with *Rhizoctonia solani* AG 2-2 IV and 2-2 IIIB in May, 2005 and a non-inoculated control. Several crop sequences were grown in inoculated and non-inoculated plots from 2005 to 2009.

	Rhizoctonia Soil Index Value in plots sown to sugarbeet/year (0-100 scale)[x]		
	2006		2009
Inoculum			
Non-inoculated	14a		15.5
R. solani AG 2-2 IV	18a		13.8
R. solani AG 2-2 IIIB	48 b		17.5
P-value	0.003		0.58
LSD (P=0.05)[y]	15.5		NS
Crop Sequence (2005-2006)[z]		Crop Sequence (2005- 2009)[z]	
W-SB	18.8a	W-SB-W-W-SB	10.8a
Soy-SB	31.6 b	Soy-SB-W-Soy-SB	25.6 b
C-SB	30.6 b	C-SB-W-C-SB	10.3a
P-value	0.041		0.005
LSD (P=0.05)[y]	10.8		9.6
Interaction	0.041		0.027

[x] SIVs determined by adding soil of each sample to plastic pots (four pots/sample), planting with 25 seed of sugarbeet 'ACH 261' (to "bait" *R. solani* from soil) and placing in a controlled environment chamber to favor optimal emergence and disease. Stand counts were made three times weekly beginning at emergence and dying seedlings were removed to prevent disease spread. At 4 weeks after planting, surviving seedlings were rated for disease. Disease ratings and numbers of dead seedlings during the 4-week assay were used to calculate a Rhizoctonia SIV (0-100 scale, 0 = soil *Rhizoctonia*-free, 100 = all seedlings died in 4-week assay and soil severely infested with *Rhizoctonia*).

[y] LSD= Least Significant Difference, P=0.05. For each year and column, when P=0.05, numbers followed by the same letter are not significantly different. NS = not significantly different.

[z] W=wheat, Soy=soybean, C=corn, SB=sugarbeet.

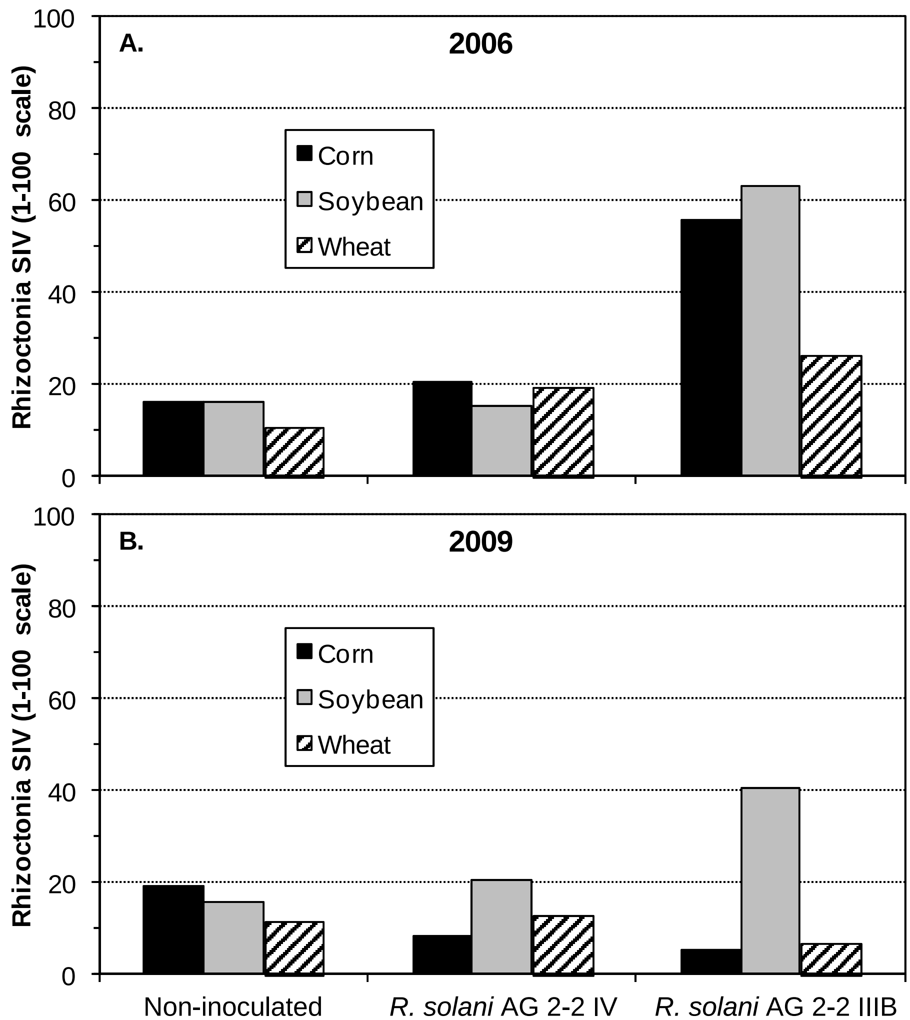

Fig. 1. Rhizoctonia soil index values (SIVs) of samples collected within one month of planting sugarbeet in **A.)** May, 2006, and **B.)** May, 2009. Field plots were inoculated with *Rhizoctonia solani* AG 2-2 IV and AG 2-2 IIIB in 2005; a control was not inoculated. Rotation crops grown in 2005 and 2008 were corn, soybean, and wheat. The SIVs were determined by adding soil of each sample to plastic pots (four pots/sample), planting with 25 sugarbeet seed of 'ACH 261' (to "bait" *R. solani* from soil), and placing in a controlled environment chamber to favor disease. At 4 weeks after planting, surviving seedlings were rated for disease; disease ratings and numbers of dead seedlings were used to calculate Rhizoctonia SIVs (0 to 100 scale, where 0 = *Rhizoctonia*-free soil, 100 = all seedlings died and soil is severely infested with *Rhizoctonia*). Each bar is an average of four soil samples.

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In 2009, SIVs were lower than in 2006 in plots previously inoculated with *R. solani* 2-2 IIIB (Table 3). Values were the same among soil treatments but were significantly higher for the rotation that included two soybean crops (soybean-sugarbeet-wheat-soybean-sugarbeet = Soy-SB-W-Soy-SB, respectively) than for the other crop sequences (W-SB-W-W-SB or Corn (C)-SB-W-C-SB). Figure 1B shows the interaction between main soil treatment and crop sequence. Plots inoculated with *R. solani* AG 2-2 IIIB and sown with two crops of soybean had a higher SIV (40) compared to all other soil treatments and crop sequences, which averaged SIVs $\leq$ 20.

DISCUSSION

Sugarbeets grown in 2009 in field plots infested with *R. solani* AG 2-2 in 2005 were healthy and nearly *Rhizoctonia*-free. In 2006, sugarbeet damping-off and RCRR occurred in these plots when they were inoculated with both ISGs of AG 2-2 and was most severe in AG 2-2 IIIB-inoculated plots sown with soybean or corn (3). In 2006, Rhizoctonia SIVs were $\leq$ 20 across plots, except for AG 2-2 IIIB plots sown with soybean and corn, where SIVs were 55 and 60, respectively. Soybean and corn are susceptible to AG 2-2 IIIB (2-4) and thus, are assumed to maintain or increase populations of the pathogen. From 2006 to 2009, SIVs declined from 55 to 8 in AG 2-2 IIIB plots sown to sugarbeet-wheat-corn-sugarbeet, respectively, and SIVs declined from 65 to 40 in AG 2-2 IIIB plots sown to sugarbeet-wheat-soybean-sugarbeet, respectively. Ruppel (1) concluded that decline in survival of *R. solani* was related to degradation of debris/food base and reported a 74-80% loss in survival of *R. solani* after diseased sugarbeet roots were buried in soil for one year. In our trials, RCRR was severe on sugarbeet in 2006 and wheat was sown across all plots in 2007. Planting a full-season crop of wheat (a non-host) in 2007 may have allowed the population of *R. solani* AG 2-2 to decline. Planting soybean (a very susceptible crop) in 2008, however, may have increased the fungus. It was unexpected that 2009 SIVs would be low in plots inoculated with AG 2-2 IIIB and sown twice with corn since 2005, because the pathogen also increased on corn roots (2,3).

Although RCRR was commonly observed in fields at the University of Minnesota, Northwest Research and Outreach Center and in the RRV in 2009, it was not observed in the long-term rotation trial described in this article. It may be possible that environmental conditions were unfavorable for infection and disease development. In any case, all crop sequences resulted in very low RCRR on sugarbeet and good yields, despite SIV values being high for subplots where soil was inoculated with *R. solani* AG 2-2 IIIB in 2005 and sown twice to soybean (a highly susceptible crop) in 2005 and 2008.

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