LONG-TERM CROP ROTATION EFFECTS ON SUGARBEET IN *RHIZOCTONIA*-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 (1), 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 may be 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 rotations between sugarbeet crops. In the Red River Valley from 1995 to 2007, hard red spring wheat production decreased 33% (from 3,045,230 to 2,032,030 acres). On the other hand, during this time there was increased planting of *Rhizoctonia*-susceptible crops. Soybean production 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 best sequence of crops to reduce populations of the pathogen.

OBJECTIVES

Experiments were conducted to determine long-term effects of several crop rotation sequences on survival of *R. solani* and RCRR on sugarbeet.

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 hours, each plot was divided into subplots and sown with wheat, soybean, and corn. The following year, all subplots were planted to sugarbeet. In 2006, another duplicate trial was established. 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. Rotation sequences were identical for the two trials (each conducted over 4 years) and are shown in Table 1. All crops were grown following standard fertility and production practices.

Table 1. Crop sequences in field trials inoculated in with *Rhizoctonia solani* AG 2-2 IV, *R. solani* AG 2-2 IIIB, and a non-inoculated control and then sown with full-season crops of wheat, corn, and soybean in year 1. Two identical trials were conducted from 2005 to 2009 and from 2006 to 2010.

	Plot treatments and crop grown each consecutive year								
Year	Non-inoculated control			AG 2-2 IV			AG 2-2 IIIB		
1	Wheat	Soybean	Corn	Wheat	Soybean	Corn	Wheat	Soybean	Corn
2	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet
3	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat	Wheat
4	Wheat	Soybean	Corn	Wheat	Soybean	Corn	Wheat	Soybean	Corn
5	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet	Sugarbeet

Plots inoculated in May of year 1 and then sown with hard red spring wheat, soybean and corn within 24 hours.

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The trial originally established in 2005 was sown to sugarbeet in 2006 and in 2009 (5). The trial established in 2006 was sown to sugarbeet in 2007 (4) and 2010. In the 2009 and 2010 trials, a Roundup Ready sugarbeet variety susceptible to RCRR (rating of 4.3 and 5.76, respectively) was sown. 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, 2009 and September 22, 2010. Data were collected for number of marketable roots and 20 roots were arbitrarily 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. Each year when sugarbeet was sown, soil samples were collected from each subplot and assayed to determine the Rhizoctonia soil index value (SIV). The assay measures relative disease potential (0 to 100 scale) where 0 = no Rhizoctonia detected and 100 = all seedlings died or severely diseased in the 4-week assay (and disease potential in a field will be very high if weather conditions are wet and warm). Six soil cores (2.5-inch diameter) were collected to a 6-inch depth and combined for each subplot. Assays to determine Rhizoctonia SIVs were done by planting 25 sugarbeet seed of 'Beta 87RR38' 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 ^{0}F for 1 week for optimal emergence. Temperatures then were increased to 79 $\pm$ 2 ^{0}F (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 spread. At 4 weeks after planting, surviving seedlings were rated for root rot. These ratings and numbers of dying seedlings during the assay were used to calculate Rhizoctonia SIVs.

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

RESULTS

Sugarbeet: 1 year after soil inoculation. For comparison purposes RCRR ratings and sugarbeet yields in 2006 and 2007 trials are provided in Table 2 to illustrate how two identical trials can have very different outcomes one year after plots were inoculated with *R. solani* AG 2-2 and then seeded with full-season rotation crops. In both years there were no significant interactions between inoculum and previous crops, so these are presented as main treatments. In both years, RCRR was significantly different among the three soil treatments; disease was most severe in plots inoculated the previous year with *R. solani* AG 2-2 IIIB, lowest in the non-inoculated control, and intermediate in plots inoculated with *R. solani* AG 2-2 IV. In both years, severity of RCRR was unaffected by previous crop (wheat, soybean, corn). Overall, RCRR was more severe in 2006 than in 2007 because or more favorable weather (wet and warm), which resulted in lower yields for all treatments in 2006.

When sugarbeets were sown in 2006 and 2007 trials, Rhizoctonia soil index values (SIVs) did not correspond to severity of RCRR. In both years there were significant interactions between soil treatment (inoculated and non-inoculated) and previous crop (wheat, corn, soybean), which are illustrated in Fig. 1. Rhizoctonia SIVs were lower in 2006 (Fig. 1A) than in 2007 (Fig. 1B), although in the field, RCRR was more severe in 2006 than in 2007 (Table 2). The SIVs in 2006 were less than 20 for plots inoculated with *R. solani* AG 2-2 IV and the non-inoculated control

Table 2. Sugarbeet ratings for Rhizoctonia crown and root rot and yields in 2006 and 2007 trials originally inoculated with *R. solani* AG 2-2 IV, *R. solani* AG 2-2 IIIB, or not inoculated (control) and then sown with full-season crops of spring wheat, soybean, and corn the previous year (2005 and 2006, respectively). Data previously reported in Sugarbeet Research & Extension Reports 38:272-280 (4).

	RCRR (0-7 scale)[Z]		No. roots/100 ft row @ harvest		Yield (T/A)		Recov. suc (lb/A)		Gross return ($/A)	
Main treatment[V]	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
Inoculum[W]										
Non-inoculated control	1.4 a	1.6 a	175 a	167 a	24.1 a	29.1 a	7213 a	9162 a	803 a	1038 a
R. solani AG 2-2 IV	3.5 b	2.3 b	105 b	142 b	18.5 b	28.9 a	5213 b	8907 a	536 b	988 a
R. solani AG 2-2 IIIB	6.3 c	4.8 c	37 c	90 c	7.5 c	24.6 b	1806 c	7360 b	145 c	788 b
LSD ($P = 0.05$)[Y]	0.8	0.5	22	17	4	4	1128	1150	119	129
Previous crop[X]										
Wheat	3.4	2.8	117	140	18.9 a	28.0	5371 a	8595	562 a	948
Soybean	3.9	2.7	102	133	15.1 b	27.7	4627 b	8617	482 ab	964
Corn	4.0	3.3	97	125	15.0 b	26.9	4234 b	8219	439 b	901
LSD ($P = 0.05$)[Y]	NS	NS	NS	NS	2	NS	666	NS	87	NS

[V] The 2006 sugarbeet crop was sown in a trial inoculated in May, 2005 with *R. solani* AG 2-2 IV, *R. solani* AG 2-2 IV (11.3 oz per 990 ft^2) or not inoculated and then sown with full-season crops of wheat, soybean and corn. In 2007, sugarbeet was sown in a trial inoculated in May, 2006 and then sown with the same three rotation crops as in 2005.

[W] Each value is averaged across previous crop.

[X] Each value is averaged across soil inoculum.

[Y] For each column, values followed by the same letter are not significantly ($P = 0.0.5$); NS = not significantly different.

[Z] RCRR = Rhizoctonia crown and root rot ratings based on a 0 to 7 scale: 0 = root healthy, 7 = root completely rotted and foliage dead.

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Table 3. Combined sugarbeet ratings for Rhizoctonia crown and root rot and yields in trials conducted in 2009 and 2010; the trials were each inoculated with *R. solani* AG 2-2 IV, *R. solani* AG 2-2 IIIB, and not inoculated (control) in 2005 and 2006, respectively, and then sown with full-season crops of wheat, soybean and corn; each trial was planted to sugarbeet in 2006 and 2007, respectively and in the next 2 years were sown with the same crop sequences.

	RCRR	No. roots/100 ft		Sucrose			Gross return
Main treatment	**(0-7 scale)[Z]**	**row @ harvest**	**Yield (T/A)**	**%**	**lb/T**	**lb recov./A**	**$/A**
Inoculum[W]							
Non-inoculated control	1.6	137	26.7	17.0	318	8340	1210
R. solani AG 2-2 IV	1.6	135	26.0	17.1	319	8314	1212
R. solani AG 2-2 IIIB	1.7	136	26.5	17.0	319	8475	1235
LSD ($P = 0.05$)[Y]	NS	NS	NS	NS	NS	NS	NS
Previous crop[X]							
W-SB-W-W	1.6	137	26.7	16.8	314	8397	1204
Soy-SB-W-Soy	1.6	135	26.2	17.1	321	8446	1241
C-SB-W-C	1.7	136	25.8	17.1	321	8286	1213
LSD ($P = 0.05$)[Y]	NS	NS	NS	NS	NS	NS	NS

[V] The 2006 sugarbeet crop was sown in a trial inoculated in May, 2005 with *R. solani* AG 2-2 IV, *R. solani* AG 2-2 IV (11.3 oz per 990 ft2) or not inoculated and then sown with full-season crops of wheat, soybean and corn. In 2007, sugarbeet was sown in a trial inoculated in May, 2006 and then sown with the same three rotation crops, as in 2005.

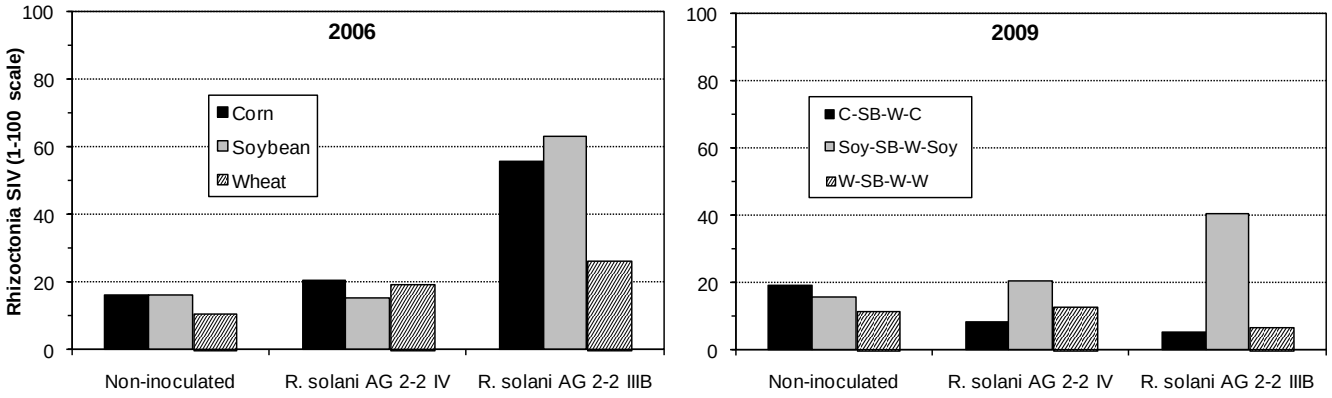
[W] Each value is averaged across previous crop.

[X] Each value is averaged across soil inoculum; W = wheat, Soy = soybean, C = Corn, SB = sugarbeet.

[Y] NS = not significantly different ($P = 0.05$).

[Z] RCRR = Rhizoctonia crown and root rot ratings based on a 0 to 7 scale: 0 = root healthy, 7 = root completely rotted and foliage dead.

A. Sugarbeet trial 1 (2006 & 2009)



B. Sugarbeet trial 2 (2007 & 2010)

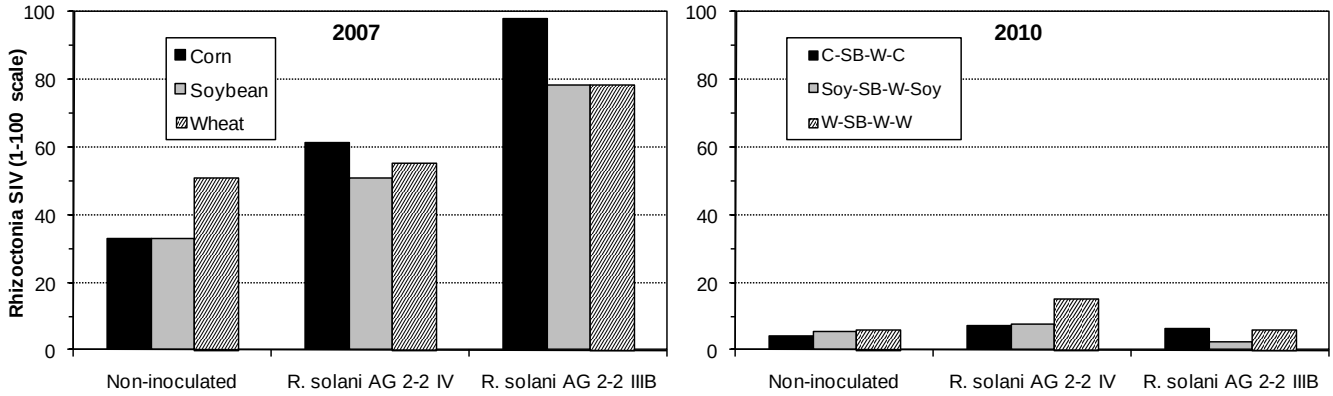


Fig. 1. Rhizoctonia Soil Index Values in two sugarbeet trials at 2 and 4 years after soil was inoculated with *Rhizoctonia solani* AG 2-2 IV, *R. solani* AG 2-2 IIIB and a non-inoculated control in year 1 and sown with corn (C), soybean (Soy), and wheat (W): **A**) sugarbeet sown in 2006 and 2009 and **B**) sugarbeet sown in 2007 and 2010. In year 4 of both trials, sugarbeet (SB) followed the same three crops sequences: C-SB-W-C, Soy-SB-W-Soy, and W-SB-W-W.

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and were unaffected by previous crop compared to plots inoculated with *R. solani* AG 2-2 III and sown with corn or soybean (Fig. 1A). In 2007, SIVs in the non-inoculated control ranged from 25 to 35, depending upon rotation crop and in plots inoculated with *R. solani* AG 2-2 IV ranged from 55 to 62; in plots inoculated with *R. solani* AG 2-2 IIIB, SIVs were especially high following corn (= 98) (Fig. 1B).

Sugarbeet: 4 years after soil inoculation. When sugarbeet was sown in 2009 and 2010 in the same trials inoculated with *R. solani* AG 2-2 in 2005 and 2006, respectively, there were no significant differences of soil treatment or previous crop on RCRR or sugarbeet yield and quality, so results were combined for both years and are illustrated in Table 3. Weather was warm and wet and favorable for infections by *R. solani* AG 2-2 in both years. The level of RCRR, however, was low and numbers of roots, yields, quality, and dollar return per acre were the same in plots that had been inoculated with *R. solani* AG 2-2 and in the non-inoculated control, regardless of sequence of rotation crops.

In the sugarbeet trial sown in 2009, Rhizoctonia SIVs were about the same and low (< 20, Fig. 1C) compared to 2006 (Fig. 1A) for the non-inoculated control and in plots inoculated with *R. solani* AG 2-2 IV. SIVs in plots inoculated with *R. solani* AG 2-2 IIIB decreased in 2009 (Fig. 1C) compared to 2006 (Fig. 1A), but overall remained

highest (SIV = 40) when the crop sequence included two soybean crops (soybean-sugarbeet-wheat-soybean). In the sugarbeet trial sown in 2010, Rhizoctonia SIVs dropped drastically (< 20, Fig. 1D) compared to 2007 (Fig. 1B) across all soil treatments and rotation sequences.

DISCUSSION

Our trials show that severity of RCRR was negligible on sugarbeet after various two-year sequences of rotation crops differing in susceptibility to *R. solani* AG 2-2, even when RCRR had been severe on the previous sugarbeet crop. These results are contrary to recommended rotation practices to minimize build-up of *R. solani* in soil by not planting susceptible rotation crops. In our trials, sugarbeet was followed by hard red spring wheat and then by wheat, corn, or soybean. Perhaps the wheat crop following sugarbeet, even when RCRR was severe, was enough to reduce the *R. solani* population to safe levels. In 2009, Rhizoctonia SIVs were low in all subplots except where soybean had grown 2 years out of 4 in plots inoculated with *R. solani* AG 2-2 IIIB, however, disease occurrence in the field was just as low on sugarbeet grown in this treatment compared to plots that had been inoculated with *R. solani* AG 2-2 IV and the non-inoculated control sown to all rotation crops. Overall, Rhizoctonia SIVs were considerably lower 4 years after inoculation with *R. solani* AG 2-2 for all crop sequences compared to the non-inoculated control and these results were consistent with sugarbeet performance in the field.

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