

EVALUATION OF SEED TREATMENTS, IN-FURROW FUNGICIDES, AND IN-FURROW BIOCONTROL AGENTS FOR MANAGEMENT OF *RHIZOCTONIA SOLANI* IN SUGARBEET, 2025

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INTRODUCTION

Over the past decade, *Rhizoctonia solani*, the causal agent of damping-off and Rhizoctonia crown and root rot (RCRR), has consistently been the most frequently diagnosed root disease of sugarbeet in Minnesota and North Dakota (Brantner and Windels 2009, 2011; Crane et al. 2013; Brantner 2015; Brantner and Chanda 2017, 2019; Lien et al. 2022, 2024). Warm soils with adequate moisture strongly favor pathogen development, leading to preemergence and post-emergence damping-off that reduces early-season stands. root and crown rot later in the season contributes to stand decline, reduced root yield, and diminished sucrose quality. In storage, moderately to severely infected roots have greater sugar losses due to increased respiration, which can further impact storability of adjacent healthy roots (Campbell et al. 2013). The pathogen is presumed to be present in most agricultural soils across the region, and more than half of growers surveyed in 2023 reported fields affected by RCRR (Hakk et al. 2024). This widespread prevalence is supported by the pathogen's broad host range, including soybeans, edible beans, and corn (Windels and Brantner 2006, 2010a, 2010b), and its ability to persist for multiple years in soil as sclerotia or infected residues, with dissemination facilitated by water, soil movement, and tare soil from harvest operations.

Effective management of diseases caused by *R. solani* relies on an integrated strategy that may include rotation with non-host crops such as small grains, use of Rhizoctonia tolerant sugar beet varieties, early planting when soils are cooler, improved soil drainage, and applications of fungicides as seed treatments, in-furrow (IF) placements, or postemergence sprays (Windels et al. 2009; Chanda et al. 2016, 2017, 2019; Brantner and Chanda 2018, 2020; Lien et al. 2022, 2023, 2024). Commercial sugarbeet seed is routinely sold with fungicide seed treatments targeting *R. solani*, although the active ingredient varies among brands. Growers can also supplement protection with IF fungicides at planting, which generally provide longer soil persistence and extended early-season activity relative to seed-applied products. Alongside these chemical control options, interest in biological control agents has increased due to their potential environmental benefits and compatibility with integrated disease management programs.

OBJECTIVES

A field trial was established to evaluate various at-planting fungicide treatments (seed treatment, in-furrow fungicides, and in-furrow biocontrol agents) for 1) control of early-season damping-off and RCRR and 2) effect on plant stand, yield, and quality of sugarbeet.

MATERIALS AND METHODS

The trial was established at the University of Minnesota, Northwest Research and Outreach Center (NWROC), Crookston, on a Hegne-Fargo silty clay soil with an organic matter content of 5.6% using a moderately susceptible sugar beet variety ('Crystal 793RR'; Brantner et al. 2025). Field plots were fertilized for optimal yield and quality according to University of Minnesota Extension guidelines in the fall of 2024. Treatments were arranged in a randomized complete block design with four replicates. Seed treatments were applied by Germaines Seed Technology, Fargo, ND. All seeds were commercially treated with Allegiance, Thiram, and Tachigaren (45 g/unit) as base treatment. In-furrow fungicides and biocontrol agents (Table 1) treatments were applied down the drip tube in 6 gallons of water/A to seeds with base treatment only. The nontreated control received base treatment only. Prior to planting, soil was infested with *R. solani* AG 2-2-infested whole barley (a mixture of two AG 2-2 IIIB and two AG 2-2 IV isolates) at 44.6 lb/A (≈50 kg/ha). Infested barley was hand-broadcast across plots and incorporated with

an 11-ft Rau seedbed finisher. The trial was sown on 07 May in six-row plots (22-inch row spacing, 30-ft rows) at a 4.5-inch seed spacing.

Counter 20G was applied with a modified in-furrow application at 7.5 lb/A followed by a postemergence application of Mustang Maxx (4 fl oz/A) on 04 June (10 gal/A, 30 psi, TeeJet 8002 nozzles) for sugarbeet root maggot management; approximate fly counts were 33 and 110 flies per sticky-stake trap on 03 June and 05 June, respectively. Preplant ethofumesate (6 pt/A) was incorporated using a front-mounted spray boom on a Rau seedbed finisher, followed by a combination of RoundUp PowerMax 3 (28 fl oz/A) and Stinger HL (3 fl oz/A) on 04 June, and an application of Sequence (2.5 pt/A) on 27 June for weed control. Cercospora leaf spot was managed using fungicide program consisting of Inspire XT + Manzate Pro-Stick (7 fl oz + 2 lb/A) on 25 July, SuperTin 4L + Topsin 4.5 FL (8 + 10 fl oz/A) on 13 August, and Proline 480 SC + Manzate Pro-Stick (5.7 fl oz + 2 lb/A) on 26 August.

Plant stands were evaluated from May 19 (12 DAP) through June 10 (34 DAP) by counting healthy plants in the center two rows of each plot. On September 16, plots were defoliated, and the center two rows of each plot were harvested mechanically and weighed for root yield. Immediately after harvest, ten representative roots per plot were submitted to the American Crystal Sugar Company Quality Tare Laboratory (East Grand Forks, MN) for sugar quality analysis. Twenty roots per plot were arbitrarily selected and rated for *Rhizoctonia* crown and root rot (RCRR) severity based on a 0–10 scale with 10% increments (0 = 0%, 5 = 41–50%, 10 = 91–100%), and the remaining harvested roots were counted. Ratings were midpoint-transformed to percent severity for statistical analysis. Statistical analysis was conducted in R (v. 4.3.3; R Core Team 2025). A mixed-model analysis of variance was performed using the lmerTest package (v. 3.1-3), with treatments defined as the fixed factor and replication as the random factor. Treatment means were separated at the 0.10 significance level using emmeans (v. 1.11.1) with no adjustments. A similar model was used to compare application types (seed treatments, in-furrow fungicides, and in-furrow biocontrol agents), with application type defined as the fixed factor.

RESULTS AND DISCUSSION

Total rainfall in April and May measured 1.79 and 2.01 inches, respectively, which was similar to the 30-year averages and created conditions suitable for moderate early-season *Rhizoctonia* pressure. Plant stand counts taken on 19 May (12 DAP) did not differ significantly among treatments, although Bexfond, Serenade ASO, and Headline SC had the highest numerical stands (Table 1). When plant stands were analyzed by application type, a significant difference was detected in which the in-furrow biocontrol treatments resulted in faster plant emergence than the in-furrow fungicides and seed treatments but were not different from the nontreated control (Table 1; Fig. 1). By 10 June (34 DAP), seed treatments maintained the highest plant populations and were significantly greater than in-furrow fungicides but did not differ from the in-furrow biocontrol agents or the nontreated control (Table 1; Fig. 1).

At harvest, the number of harvested roots differed among treatments. Systiva XS and Bexfond had a greater number of harvested roots than Propulse, while the remaining treatments did not differ significantly (Table 2). No significant treatment effects ($P > 0.10$) were observed for RCRR severity or incidence, percent sugar, sugar loss to molasses (SLM), root yield, or recoverable sucrose (Table 2). When analyzed by application type, only RCRR severity and percent sugar differed significantly (Table 2). Seed treatments and in-furrow fungicides resulted in the lowest RCRR severity, while seed treatments produced the highest percent sugar (Table 2). Overall, IF biological treatments improved early emergence compared to IF fungicide treatments, which carried some risk of reduced stands when planting conditions were not optimal. Even with continued rainfall in July producing moderate RCRR pressure, treatments performed similarly in terms of reducing disease severity.

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Table 1. Effects of at-planting fungicide treatments on emergence and stand establishment in a *Rhizoctonia*-infested field trial planted on 07 May 2025 at the University of Minnesota, Northwest Research and Outreach Center, Crookston.

Treatment and (rate) ^t	Plants per 100-ft row ^u					
	May 19 (12 DAP) ^{v,w}	May 23 (16 DAP)	May 28 (21 DAP)	June 2 (26 DAP)	June 6 (30 DAP)	June 10 (34 DAP)
Nontreated Control	98	122	188 bc	195 bc	194 abc	198 abc
Kabina ST (14 g) ^x	99	120	188 bc	200 c	202 c	208 c
Systiva XS (5 g) ^x	104	129	193 c	203 c	205 c	209 c
Vibrance (1.5 g) ^x	101	119	183 bc	194 bc	196 abc	198 abc
Zeltera (0.1 g) ^x	98	122	190 bc	198 bc	200 bc	203 bc
Quadris (9.5 fl oz) ^y	109	130	178 abc	183 abc	184 abc	190 abc
Elatus WG (7.1 oz) ^y	98	119	174 abc	179 abc	181 abc	183 abc
AZteroid FC3.3 (5.7 fl oz) ^y	107	125	192 bc	204 c	202 c	204 bc
Headline SC (9 fl oz) ^y	120	142	186 bc	198 bc	197 abc	202 bc
Priaxor (6.7 fl oz) ^y	101	122	183 bc	195 bc	196 abc	202 bc
Proline 480 SC (5.7 fl oz) ^y	85	112	160 ab	168 ab	172 ab	176 ab
Propulse (13.6 fl oz) ^y	88	103	149 a	162 a	167 a	171 a
Zironar (12 fl oz) ^z	102	132	170 abc	179 abc	178 abc	181 abc
Bexfond (14 fl oz) ^z	128	145	194 c	202 c	201 bc	207 c
Serenade ASO (128 fl oz) ^z	127	147	195 c	198 bc	199 bc	205 bc
Howler EVO (40 fl oz) ^z	111	127	195 c	204 c	205 c	208 c
<i>P</i> -value	0.1188	0.2781	<0.0001	<0.0001	<0.0001	<0.0001

Analysis by Application Type

Nontreated Control	98 ab	122 ab	188 ab	195 ab	194 ab	198 ab
Fungicide Seed Treatments	101 a	122 ab	188 b	199 b	201 b	204 b
In-furrow Fungicide Treatments	101 a	122 a	175 a	184 a	186 a	190 a
In-furrow Biocontrol Agents	117 b	138 b	189 b	196 b	196 ab	200 ab
<i>P</i> -value	0.0027	0.0991	0.0096	0.0110	0.0075	0.0100

^t Treatments were applied as a seed treatment or in-furrow application; the active ingredient and FRAC group of each product is as follows: Kabina is penthiopyrad (7), Systiva XS is fluxapyroxad (7), Vibrance is sedaxane (7), Zeltera is inpyrfluxam (7), Elatus WG is azoxystrobin (11) + benzovindiflupyr (7), Quadris and AZteroid FC3.3 are azoxystrobin (11), Headline SC is pyraclostrobin (11), Priaxor is fluxapyroxad (7) + pyraclostrobin (11), Proline 480 SC is prothioconazole (3), Propulse is fluopyram (7) + prothioconazole (3), Zironar is *Bacillus licheniformis* FMCH001 + *B. subtilis* FMCH002 (BM02), Bexfond is *B. amyloliquefaciens* subsp. *plantarum* FZB42 (BM02), Serenade ASO is *B. subtilis* QST713 (BM02), Howler EVO is *Pseudomonas chlororaphis* AFS009 (BM02).

^u Plant stands based on the number of plants in the center two rows of each plot.

^v Days after planting; DAP.

^w Means within a column followed by a common letter are not significantly different by Estimated Marginal Means (EMMs) at the 0.10 significance level.

^x Fungicide seed treatments; rates are per unit of seed (100,000 seeds); applied by Germain's Seed Technology, Fargo, ND

^y In-furrow fungicide treatments; rates are per acre and applied down a drip tube in 6 gallons total volume/acre.

^z In-furrow biocontrol agents; rates are per acre and applied down a drip tube in 6 gallons total volume/acre.

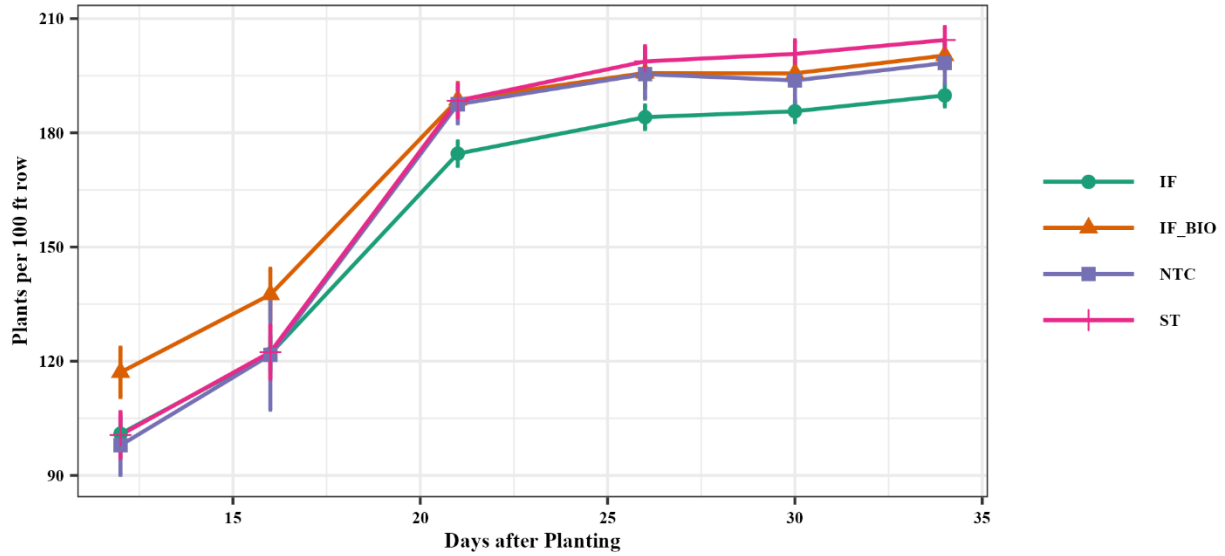


Fig. 1. Emergence and stand establishment of seed treatments (ST), in-furrow fungicides (IF), and in-furrow biocontrol agents (IF_BIO) compared to the nontreated control (NTC) in a sugarbeet field trial infested with *Rhizoctonia solani* AG 2-2 in Crookston, MN planted on 07 May 2025.

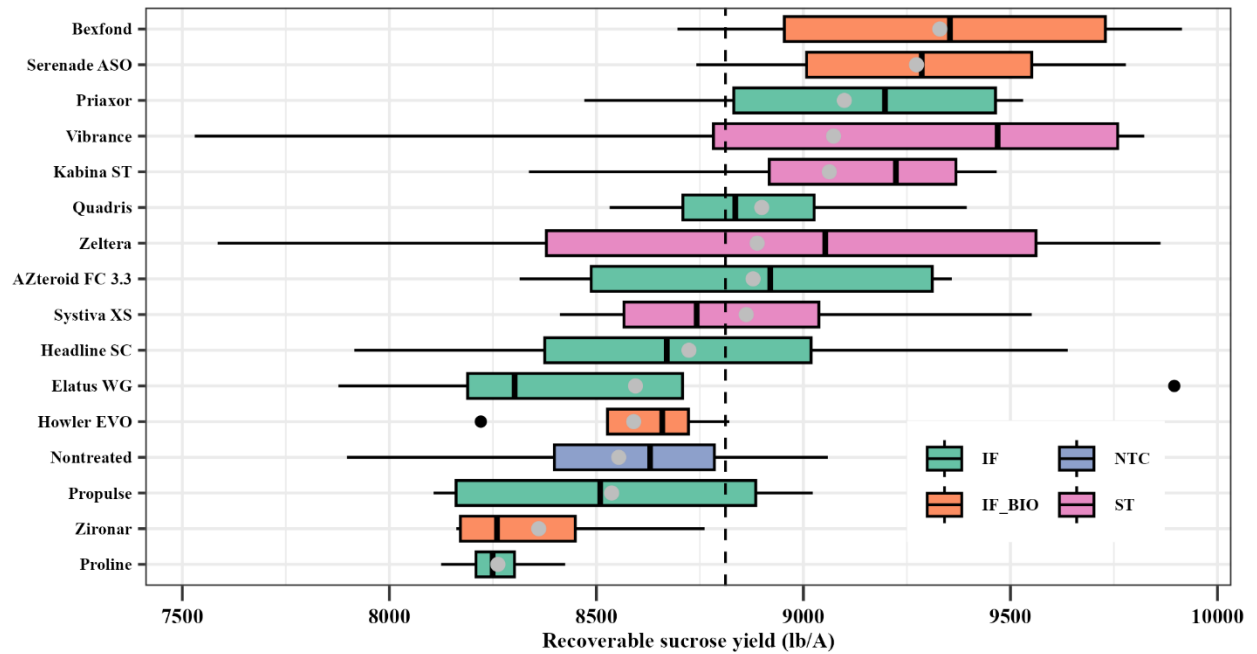


Fig. 2. Effect of at-planting treatments applied as either a seed treatment (ST), and in-furrow fungicide (IF), or in-furrow biocontrol agents (IF_BIO) on recoverable sucrose (lbs/A) in sugarbeet compared to the nontreated control (NTC) in a field trial infested with *Rhizoctonia solani* AG 2-2 in Crookston, MN. Boxplots display the distribution of data for each treatment based (minimum, first quartile, median, third quartile, and maximum); filled black dots represent outliers; filled gray dots represent treatment means. The dashed horizontal line represents the mean of all treatments in this trial.

Table 2. Effects of at-planting treatments on Rhizoctonia crown and root rot (RCRR) and sugarbeet yield and quality in a *Rhizoctonia*-infested field trial at the University of Minnesota, Northwest Research and Outreach Center, Crookston planted on 07 May 2025.

Treatment and (rate) ^p	Harvested Roots ^q	Plant Loss (%) ^r	RCRR Severity (%) ^{s,t}	RCRR Incidence (%) ^u	Sugar (%)	SLM (%) ^v	Root Yield (tons/A)	Sucrose Yield (lbs/A) ^w
Nontreated Control	161 ab	18.9	9.1	27.5	17.28	1.43	27.0	8554
Kabina ST (14 g) ^x	168 ab	19.0	4.6	16.3	17.94	1.31	27.3	9063
Systiva XS (5 g) ^x	171 b	18.2	6.3	25.0	17.32	1.37	27.8	8862
Vibrance (1.5 g) ^x	168 ab	15.4	6.9	22.5	17.50	1.37	28.1	9073
Zeltera (0.1 g) ^x	163 ab	19.9	5.2	21.3	17.58	1.41	27.4	8888
Quadris (9.5 fl oz) ^y	155 ab	18.2	7.9	33.8	17.03	1.27	28.3	8899
Elatus WG (7.1 oz) ^y	160 ab	12.9	6.5	25.0	17.30	1.35	26.9	8594
AZteroid FC3.3 (5.7 fl oz) ^y	164 ab	20.4	5.0	27.5	17.24	1.34	27.9	8878
Headline SC (9 fl oz) ^y	165 ab	18.4	8.7	33.8	17.05	1.44	27.9	8724
Priaxor (6.7 fl oz) ^y	170 ab	15.9	7.3	26.3	17.20	1.34	28.7	9099
Proline 480 SC (5.7 fl oz) ^y	152 ab	14.0	4.7	17.5	17.25	1.40	26.1	8262
Propulse (13.6 fl oz) ^y	139 a	19.0	5.1	23.8	17.25	1.36	26.9	8537
Zironar (12 fl oz) ^z	149 ab	17.5	11.3	31.3	17.24	1.39	26.4	8361
Bexfond (14 fl oz) ^z	177 b	14.5	6.5	22.5	17.39	1.33	29.0	9329
Serenade ASO (128 fl oz) ^z	166 ab	19.2	8.8	32.5	17.54	1.30	28.6	9273
Howler EVO (40 fl oz) ^z	170 ab	18.4	10.9	37.5	16.87	1.30	27.6	8590
<i>P</i> -value	0.0301	0.2190	0.2783	0.2879	0.0918	0.4781	0.4232	0.3366

Analysis by Application Type

Nontreated Control	161	18.9	9.1 ab	27.5	17.28 ab	1.43	27.0	8554
Fungicide Seed Treatments	168	18.1	5.7 a	21.3	17.59 b	1.36	27.7	8971
In-furrow Fungicide Treatments	158	17.0	6.5 a	26.8	17.19 a	1.36	27.5	8713
In-furrow Biocontrol Agents	166	17.4	9.4 b	30.9	17.26 ab	1.33	27.9	8888
<i>P</i> -value	0.1518	0.7225	0.0239	0.1040	0.0193	0.3129	0.7629	0.4059

^p Treatments were applied as a seed treatment or in-furrow application; the active ingredient and FRAC group of each product is as follows: Kabina is penthiopyrad (7), Systiva XS is fluxapyroxad (7), Vibrance is sedaxane (7), Zeltera is inpyrfluxam (7), Elatus WG is azoxystrobin (11) + benzovindiflupyr (7), Quadris and AZteroid FC3.3 are azoxystrobin (11), Headline SC is pyraclostrobin (11), Priaxor is fluxapyroxad (7) + pyraclostrobin (11), Proline 480 SC is prothioconazole (3), Propulse is fluopyram (7) + prothioconazole (3), Zironar is *Bacillus licheniformis* FMCH001 + *B. subtilis* FMCH002 (BM02), Bexfond is *B. amyloliquefaciens* subsp. *plantarum* FZB42 (BM02), Serenade ASO is *B. subtilis* QST713 (BM02), Howler EVO is *Pseudomonas chlororaphis* AFS009 (BM02).

^q Harvested roots are equal to number of roots per 100 ft of row.

^r Plant loss percent equals 100 * (Maximum number of live plants – number of harvested roots) / (Maximum number of live plants).

^s Percent severity of Rhizoctonia crown and root rot based on a 0 to 10 scale with a 10% incremental increase per each unit of rating (i.e., 0=0%, 5 = 41-50%, 10=91-100%). Each rating was mid-point transformed to percent severity for statistical analysis.

^t Means within a column followed by a common letter are not significantly different by Estimated Marginal Means (EMMs) at the 0.10 significance level.

^u Percent incidence of rated roots with > 0% of rot on the root surface.

^v Percent sugar loss to molasses (SLM).

^w Recoverable sucrose per acre; equal to yield*(percent sugar – percent SLM)*20.

^x Fungicide seed treatments; rates are per unit of seed (100,000 seeds).

^y In-furrow fungicide treatments; rates are per acre and applied down a drip tube in 6 gallons total volume/acre.

^z In-furrow biocontrol agents; rates are per acre and applied down a drip tube in 6 gallons total volume/acre.

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