SWEET CORN IN ROTATION WITH SUGARBEET AS A POTENTIAL HOST OF *RHIZOCTONIA SOLANI* AG 2-2

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Rhizoctonia crown and root rot (RCRR) is an increasing problem throughout sugarbeet-growing areas of Minnesota and North Dakota. The disease is caused by the soilborne fungus, *Rhizoctonia solani*, which is separated into different genetic populations called anastomosis groups (AGs) (5). The AG causing RCRR on sugarbeet is AG 2-2, which is further divided into the intraspecific groups (ISGs) AG 2-2 IV and AG 2-2 IIIB (5,7). Both ISGs cause RCRR on sugarbeet, but AG 2-2 IV is reported as the primary cause (7) while AG 2-2 IIIB is reported as the more aggressive population (6). A recent report testing aggressiveness on sugarbeet and rotation crops of 24 isolates each of *R. solani* AG 2-2 IIIB and IV showed similar aggressiveness for AG 2-2 IIIB and AG 2-2 IV on adult sugarbeet while AG 2-2 IIIB isolates were more aggressive on sugarbeet seedlings (14). On rotation crops, isolates of both AGs varied in aggressiveness, and bean crops (soybean and pinto bean) were most susceptible, sunflower and corn (field and sweet corn) were intermediate, and wheat was least susceptible (14).

In Europe, *R. solani* AG 2-2 IIIB is an aggressive root pathogen on both corn and sugarbeet in rotation (4). In the southeastern U.S.A., *R. solani* AG 2-2 IIIB causes a crown and brace root rot on corn (8,9). Recent reports in Minnesota have demonstrated that corn is a host for *R. solani* AG 2-2 IIIB, and soybean for both ISGs, without any effects on yield or presence of aboveground symptoms (1,11,12,13). In southern Minnesota, sugarbeet follows corn on 75% acres, sweet corn (10%), soybean (10%), and other crops (5%). Information is not available on the relationship of sweet corn to *R. solani* AG 2-2 ISGs.

OBJECTIVES

A field trial was established in southern Minnesota to determine 1) pathogenicity and survival of *R. solani* AG 2-2 IV and AG 2-2 IIIB on sweet corn compared to field corn, soybean, and wheat and 2) effects on a subsequent sugarbeet crop.

MATERIALS AND METHODS

2011 Rotation crops. A field trial was established in a split plot design with six replicates in the spring of 2011 near Maynard, Minnesota. Main plots (88 ft wide by 20 ft long) consisted of a non-inoculated control, inoculation with *R. solani* AG 2-2 IV, and inoculation with *R. solani* AG 2-2 IIIB. Inoculum of *R. solani* was grown for 3 weeks on sterilized barley, air-dried in the greenhouse, and hand-spread in plots (at an equivalent of 31 lb A^{-1}) and incorporated into soil on May 18. There were 11 ft by 20 ft buffers between each main plot. Main plots were divided into eight, 11 ft by 20 ft subplots which were sown on May 19, June 8 and June 30 to an early-, mid-, and late-maturing sweet corn variety, respectively. Field corn and soybean were planted on May 18 and wheat on May 19. Field corn and soybean were Roundup Ready varieties. Within main plots, there were 11 ft buffers between sweet corn and each field crop and between wheat and each RoundUp Ready crop. On July 1, weeds were controlled in sweet corn and wheat with Curtail (16 oz A^{-1}) and in field corn and soybean, with RoundUp Powermax (32 oz A^{-1}).

To obtain root disease ratings and plant samples to assay for *R. solani* AG 2-2, 10 plants of sweet corn and field corn and 20 plants of soybean and wheat were dug from each plot. Early-season sweet corn and wheat were collected on August 3 and mid- and late-maturing sweet corn, field corn, and soybean were collected on August 30. Roots were washed and rated for root rot. Sweet corn and field corn were rated on a 1-5 scale where 1 = less than 2% of roots discolored or decayed, 5 = entire root system rotted and plant dead or dying (8). Soybean basal stems and roots were rated on a 1-5 scale where 1 = no symptoms and 5 = shoot dead and more than 75% of stem girdled (3). Wheat subcrown internodes were rated on a 0-3 scale where 0 = clean and healthy and 3 = more than 50% of the surface with lesions and discoloration (10).

After roots were assessed for disease, they were assayed to isolate *R. solani* AG 2-2. Four, 1-inch root segments were excised from each sweet corn and field corn plant, surface-treated 15 seconds in 0.5% sodium hypochlorite (bleach solution), rinsed twice in sterile deionized water, and placed on modified tannic acid medium. After 1 week, *R. solani* cultures were transferred to acidified potato dextrose agar for further identification. One-inch soybean basal stem segments and wheat subcrown internodes were cultured in the same way.

Yields of sweet corn and field corn were made by hand-harvesting all ears within 10 feet of two center rows per plot on August 2 for early-, and on September 19, for mid-, and late-maturing sweet corn varieties, and in early October for field corn. Ears of field corn were shelled with a stationary corn sheller. Wheat and soybean data were not available.

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

2012 Sugarbeet crop. Plots previously infested with *R. solani* and planted with rotation crops in 2011 as described above were fertilized to recommended levels and planted to a susceptible sugarbeet variety on May 22. Sugarbeet plots were 6 rows wide, spaced 22 inches apart, and were 20 feet long. Applications of RoundUp PowerMax + Select Max (32 and 4 oz A^{-1}, respectively on July 7 and August 1) were made for weed control using a tractor-mounted sprayer and TeeJet 8003 flat fan nozzles at 40 psi. Cercospora leafspot was controlled with applications of Eminent + Manzate (13 oz + 1.5 qt A^{-1}), Supertin WP (8 oz A^{-1}), and Gem (3.5 oz A^{-1}) on July 2, July 18, and August 1, respectively.

Stand counts were done on June 10 and 22 and the middle two rows of plots were harvested on October 21. Beets were lifted and laid in place. Twenty roots were arbitrarily selected from each plot and rated for RCRR with a 0 to 7 scale, where 0 = healthy and 7 = root completely rotted and foliage dead. Roots were analyzed for yield and quality by Southern Minnesota Beet Sugar Cooperative, Renville, MN.

Data were subjected to analysis of variance (ANOVA) for main effects of inoculum and previous crop and interactions between inoculum and previous crop. Where significant (P = 0.05), means were separated by Least Significant Difference (LSD).

RESULTS

2011 Rotation crops. Root rot ratings were not significantly different (P = 0.05) among *R. solani*-inoculated and control treatments for all crops except field corn, which had significantly higher ratings in non-inoculated plots (2.9) and plots inoculated with *R. solani* AG 2-2 IIIB (2.9) compared to plots inoculated with *R. solani* AG 2-2 IV (2.6) (Table 1). Root rot ratings averaged 2.6, 2.4, and 1.9 for early-, mid-, and late-maturing sweet corn, respectively, and 1.5, 2.8, and 2.2 for wheat, field corn, and soybean, respectively.

Recovery of *R. solani* AG 2-2 from all crops was very low (data not shown). The fungus was not recovered from roots of early-maturing sweet corn. In mid-maturing sweet corn *R. solani* was isolated from 10.0% of roots in non-inoculated plots and 1.7 and 8.3% of roots in plots inoculated with *R. solani* AG 2-2 IV and AG 2-2 IIIB, respectively. In late-maturing sweet corn *R. solani* was isolated from 6.7% of roots in non-inoculated plots and 0 and 8.3% of roots in plots inoculated with *R. solani* AG 2-2 IV and AG 2-2 IIIB, respectively. The fungus was recovered from 0.8% of wheat roots in *R. solani* AG 2-2 IV-inoculated plots and was not isolated from roots in the non-inoculated or AG 2-2 IIIB-inoculated plots. In field corn, the fungus was not isolated from non-inoculated plots and plots inoculated with *R. solani* AG 2-2 IV, and was isolated from 3.3% of roots in plots inoculated with *R. solani* AG 2-2 IIIB. In soybean, *R. solani* was found in 5.8% of roots in the non-inoculated control and 19.2 and 5.0% of plants in AG 2-2 IV- and AG 2-2 IIIB-inoculated plots, respectively.

Table 1. Root rot ratings of sweet corn, wheat, field corn, and soybean sown into soil inoculated (before crops were planted) with *Rhizoctonia solani* AG 2-2 IV, AG 2-2 IIIB, or not inoculated in 2011.

	Root rot rating					
	Sweet corn (1-5)[X]			Wheat	Field corn	Soybean
Soil treatment [W]	Early	Middle	Late	(0-3)[Y]	(1-5)[X]	(1-5)[Z]
Non-inoculated	2.7	2.2	1.9	1.6	2.9	2.0
R. solani AG 2-2 IV	2.4	2.4	1.9	1.5	2.6	2.3
R. solani AG 2-2 IIIB	2.8	2.5	2.0	1.5	2.9	2.2
ANOVA *P*-value	0.217	0.680	0.748	0.755	0.050	0.173
LSD (*P* = 0.05)	NS	NS	NS	NS	0.3	NS

[W] Inoculum of *R. solani* was grown for 3 weeks on sterilized barley, air-dried in the greenhouse, and hand spread in plots on May 18 at an equivalent of 31 lb A^{-1}.

[X] Sweet corn and field corn were rated on a 1-5 scale where 1 = less than 2% of roots were discolored or decayed, 5 = entire root system rotted and plant dead or dying (8). Each number is an average of 60 plants (10 plants/plot x 6 replicates).

[Y] Wheat subcrown internodes were rated on a 0-3 scale where 0 = clean and healthy and 3 = more than 50% of the surface with lesions and discoloration (10). Each number is an average of 120 plants (20 plants/plot x 6 replicates).

[Z] Soybean basal stems and roots were rated on a 1-5 scale where 1 = no symptoms and 5 = shoot dead and more than 75% of stem girdled (3). Each number is an average of 120 plants (20 plants/plot x 6 replicates).

Table 2. Yield of sweet corn, field corn and soybean sown into soil inoculated (before crops were planted) with *Rhizoctonia solani* AG 2-2 IV, AG 2-2 IIIB, or not inoculated in 2011.

	Yield					
	Sweet corn (ton A^{-1})[X]			Wheat[Y]	Field corn[X]	Soybean[Z]
Soil treatment[W]	Early	Middle	Late	(Bu A^{-1})	(Bu A^{-1})	(Bu A^{-1})
Non-inoculated	14.8	16.8	23.7	-	164	-
R. solani AG 2-2 IV	17.3	20.8	21.4	-	172	-
R. solani AG 2-2 IIIB	14.8	19.0	21.1	-	194	-
ANOVA *P*-value	0.393	0.319	0.359	-	0.590	-
LSD (*P* = 0.05)	NS	NS	NS	-	NS	-

[W] Inoculum of *R. solani* was grown for 3 weeks on sterilized barley, air-dried in the greenhouse, and hand spread in plots on May 18 at an equivalent of 31 lb A^{-1}.

[X] Sweet corn and field corn yield estimates were made by hand-harvesting all ears within 20 feet of row per plot on August 2 for early-, and September 19, for mid-, and late-maturing sweet corn varieties, respectively, and in early October for field corn. Field corn ears were shelled with a stationary corn sheller.

[Y] Wheat yield was not available at the time of report submission.

[Z] Soybean yield was not available at the time of report submission.

Inoculum treatment had no effect on yield for early-, mid-, and late-maturing varieties of sweet corn and field corn (Table 2). Late-maturing sweet corn had the highest yields (mean = 22.0 ton A^{-1}) compared to 15.6 and 18.9 ton A^{-1} for early- and mid-maturing varieties, respectively. Yield of field corn averaged 176 bu A^{-1} across inoculum treatments. Yields of wheat soybean were not available at the time of report submission.

Table 3. Early season stand, root rot ratings, yield, and quality of sugarbeet sown May 22, 2012 in experiments inoculated in May, 2011 with *Rhizoctonia solani* AG 2-2 IV, AG 2-2 IIIB, or not inoculated and then planted to full-season crops of sweet corn, field corn, soybean, or wheat in a field near Maynard, MN.

Main effect	Stand/100 ft June 22[z]	RCRR[z] (0-7)	Yield[z] T A^{-1}	Sucrose[z] %	Sucrose lb ton^{-1}	Sucrose lb recov. A^{-1}	Revenue \$ A^{-1}
<u>Inoculum</u>							
Non-inoculated control	169	0.2 ab	20.9	13.7	198	4159	970
R. solani AG 2-2 IV	137	0.2 b	22.8	13.7	199	4532	1059
R. solani AG 2-2 IIIB	161	0.3 a	20.4	13.8	203	4098	966
LSD (P = 0.05)	NS	0.09	NS	NS	NS	NS	NS
<u>Previous crop</u>							
Early sweet corn	150	0.2	23.1 a	13.6	198	4563	1059
Middle sweet corn	144	0.2	19.0 c	13.8	203	3874	922
Late sweet corn	174	0.2	21.6 abc	13.9	202	4338	1024
Field corn	158	0.3	19.4 bc	13.8	201	3888	913
Soybean	162	0.2	22.3 ab	13.7	199	4429	1031
Wheat	149	0.2	22.7 a	13.6	198	4487	1042
LSD (P = 0.05)[Z]	NS	NS	3.2	NS	NS	NS	NS

[z] For each column, numbers followed by the same letter are not significantly different according to Fisher's protected least significant difference (LSD, P = 0.05); NS = not significantly different.

2012 Sugarbeet crop. There were no significant (P = 0.05) interactions between inoculum treatment and previous crop, so main effects are shown separately in Table 3. There were no significant effects of inoculum on early season stands, yield, sucrose, and revenue. Rhizoctonia crown and root rot ratings were statistically (P = 0.05) higher in plots inoculated with *R. solani* AG 2-2 ISG IIIB compared to plots inoculated with *R. solani* AG 2-2 ISG IV; ratings in non-inoculated plots were intermediate (Table 3).

There were no significant effects of previous crop on early season stands, RCRR, sucrose yields, or revenue. There was, however, a significant effect of previous crop on yield. Yields were significantly higher (P = 0.05) in plots following early sweet corn and wheat compared to plots following middle sweet corn and field corn; yields were intermediate in plots following soybean and late sweet corn (Table 3).

DISCUSSION

In this experiment, inoculation of soil with *R. solani* AG 2-2 IV or 2-2 IIIB did not affect root rot of rotation crops or yield of sweet corn or field corn compared to a non-inoculated control. Also, the fungus was infrequently recovered from roots of all crops, regardless of soil treatment. These results are consistent with a previous trial in 2010 (2), but not with earlier trials where root rot ratings of field corn were significantly higher in plots inoculated with *R. solani* AG 2-2 IIIB (12,13) and the fungus was isolated more frequently compared to non-inoculated plots. Previous trials also have shown consistent recovery of *R. solani* from soybean plants in plots inoculated with *R. solani* AG 2-2 IV and AG 2-2 IIIB compared to non-inoculated controls (1,13). As in previous trials, growing wheat in *Rhizoctonia*-inoculated soil did not affect yield and the fungus was infrequently recovered compared to the non-inoculated control (12,13). Differences in the 2010 and 2011 trials compared to previous trials may reflect different environmental factors including soil moisture, temperature, and other pathogens and microbes present in the soil.

Inoculation of soil with *R. solani* AG 2-2 IV or 2-2 IIIB also did not have much of an effect on a subsequent sugarbeet crop. Root rot ratings were statistically higher in plots inoculated with *R. solani* AG 2-2 IIIB compared to plots inoculated with *R. solani* AG 2-2 IV, but ratings in all plots were very low and differences were not biologically meaningful. All treatments resulted in a mean RCRR rating <1 which is 'superficial, scattered, scurfy, non-active lesions'. Yields were not affected by soil inoculation indicating that there was not enough pathogen population to cause damage to the sugarbeet crop. This is not surprising considering the lack of effect of inoculum treatments on the previous crops in 2011. This is the second year of this trial with similar results. Results from these trials are not consistent with results from earlier trials where inoculation of soil with *R. solani* AG 2-2 IIIB followed by full-season field corn (1,11,13) and inoculation of soil with *R. solani* AG 2-2 IIIB and AG 2-2 IV followed by full-season soybean crop (13) significantly affected a subsequent sugarbeet crop. Conflicting results may have occurred because of different environmental conditions in 2011 and/or 2012, which affect aggressiveness of *R. solani* in infecting roots.

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LITERATURE CITED

1. Brantner, J.R., M. Bredehoeft, C.E. Windels, and C. Dunsmore. 2010. Rhizoctonia crown and root rot on sugarbeet following corn. 2009 Sugarbeet Res. Ext. Rept. 40:219-224.

2. Brantner, J.R., C.E. Windels, M. Bredehoeft, and C. Dunsmore. 2012. Sweet corn in rotation with sugarbeet as a potential host of Rhizoctonia solani AG 2-2. 2011 Sugarbeet Res. Ext. Rept. 42:237-241.

3. Engelkes, C.A. and C.E. Windels, 1996. Susceptibility of sugar beet and beans to *Rhizoctonia solani* AG 2-2 IIIB and AG 2-2 IV. Plant Dis. 80:1413-1417.

4. Ithurrart, M.E., G. Buttner, and J. Petersen. 2004. Rhizoctonia root rot in sugar beet (*Beta vulgaris* ssp. *altissima*) – Epidemiological aspects in relation to maize (*Zea mays*) as a host plant. J. Plant Disease Protection 111:302-312.

5. Ogoshi, A. 1987. Ecology and pathogenicity of anastomosis and intraspecific groups of *Rhizoctonia solani* Köhn. Annu. Rev. Phytopathol. 25:125-143.

6. Panella, L. 2005. Pathogenicity of different anastomosis groups and subgroups of *Rhizoctonia solani* on sugarbeet (Abstr.) J. Sugar Beet Res. 42:53.

7. Sneh, B., L. Burpee, and A. Ogoshi. 1991. Identification of *Rhizoctonia* species. American Phytopathological Society, APS Press, St. Paul, MN. 133 pp.

8. Sumner, D.R. and D.K. Bell. 1982. Root diseases induced in corn by *Rhizoctonia solani* and *Rhizoctonia zeae*. Phytopathology 72:86-91.

9. Sumner, D.R. 1999. Rhizoctonia crown and brace root rot. Pages 12-13 in: Compendium of Corn Diseases, 3rd edition. D.G. White, ed. American Phytopathological Society, APS Press, St. Paul, MN.

10. Tinline, R.D., R.J. Ledingham, and B.J. Sallans. 1975. Appraisal of loss from common root rot in wheat. Pages 22-26 *in*: Biology and Control of Soil-borne Plant Pathogens. G.W. Bruehl, ed. American Phytopathological Society, St. Paul, MN.

11. Windels, C.E. and J.R. Brantner. 2005. Previous crop influences *Rhizoctonia* on sugarbeet. 2004a Sugarbeet Res. Ext. Rept. 35:227-231.

12. Windels, C.E. and J.R. Brantner. 2006. Crop rotation effects on *Rhizoctonia solani* AG 2-2. 2005 Sugarbeet Res. Ext. Rept. 36:286-290.

13. Windels, C.E. and J.R. Brantner. 2007. Rhizoctonia inoculum and rotation crop effects on a following sugarbeet crop. 2006 Sugarbeet Res. Ext. Rept. 37:182-191.

14. Windels, C.E. and J.R. Brantner. 2012. Variability in aggressiveness between and within intraspecific groups of *Rhizoctonia solani* AG 2-2. 2011 Sugarbeet Res. Ext. Rept. 42:242-252.