

EVALUATION OF FUNGICIDE SPRAY PROGRAMS TO MANAGE CERCOSPORA LEAF SPOT IN A CR+ SUGARBEET VARIETY, 2024

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INTRODUCTION

Cercospora leaf spot (CLS), caused by *Cercospora beticola*, is endemic to sugarbeet growing regions in Minnesota and North Dakota, and can cause dramatic economic losses when conditions are conducive for disease development. There is evidence that seedborne *C. beticola* can initiate CLS (Spanner et al. 2022) and may be associated with genetic diversity within *C. beticola* populations (Knight et al. 2018). However, infected leaf residue from previous sugarbeet crops is considered the primary inoculum source of *C. beticola* (Jones and Windels 1991) as conidia of *C. beticola* can be detected in spore traps in early May (Secor et al. 2022; Secor and Rivera 2024). CLS symptoms typically become visible in late June to early July and are correlated with the timing of sugarbeet canopy closure. In recent years however, DNA of *C. beticola* has been detected in asymptomatic sugarbeet leaves several weeks before initial CLS symptoms are visible in the field (Bloomquist et al. 2021; Secor et al. 2022), and initial infection of sugarbeet leaves by *C. beticola* primarily occurs throughout June (Wyatt 2024). Disease can rapidly progress following rainfall events along with warm and humid environments (Tedford et al. 2018), whereas drought conditions result in slower progression of CLS and reduced severity. This increased understanding in the epidemiology of CLS reinforces recommendations to apply effective fungicide treatments in a timely manner to significantly delay CLS development and reduce the extent of economic losses. Effective fungicide treatments include, but are not limited to, using full labeled rates, tank-mixing multiple modes of action, and rotating modes of action throughout a spray program. Initial applications should be timed preventatively (i.e., prior to the onset of visible CLS symptoms). Typically, intervals between subsequent applications should be 10- to 14-days; however, frequent rainfall can and rapid growth of sugarbeet foliage may warrant shorter intervals. A majority of currently approved sugarbeet varieties have low to moderate tolerance to CLS (Brantner and Deschene 2024); however, sugarbeet varieties with high tolerance to CLS (CR+ varieties) have been available to growers beginning in 2021. Since then, the acreage in Minnesota and North Dakota that has been planted with CR+ varieties each year has steadily increased (Hastings *personal communication*; Bloomquist *personal communication*; Metzger *personal communication*). Studies have shown that infection by *C. beticola* is not completely stopped in CR+ varieties, but rather delayed (Bhuiyan et al 2023; Bhandari et al 2023). With delayed infection and lower overall CLS severity in CR+ varieties, there is desire to reduce the cost of fungicide management by decreasing the number of total fungicide applications on these varieties. Previous field trials have shown that CR+ varieties have not needed the same rigorous fungicide programs that moderately susceptible varieties need to prevent economic loss from CLS (Mettler and Bloomquist 2021, 2022, 2023; Lien et al. 2023, 2024)

OBJECTIVES

The trial objective was to evaluate the efficacy of fungicide spray programs with differential application timing for in a highly tolerant (CR+) sugarbeet variety in which spray programs had an early or delayed initial application containing a DMI, EBDC, or copper fungicide and extended spray intervals or a standard 14-day interval for 1) the relative control of CLS disease on sugarbeet, and 2) the effect on harvestable root yield and sucrose quality.

MATERIALS AND METHODS

The field trial was established in Crookston, MN (47.81403°, -96.61279°), at the University of Minnesota Northwest Research and Outreach Center (NWROC) as a randomized complete block design with four replications. Seeds of 'Crystal 260RR', which have a 2-year CLS susceptibility rating of 2.1 (Brantner and Deschene 2024), were planted in 6-row by 25-ft long plots at a 4.5-in. spacing in 22-in rows on April 24. Plant stands were evaluated on June 24 by counting the number of live plants in the center two rows of each plot. On July 03, when plots were at approximately 90% row closure, all rows of the trial were inoculated with a mixture of fine talc and dried CLS-infected sugarbeet

leaves (1:2 w/w) using a Nalgene® 1L bottle to deliver a rate of 4.5 lb/A, equivalent to 3 g of mixture per 35 ft of row. CLS-infected sugarbeet leaves used for the inoculum were collected from nontreated plants moderately susceptible to CLS at the end of the 2023 growing season and dried in burlap bags at 95±5°F for 48 hours and stored in the dark at 68±5°F. Prior to inoculation, leaves in burlap bags were dried for an additional 24 hours at 95±5°F and ground with a Wiley Mill and passed through a 2mm sieve. Fungicides were applied to the center four rows using a tractor-mounted sprayer with XR TeeJet 11002 VS flat fan nozzles calibrated to deliver 16.8 gal water/A at 90 psi. Fungicides were applied on June 26 (**A**; 7 days prior to inoculation), July 03 (**B**; immediately following inoculation), July 16 (**C**; 13 days after inoculation; DAI), July 29 (**D**; 26 DAI), August 12 (**E**; 40 DAI), and August 25 (**F**; 53 DAI); applications were approximately every 13-14 days, with the exception of extended intervals ranging from 28, 42, or 55 days between applications. A majority of fungicide programs began on July 16 (13 DAI), which followed conditions conducive for disease development and coincided with canopy-closure. CLS disease severity was evaluated beginning 22 Jul and continued through 18 Sep, for a total of 8 evaluations, using a scale based on infected leaf area (Jones and Windels 1991); wherein, 1=0.1% (1-5 spots/leaf), 2=0.35% (6-12 spots/leaf), 3=0.75% (13-25 spots/leaf), 4=1.5% (26-50 spots/leaf), 5=2.5% (51-75 spots/leaf), 6=3%, 7=6%, 8=12% 9=25%, 10=50%. Five locations within each plot were rated on each evaluation date. The average CLS ratings from each evaluation date were used to calculate the standardized area under the disease progress stairs (sAUDPS; Simko and Piepho 2012) using the IdeTo Excel calculator (Simko 2021) for statistical analysis. On 20 Sep, plots were defoliated and the center two rows of each plot were harvested mechanically and weighed for root yield. Ten representative roots from each plot were analyzed for sugar quality at the American Crystal Sugar Company Quality Tare Laboratory, East Grand Forks, MN. Statistical analysis was conducted in R (v 4.3.1, R Core Team 2023). A mixed-model analysis of variance was performed using the package *lmerTest* (v 3.1-3), with treatment defined as the fixed factor and replication as the random factor. Means were separated at the 0.10 significance level using the package *emmeans* (v 1.8.7) with no adjustments. Weather data was retrieved from the North Dakota Agricultural Weather Network (NDAWN) Eldred, MN Station (47.68769°, -96.82221°).

RESULTS AND DISCUSSION

Above-average rainfall in April and May (Supplementary Table 1) provided adequate soil moisture to facilitate good plant emergence resulting in an average plant population of 228 plants per 100 ft row, equivalent to 85.5% emergence; there were no significant differences among treatments ($P = 0.6773$). Following inoculation, a period of temperatures and high humidity resulted in moderate daily infection values indicating a favorable environment for CLS development (Supplementary Fig. 1). Disease pressure in the nontreated control increased during the month of August and September (Fig. 1) following several rainfall events (Supplementary Fig. 1). CLS severity for this highly tolerant variety in the nontreated control reached 4.0 which is lower than the economic threshold rating of 6.0 (Table 1). There were significant differences present for both the final CLS rating on September 18 (Table 1), and overall CLS severity reported as the sAUDPS (Table 2). Nearly all fungicide spray programs resulted in a lower final CLS rating and overall CLS severity than the non-treated control. The spray program beginning with the Experimental copper was numerically lower than the nontreated control but not significantly different. The lowest CLS severity resulted from the ‘standard program’, which was a 5-spray program with 14-day application intervals and an initial application beginning on July 3 (Fig. 2). CLS severity was slightly higher when one 28-day interval was introduced in the middle of standard program (i.e., exempting application **D**), but was not significantly different from the standard program (Fig. 2) and similar to the spray program that was initiated on June 26 and contained two 28-day intervals (i.e., exempting applications **C** and **E**) and the 4-spray program that was initiated on July 13. Generally, CLS severity increased as multiple extended intervals were introduced and when intervals extended beyond 28 days. Spray programs that were initiated with a copper-based fungicide on July 16 and programs initiated on August 12 resulted in CLS severity significantly greater than the standard program. Starting with a DMI generally resulted in slightly lower CLS severity when comparing similar spray programs that were initiated on July 16, July 29, or August 12 with either a DMI or EBDC. Interestingly, the programs that were initiated on June 26 and July 3 show that starting with EBDC resulted in slightly lower CLS severity. There were no significant differences between treatments for percent sugar, percent sugar loss to molasses (SLM), root yield, or recoverable sucrose yield. However, numerical differences show that the nontreated control resulted in the lowest root yield (Table 2).

Table 1. Select *Cercospora* leaf spot (CLS) 0-10 ratings associated with fungicide spray programs to manage CLS of sugarbeets in a CLS-inoculated field trial planted on April 24, 2024 and inoculated on July 03, 2024 at the University of Minnesota, Northwest Research and Outreach Center, Crookston.

Program ^z	Treatment(s) and timing ^y	CLS ratings (0-10)					
		Jul 25	Aug 9	Aug 19	Aug 28	Sept 6	Sept 18
Non-Treated Control	Nontreated Control	0.0	1.0	1.6	1.8	3.4	4.0
6 Spray (Skip 3 & 5)	Inspire XT A + Manzate Pro-Stick AD + Super Tin BF + Topsin 4.5 FL B + Proline 480 SC D + Priaxor F	0.2	1.0	0.8	0.6	1.3	1.6
5 Spray	Inspire XT B + Manzate Pro-Stick BDE + Super Tin CF + Topsin 4.5 FL C + Proline 480 SC D + Priaxor F	0.0	1.1	0.8	0.4	1.0	1.2
5 Spray (Skip 3)	Inspire XT B + Manzate Pro-Stick BE + Super Tin CF + Topsin 4.5 FL C + Proline 480 SC E + Priaxor F	0.0	1.0	0.9	0.9	0.9	1.6
4 Spray	Inspire XT C + Manzate Pro-Stick CE + Super Tin DF + Topsin 4.5 FL D + Proline 480 SC E + Priaxor F	0.2	1.2	0.9	0.7	1.1	1.4
4 Spray (Skip 3)	Inspire XT C + Manzate Pro-Stick C + Super Tin D + Topsin 4.5 FL D + Proline 480 SC F + Priaxor F	0.2	1.1	1.0	0.9	1.2	1.8
3 Spray	Inspire XT D + Manzate Pro-Stick D + Super Tin E + Topsin 4.5 FL E + Proline 480 SC F + Priaxor F	0.2	1.0	1.0	0.8	1.1	1.4
3 Spray (Skip 2; DMI Start)	Inspire XT D + Manzate Pro-Stick D + Super Tin F + Priaxor F	0.0	1.2	1.0	0.8	1.9	1.8
3 Spray (Skip 2; EBDC Start)	Manzate Pro-Stick D + Super Tin F + Priaxor F	0.2	1.0	1.1	1.0	2.5	2.7
2 Spray (DMI Start)	Inspire XT E + Manzate Pro-Stick E + Super Tin F + Priaxor F	0.1	1.2	1.1	1.2	1.8	2.6
2 Spray (EBDC Start)	Manzate Pro-Stick E + Super Tin F + Priaxor F	0.2	1.0	1.1	1.4	1.9	2.6
6 Spray (Skip 3, 4, & 5; (EBDC Start)	Inspire XT A + Manzate Pro-Stick AB + Super Tin F + Priaxor F	0.0	0.8	1.0	0.9	1.4	2.0
6 Spray (Skip 3, 4, & 5; DMI Start)	Manzate Pro-Stick AB + Inspire XT B + Super Tin F + Priaxor F	0.1	0.8	1.2	1.2	1.8	2.0
5 Spray (Skip 3 & 4; DMI Start)	Inspire XT B + Manzate Pro-Stick BC + Super Tin F + Priaxor F	0.0	1.2	1.1	0.8	1.5	2.1
5 Spray (Skip 3 & 4; EBDC Start)	Manzate Pro-Stick BC + Inspire XT C + Super Tin F + Priaxor F	0.0	1.1	1.0	0.8	1.2	1.8
4 Spray (Skip 3; DMI Start)	Inspire XT C + Manzate Pro-Stick CD + Super Tin F + Priaxor F	0.1	0.9	1.1	0.8	1.2	1.9
4 Spray (Skip 3; EBDC Start)	Manzate Pro-Stick CD + Inspire XT D + Super Tin F + Priaxor F	0.2	1.0	1.0	0.7	1.6	1.9
4 Spray (Skip 3; Badge SC Start)	Badge SC C + Manzate Pro-Stick D + Inspire XT D + Super Tin F + Priaxor F	0.2	1.2	1.1	1.1	2.3	2.5
4 Spray (Skip 3; Cuprofix Start)	Cuprofix C + Manzate Pro-Stick D + Inspire XT D + Super Tin F + Priaxor F	0.2	0.9	1.0	1.0	2.0	2.6
4 Spray (Skip 3; Exp. Copper Start)	Experimental Copper C + Manzate Pro-Stick D + Inspire XT D + Super Tin F + Priaxor F	0.2	1.0	1.2	1.6	2.2	3.0
<i>P</i> -value		-	.	***	***	***	***

^z Description of spray program; Crystal 260RR with two-year *Cercospora* rating of 2.1 (CR+) was used for all treatments.

^y Treatment rates per acre are as follows: Inspire XT = 7 fl oz, Manzate Pro-Stick = 2 lb, Super Tin = 8 fl oz, Topsin 4.5 FL = 10 fl oz, Proline 480 SC = 5.7 fl oz, Priaxor = 6.7 fl oz, Badge SC = 32 fl oz, Cuprofix = 3 lb, Experimental Copper = 20 fl oz; Non-ionic surfactant (NIS; Activator90) was used at a rate of 0.125% v/v with Provysol and Proline 480 SC; letters represent the following dates: **A**= Jun 26 (-7 DAI), **B**= Jul 3 (0 DAI), **C**= Jul 16 (13 DAI), **D**= Jul 29 (26 DAI), **E**= Aug 12 (40 DAI), **F**= Aug 25 (53 DAI)

^x Significance codes: 0.001 (***), 0.01 (**), 0.05 (*), 0.05 (.), >0.05 (-)

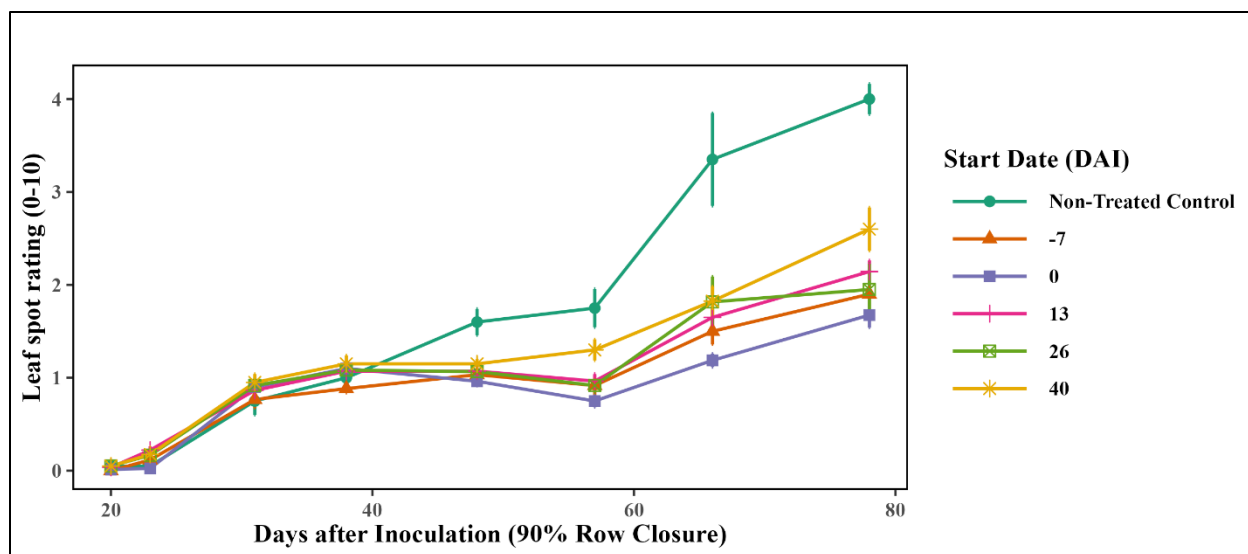


Fig. 1. Effect of foliar fungicide programs grouped by the initial application in respect to days after inoculation (DAI), equivalent to 90% row closure, in sugarbeets highly tolerant to CLS (CR+) on development of CLS on sugarbeets in a CLS-inoculated field trial planted April 23, 2024, and inoculated on July 03, 2024.

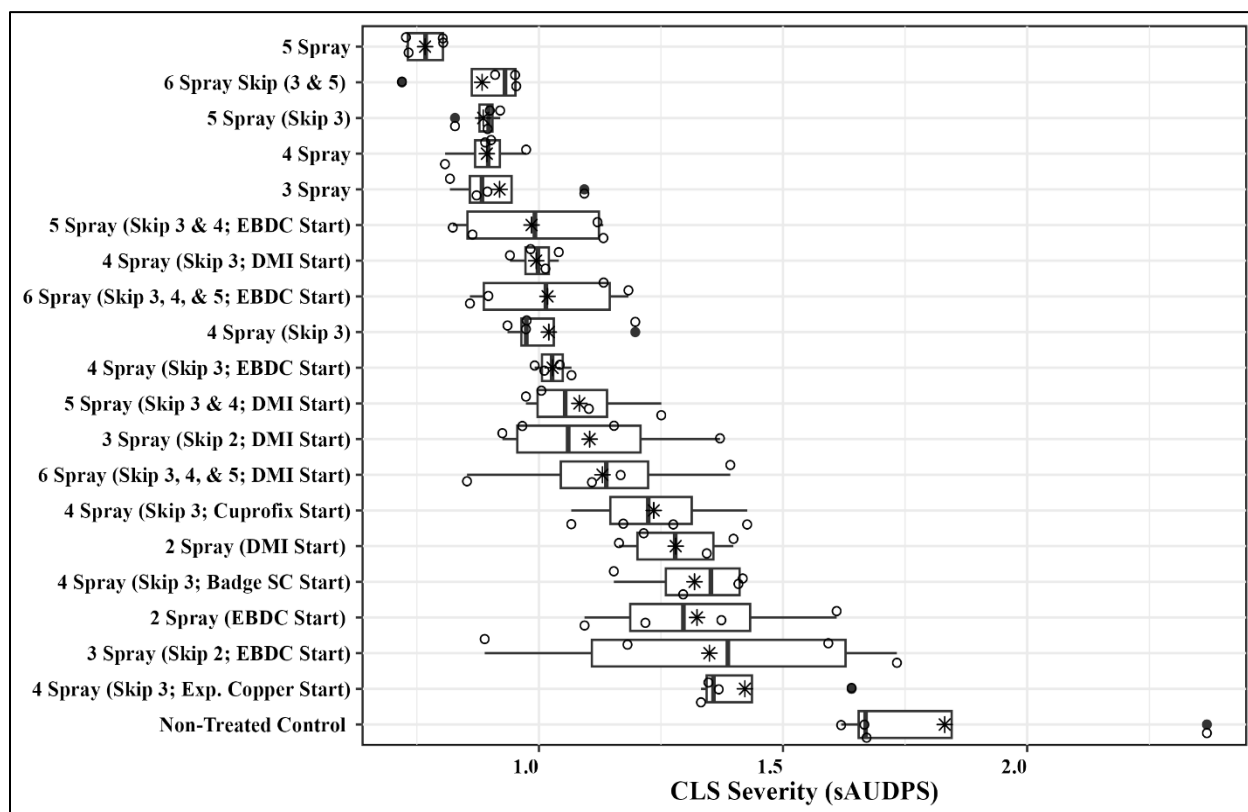


Fig. 2. Effect of foliar fungicide programs in sugarbeets highly tolerant to CLS (CR+) on total CLS severity (sAUDPS) on sugarbeets in a CLS-inoculated field trial planted April 23, 2024, and inoculated on July 03, 2024. Box-whisker plots display the distribution of data for each treatment (minimum, first quartile, median, third quartile, and maximum); filled dots represent outliers; asterisks represent treatment means; hollow dots represent individual data points in respect to replications

Table 2. Effects of fungicide spray programs on CLS disease, root yield, and sucrose quality of sugarbeets in a CLS-inoculated field trial planted on April 23, 2024 and inoculated July 03, 2024 at the University of Minnesota, Northwest Research and Outreach Center, Crookston.

Spray Program ^z	CLS Severity (sAUDPS) ^{y,x}	Sugar (%)	SLM (%)	Root Yield (tons/A)	Sucrose Yield (lb/A)
Non-Treated Control	1.8 f	16.50	1.39	26.6	8022
6 Spray (Skip 3 & 5)	0.9 ab	15.54	1.40	29.0	8210
5 Spray	0.8 a	15.41	1.45	28.2	7883
5 Spray (Skip 3)	0.9 a-c	15.85	1.40	27.6	7960
4 Spray	0.9 ab	16.26	1.39	28.9	8573
4 Spray (Skip 3)	1.0 a-d	15.59	1.47	29.3	8275
3 Spray	0.9 ab	15.75	1.39	27.4	7884
3 Spray (Skip 2; DMI Start)	1.1 a-e	15.69	1.43	28.2	8018
3 Spray (Skip 2; EBDC Start)	1.4 de	16.06	1.32	28.0	8231
2 Spray (DMI Start)	1.3 c-e	16.13	1.37	27.1	7998
2 Spray (EBDC Start)	1.3 c-e	15.73	1.40	27.0	7757
6 Spray (Skip 3, 4, & 5; (EBDC Start)	1.1 a-e	16.00	1.40	26.9	7855
6 Spray (Skip 3, 4, & 5; DMI Start)	1.0 a-e	16.14	1.33	27.3	8070
5 Spray (Skip 3 & 4; DMI Start)	1.1 a-e	16.04	1.32	27.2	8005
5 Spray (Skip 3 & 4; EBDC Start)	1.0 a-d	16.22	1.33	27.7	8250
4 Spray (Skip 3; DMI Start)	1.0 a-e	15.73	1.38	27.8	7993
4 Spray (Skip 3; EBDC Start)	1.0 a-e	15.55	1.40	28.4	8024
4 Spray (Skip 3; Badge SC Start)	1.3 b-e	16.06	1.38	28.5	8359
4 Spray (Skip 3; Cuprofix Start)	1.2 b-e	16.24	1.37	27.1	8073
4 Spray (Skip 3; Exp. Copper Start)	1.4 ef	15.69	1.47	27.5	7824
<i>P</i> -value	<0.0001	0.2857	0.4870	0.3678	0.9673

^z Crystal 260RR with two-year *Cercospora* rating of 2.1 (CR+) was used for all treatments; fungicides and application dates for each program are listed in Table 1.

^y Standardized Area Under Disease Progress Stairs (sAUDPS) is a mid-point combination of all CLS ratings and represents total CLS severity.

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

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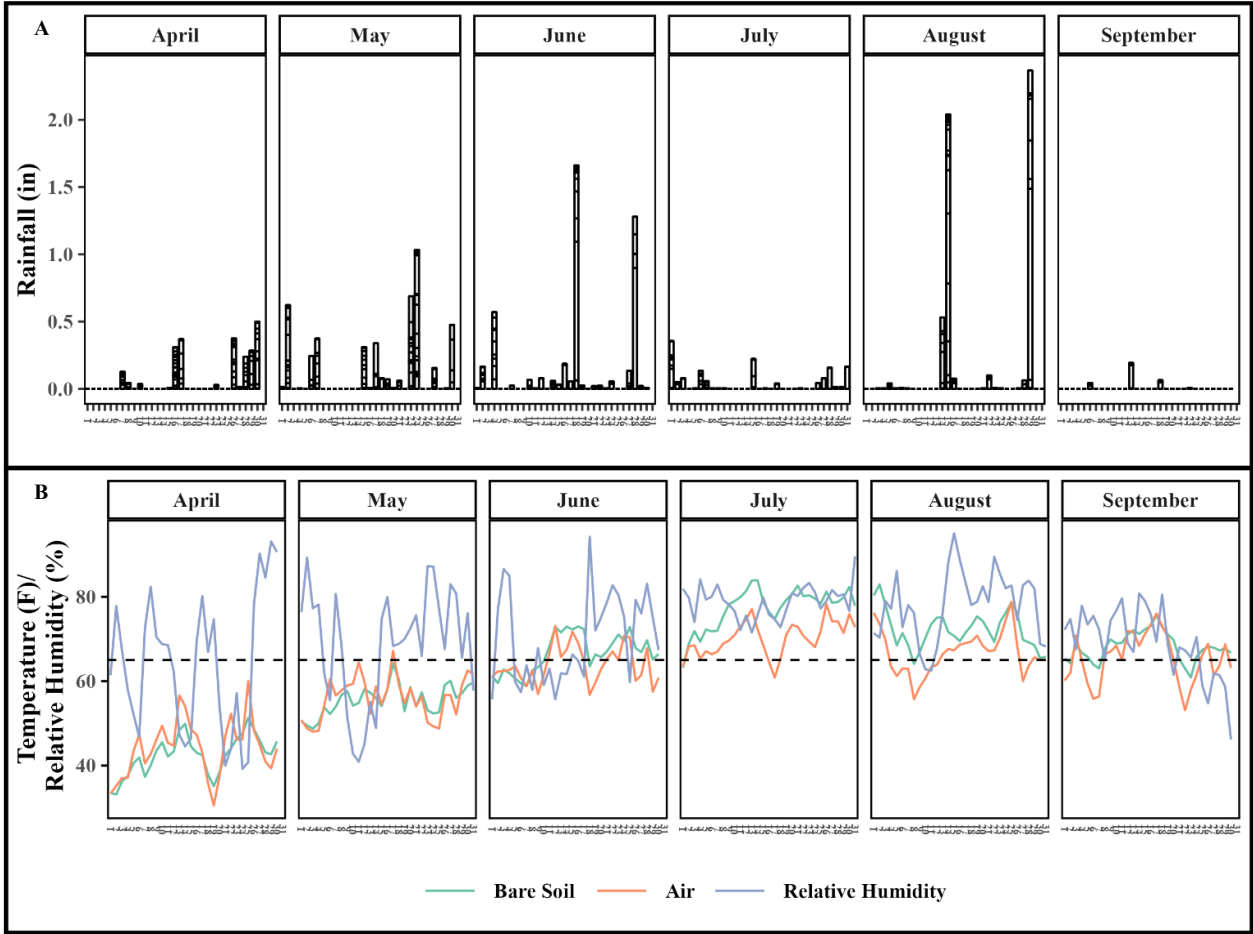
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SUPPLEMENTARY WEATHER TABLE AND FIGURE

Supplementary Table S1. Weather data for the 2024 growing season compared to the normal (30-year average). Data was retrieved from the North Dakota Agricultural Weather Network Eldred, MN station (47.68769, -96.82221), located approximately 12.8 miles southwest of the Northwest Research and Outreach Center, Crookston, MN.

Month	Total Rainfall (inch)		Average Air Temperature (°F)	
	2024	Normal ^z	2024	Normal
April	2.33	1.41	44.3	41.7
May	4.49	2.86	55.5	55.4
June	4.48	4.01	63.4	65.8
July	1.42	3.45	70.0	69.8
August	5.26	2.86	66.6	68.0
September	0.31	2.03	66.0	60.2

^z Normals are interpolated from National Weather Service (NWS) Cooperative stations (1991-2020) and are defined as the average of a variable for a continuous 3-decade (30-year) period.



Supplementary Fig. S1. Daily rainfall totals in which stacked bars represent 1-hour intervals (A) and daily mean air temperature, 4-in. bare soil temperature, and relative humidity (B) for the 2024 growing season retrieved from the Eldred North Dakota Agricultural Weather Network station (47.68769, -96.82221), located approximately 12.8 miles southwest of the Northwest Research and Outreach Center, Crookston, MN. The dotted horizontal line represents 65°F.