EVALUATION OF FUNGICIDE SPRAY PROGRAMS TO MANAGE CERCOSPORA LEAF SPOT IN A CR+ SUGARBEET VARIETY, 2025

Austin K. Lien[1], James A. Deleon[2] and Ashok K. Chanda[3]

[1]Research Professional 3; [2]Junior Laboratory Technician; [3]Associate Professor and Extension Sugarbeet Pathologist
University of Minnesota, Department of Plant Pathology, St. Paul, MN and
Northwest Research and Outreach Center, Crookston, MN
Corresponding Author: Ashok Chanda, achanda@umn.edu

INTRODUCTION

Cercospora leaf spot (CLS), caused by *Cercospora beticola*, continues to be a major foliar disease of sugarbeet in Minnesota and North Dakota and can cause substantial losses when weather conditions favor infection (Jones and Windels 1991). Although seedborne inoculum may contribute to early-season pathogen presence (Spanner et al. 2022) and reflects underlying genetic diversity in regional populations (Knight et al. 2018), infected residue from previous sugarbeet crops remains the primary inoculum source, with airborne conidia detectable as early as May (Secor et al. 2022; Secor and Rivera 2024). Symptoms of CLS generally appear from late June into early July as canopies close; however, recent field studies have detected *C. beticola* DNA in asymptomatic foliage weeks before visible symptoms develop, indicating that most infections likely occur throughout June (Bloomquist et al. 2021; Secor et al. 2022; Wyatt 2024). Rapid disease escalation is associated with warm, humid periods following rainfall (Tedford et al. 2018), whereas drought slows progression.

This evolving understanding of CLS epidemiology underscores the importance of well-timed, effective fungicide programs to slow disease development and protect yield and sugar quality. Recommended programs include using full labeled rates, tank-mixing with multiple modes of action, and rotation among modes of action throughout the season. Initiation of fungicide application prior to onset of visible symptom remains critical. While highly tolerant "CR+" varieties introduced in 2021 have shown delayed infection and reduced severity compared with moderately susceptible varieties in previous years (Bhuiyan et al. 2023; Bhandari et al. 2023), local *C. beticola* populations are rapidly adapting to these varieties and making them less reliable in the absence of a standard fungicide spray program. Field research demonstrates that they still require multiple, timely fungicide applications to avoid economic losses (Mettler and Bloomquist 2021, 2022, 2023; Lien et al. 2025). As the industry moves away from strategies aimed at reducing the total number of sprays or widening spray intervals, there is increased interest in understanding the risks associated with extended spray intervals and the relative benefits of initiating fungicide programs with a demethylation inhibitor (DMI) + ethylene bisdithiocarbamate (EBDC) combination versus EBDC alone. Evaluating these management questions is essential for maintaining effective CLS control amid continued pathogen pressure and changing production practices.

OBJECTIVES

The trial objective was to evaluate the efficacy of fungicide spray programs with differential application timing 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 trial was conducted at the University of Minnesota Northwest Research and Outreach Center in Crookston, MN, using a randomized complete block design with four replicates. The objective was to evaluate the efficacy of fungicide spray programs for managing CLS in a highly tolerant sugar beet variety. Fungicide programs consisted of either an early or delayed initial application of a DMI + EBDC tank-mixture, EBDC alone, or a copper fungicide alone. Subsequent applications were made at approximately 2-week intervals, with some programs including extended intervals of approximately 4, 6, or 8 weeks. Sugar beet seeds 'Crystal 260RR' were sown on 19 May in 6-row plots (35 ft long) with 22-in. row spacing and an in-row spacing of 4.5 in. Plant stands were recorded on 23 June. On 8 July, at approximately 90% row closure, all rows were inoculated with a mixture of fine talc and dried

CLS-infected sugar beet leaves (1:2 w/w) applied at 4.5 lb/A. Inoculum was collected at the end of the 2024 growing season and 60% of the CLS-leaf material was collected from a “CR+” variety. Fungicides were applied to the center four rows using a tractor-mounted sprayer equipped with XR TeeJet 11002 VS nozzles calibrated to deliver 16.8 gal water/A at 90 psi. Applications occurred on 1 July, 8 July, 24 July, 7 August, 19 August, and 2 September. Cercospora leaf spot severity, expressed as percent diseased leaf area, was assessed using a modified spot-percentage scale based on Shane and Teng (1992): 1 = 0.1%, 2 = 0.35%, 3 = 0.75%, 4 = 1.5%, 5 = 2.5%, 6 = 3%, 7 = 6%, 8 = 12%, 9 = 25%, and 10 = 50%. Severity ratings were collected from five locations within the center four rows of each plot beginning 30 July and continued weekly through 22 September, for a total of six evaluations. 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. Plots were defoliated on 24 September, and the center two rows were harvested and weighed to determine root yield. Ten roots per plot were subsampled for sugar quality analysis at the American Crystal Sugar Company Quality Tare Laboratory in East Grand Forks, MN. All statistical analyses were performed in R (v. 4.3.3). A mixed-model analysis of variance was conducted using the lmerTest package (v. 3.1-3), with treatment specified as a fixed effect and replication as a random effect. Estimated marginal means were obtained and separated using emmeans (v. 1.11.0) at the $\alpha = 0.10$ significance level with no adjustment for multiple comparisons. Weather data was retrieved from the Minnesota Agricultural Weather Network, Crookston, MN Station (47.823333°, -96.620556°).

RESULTS AND DISCUSSION

A weather station located 0.63 miles north-northwest of the research plots maintained by the Northwest Research and Outreach Center, Crookston, MN (47.815374, -96.614200) recorded a total rainfall of 1.79 and 2.01 in. for April and May, which was near the 30-year average of 1.27 and 2.75 in., respectively (Supplementary Table S1). Extreme fluctuating temperatures and heavy rainfall events around the time of the initial planting contributed to soil crusting and variable emergence of sugar beet seedlings in the area. After replanting, plant populations averaged 225 plants per 100 ft of row (84.3% germination), and no significant differences among treatments were detected ($P = 0.3265$). Due to the delayed planting in 2025, canopy development was also later than normal. The trial was inoculated on July 8, coinciding with approximately 90% row closure. The first leaf spots were observed on July 16 in a nearby trial, confirming favorable conditions for disease development and frequent rainfall during late July and August created favorable conditions for CLS progression, resulting in rapid disease increase through August and September (Supplemental Fig. S1). Significant treatment differences were detected beginning 30 July and persisted through the remainder of the season (Table 1; Fig. 1). The nontreated control exhibited the greatest CLS ratings at all subsequent evaluations, exceeding the economic threshold (rating = 6, ~3% CLS severity) by 10 September. Generally, all fungicide spray programs initiated at or prior to disease onset and contained 3 or more fungicide applications maintained CLS ratings below the economic threshold throughout the trial period.

Significant treatment effects ($P < 0.0001$) were detected for overall CLS severity measured as sAUDPS (Table 2; Fig 2). The nontreated control exhibited the highest CLS severity, whereas nearly all fungicide spray programs significantly reduced disease relative to the control. Exceptions included two programs initiated with application C that incorporated a 40-day extended interval, and two programs initiated with application E, which did not significantly differ from the nontreated control. Numerically, the lowest CLS severity occurred in variations of the “standard 5-spray program,” consisting of five applications at 14-day intervals beginning with application B prior to row closure on 8 July. Within this program, substituting Manzate Pro-Stick alone, Inspire XT + Manzate Pro-Stick, or Super Tin 4L + Topsin 4.5FL for individual applications did not affect CLS severity. Introducing a single 30-day interval into the standard 5-spray sequence (e.g., omitting application D or E) led to slightly higher CLS severity (Fig. 2), although differences were not statistically significant (Table 2). Likewise, the “standard 4-spray program,” initiated with application C, at disease onset on 24 July (16 days after inoculation), resulted in greater CLS severity (Fig. 2) but did not differ statistically from the standard 5-spray program (Table 2). In contrast, spray programs consisting of three or fewer fungicide applications had significantly greater CLS severity than the standard 5-spray program, regardless of application timing. No significant treatment effects were observed for percent sugar, sugar loss to molasses (SLM), or recoverable sucrose per acre; however, root yield varied significantly among treatments (Table 2). The standard 5-spray program produced the highest root yield, consistent with its superior suppression of CLS.

Table 1. Cercospora leaf spot (CLS) 0-10 ratings associated with fungicide spray programs to manage CLS of sugarbeet in a CLS-inoculated field trial planted on 19 May 2025 and inoculated on 08 July 2025 at the University of Minnesota, Northwest Research and Outreach Center, Crookston.

#	Spray Program [v]	Longest Spray Interval (days)	Treatment(s)[w] and timing[x]	CLS ratings (0-10)[y]					
				Jul 30	Aug 13	Aug 21	Aug 28	Sept 10	Sept 22
1	Nontreated	NA	Nontreated Control	0.6	0.9	2.5	4.5	6.2	7.1
2	DMI fb Tin (AB-D-F)	30	Inspire XT **A** + Manzate Pro-Stick **AD** + Super Tin 4L **BF** + Topsin 4.5 FL **B** + Proline 480 SC **D** + Priaxor **F**	0.1	0.2	0.9	1.4	2.6	4.0
3	DMI fb EBDC (AB---F)	56	Inspire XT **A** + Manzate Pro-Stick **AB** + Super Tin 4L **F** + Priaxor **F**	0.0	0.2	1.2	2.3	3.8	5.3
4	EBDC fb DMI (AB---F)	56	Manzate Pro-Stick **AB** + Inspire XT **B** + Super Tin 4L **F** + Priaxor **F**	0.0	0.4	1.2	2.2	4.0	5.6
5	DMI fb Tin (-BCDEF)	16	Inspire XT **B** + Manzate Pro-Stick **BDE** + Super Tin 4L **CF** + Topsin 4.5FL **C** + Proline 480 SC **D** + Priaxor **F**	0.1	0.0	0.6	1.2	2.1	3.2
6	DMI fb EBDC (-BCDEF)	16	Inspire XT **B** + Manzate Pro-Stick **BCE** + Super Tin 4L **DF** + Topsin 4.5FL **D** + Proline 480 SC **E** + Priaxor **F**	0.0	0.1	0.8	1.4	2.0	2.5
7	EBDC fb DMI (-BCDEF)	16	Manzate Pro-Stick **BCE** + Inspire XT **C** + Super Tin 4L **DF** + Topsin 4.5FL **D** + Proline 480 SC **E** + Priaxor **F**	0.0	0.1	0.8	1.3	2.2	2.7
8	DMI fb Tin (-BC-EF)	26	Inspire XT **B** + Manzate Pro-Stick **BE** + Super Tin 4L **CF** + Topsin 4.5FL **C** + Proline 480 SC **E** + Priaxor **F**	0.1	0.2	0.8	1.4	2.9	3.2
9	DMI fb Tin (-BCD-F)	26	Inspire XT **B** + Manzate Pro-Stick **BD** + Super Tin 4L **CF** + Topsin 4.5FL **C** + Proline 480 SC **D** + Priaxor **F**	0.1	0.0	0.7	1.2	2.1	3.8
10	DMI fb EBDC (-BC--F)	40	Inspire XT **B** + Manzate Pro-Stick **BC** + Super Tin 4L F + Priaxor **F**	0.0	0.1	1.1	2.5	3.9	4.5
11	EBDC fb DMI (-BC--F)	40	Manzate Pro-Stick **BC** + Inspire XT **C** + Super Tin 4L **F** + Priaxor **F**	0.0	0.1	0.8	2.2	3.7	4.7
12	DMI fb Tin (--CDEF)	14	Inspire XT **C** + Manzate Pro-Stick **CE** + Super Tin 4L **DF** + Topsin 4.5FL **D** + Proline 480 SC **E** + Priaxor **F**	0.3	0.1	1.2	2.1	3.3	3.6
13	DMI fb Tin (--CD-F)	26	Inspire XT **C** + Manzate Pro-Stick **C** + Super Tin 4L **D** + Topsin 4.5FL **D** + Proline 480 SC **F** + Priaxor **F**	0.3	0.2	1.5	2.0	3.7	5.1
14	DMI fb EBDC (--CD-F)	26	Inspire XT **C** + Manzate Pro-Stick **CD** + Super Tin 4L **F** + Priaxor **F**	0.4	0.1	1.2	2.8	5.2	6.2
15	EBDC fb DMI (--CD-F)	26	Manzate Pro-Stick **CD** + Inspire XT **D** + Super Tin 4L **F** + Priaxor **F**	0.3	0.2	1.5	2.4	4.2	5.3
16	CuOCl fb DMI (--CD-F)	26	Badge SC **C** + Inspire XT **D** + Manzate Pro-Stick **D** + Super Tin 4L **F** + Priaxor **F**	0.4	0.3	1.5	2.3	4.5	6.7
17	CuSO4 fb DMI (--CD-F)	26	Cuprofix Flex **C** + Inspire XT **D** + Manzate Pro-Stick **D** + Super Tin 4L **F** + Priaxor **F**	0.5	0.3	1.1	2.8	4.8	6.0
18	DMI fb EBDC (--C--F)	40	Inspire XT **C** + Manzate Pro-Stick **C** + Super Tin 4L **F** + Priaxor **F**	0.3	0.2	1.9	3.6	5.6	6.2
19	EBDC fb DMI (--C--F)	40	Manzate Pro-Stick **C** + Super Tin 4L **F** + Priaxor **F**	0.3	0.3	2.4	4.2	5.8	7.1
20	DMI fb Tin (---DEF)	14	Inspire XT **D** + Manzate Pro-Stick **D** + Super Tin 4L **E** + Topsin 4.5FL **E** + Proline 480 SC **F** + Priaxor **F**	0.3	0.3	1.7	3.0	4.9	5.7
21	DMI (---D-F)	26	Inspire XT **D** + Manzate Pro-Stick **D** + Super Tin 4L **F** + Priaxor **F**	0.3	0.5	1.9	3.0	5.0	6.3
22	EBDC (---D-F)	26	Manzate Pro-Stick **D** + Super Tin 4L **F** + Priaxor **F**	0.3	0.3	1.8	3.1	5.0	6.6
23	DMI (----EF)	14	Inspire XT **E** + Manzate Pro-Stick **E** + Super Tin 4L **F** + Priaxor **F**	0.3	0.6	2.6	3.6	5.4	6.0
24	EBDC (----EF)	14	Manzate Pro-Stick **E** + Super Tin 4L **F** + Priaxor **F**	0.2	0.7	2.5	4.1	5.5	6.6
			LSD (α =0.10)	0.18	0.21	0.42	0.52	0.56	0.71
			P-value[z]	***	***	***	***	***	***

[v] Description of spray program; Crystal 260RR with two-year Cercospora rating of 2.6 (CR+) was used for all treatments.

[w] Treatment rates per acre are as follows: Inspire XT = 7 fl oz, Manzate Pro-Stick = 2 lb, Super Tin 4L = 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 Flex = 1.5 lb; Non-ionic surfactant (Activator 90) was used at a rate of 0.125% v/v with Proline 480 SC.

[x] Application letter code for the following dates: **A** = 01 July (7 days prior to inoculation; 70% row-closure), **B** = 08 July (day of inoculation; 90% row-closure), **C** = 24 July (disease onset; 16 days after inoculation; DAI), **D** = 07 August (30 DAI), **E** = 19 August (42 DAI), **F** = 02 September (56 DAI); any treatment beginning with application C, D, or E denotes a delayed initial application.

[y] CLS ratings, based on percent infected leaf area (i.e., 1=0.1%, 2=0.35%, 3=0.75%, 4=1.5%, 5=2.5%, 6=3%, 7=6%, 8=12% 9=25%, 10=50%), are an average of 20 ratings (5 per plot across 4 replicates).

[z] Significance codes: 0.001 (***), 0.01 (**), 0.01 (*), 0.05 (.), >0.05 (-)

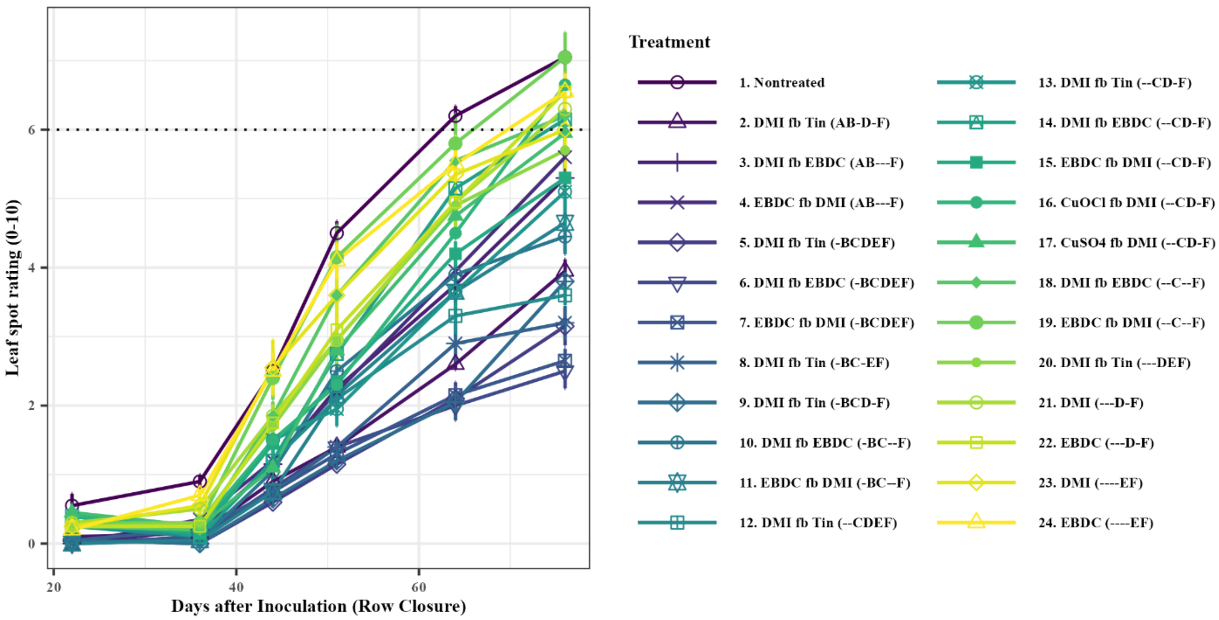

Fig. 1. Effect of foliar fungicide programs grouped by the initial application in respect to days after inoculation, equivalent to 90% row closure, in a highly CLS tolerant (CR+) variety on development of CLS in a inoculated field trial. Trial was planted on 19 May 2025 and inoculated on 08 July 2025.

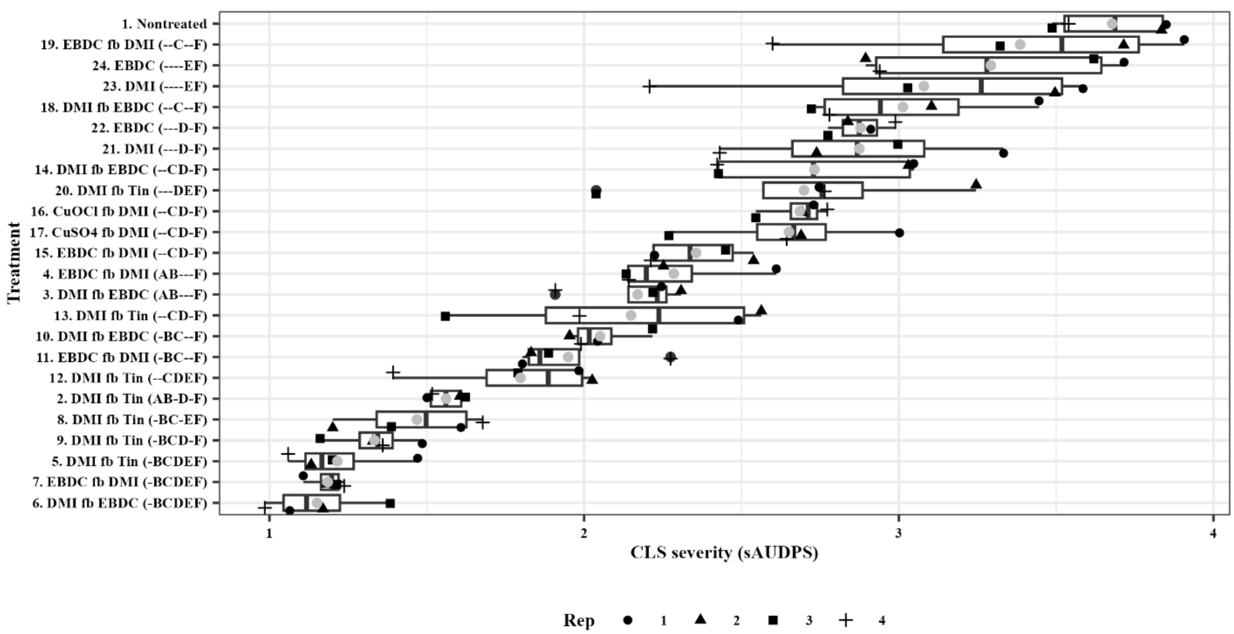

Fig. 2. Effect of foliar fungicide programs compared to the nontreated control on the severity of Cercospora leaf spot (CLS) reported as the standardized area under the disease progress stairs (sAUPDS) in a sugarbeet field trial inoculated with CLS-infested leaves in Crookston, MN. Box-whisker plots display the distribution of data for each treatment (minimum, first quartile, median, third quartile, and maximum); shapes represent each data point; gray filled dots represent treatment means.

Table 2. Effects of fungicide spray programs on CLS severity, root yield, and sucrose quality of sugarbeet in a CLS-inoculated field trial planted on 19 May 2025 and inoculated 08 July 2025 at the University of Minnesota, Northwest Research and Outreach Center, Crookston.

#	Spray Program [v]	CLS Severity (sAUDPS) [w,x]	Sugar (%)	Sugar Loss to Molasses (%)	Root Yield (tons/A)	Sucrose Yield (lbs/A)
1	Nontreated	3.68 k	15.92	1.28	22.8 ab	6720
2	DMI fb Tin (AB-D-F)	1.56 a-d	16.17	1.28	24.4 ab	7285
3	DMI fb EBDC (AB---F)	2.17 d-f	16.16	1.25	23.6 ab	7052
4	EBDC fb DMI (AB---F)	2.29 e-g	16.11	1.21	24.9 ab	7429
5	DMI fb Tin (-BCDEF) [y]	1.22 a	16.01	1.25	26.1 b	7713
6	DMI fb EBDC (-BCDEF)	1.15 a	15.78	1.24	24.8 ab	7237
7	EBDC fb DMI (-BCDEF)	1.19 a	16.31	1.25	25.7 ab	7740
8	DMI fb Tin (-BC-EF)	1.47 a-c	15.95	1.28	23.9 ab	6995
9	DMI fb Tin (-BCD-F)	1.33 ab	16.05	1.24	25.1 ab	7448
10	DMI fb EBDC (-BC--F)	2.05 c-f	15.66	1.27	23.3 ab	6735
11	EBDC fb DMI (-BC--F)	1.95 b-e	16.68	1.24	24.0 ab	7434
12	DMI fb Tin (--CDEF) [z]	1.80 a-e	16.55	1.28	23.1 ab	7062
13	DMI fb Tin (--CD-F)	2.15 c-f	15.68	1.31	24.0 ab	6907
14	DMI fb EBDC (--CD-F)	2.73 f-j	15.79	1.25	23.8 ab	6938
15	EBDC fb DMI (--CD-F)	2.36 e-h	16.80	1.25	23.5 ab	7316
16	CuOCl fb DMI (--CD-F)	2.68 f-i	16.45	1.24	24.2 ab	7356
17	$CuSO_4$ fb DMI (--CD-F)	2.65 f-i	16.16	1.26	22.0 a	6552
18	DMI fb EBDC (--C--F)	3.01 h-k	16.00	1.36	23.4 ab	6855
19	EBDC fb DMI (--C--F)	3.39 jk	16.25	1.24	24.1 ab	7234
20	DMI fb Tin (---DEF)	2.70 f-j	15.80	1.29	23.3 ab	6779
21	DMI (---D-F)	2.88 g-j	16.18	1.28	22.8 ab	6791
22	EBDC (---D-F)	2.88 g-j	16.49	1.25	22.3 a	6804
23	DMI (----EF)	3.08 i-k	16.26	1.23	23.1 ab	6939
24	EBDC (----EF)	3.29 i-k	15.90	1.27	22.3 ab	6529
	CV (%)	**33.8**	4.22	5.70	**8.27**	10.7
	LSD (α = 0.10)	**0.325**	0.668	0.079	**1.80**	682.4
	P-value	**<0.0001**	0.2905	0.6839	**0.0238**	0.1555

[v] 'Crystal 260RR' variety (CR+) with two-year mean CLS rating of 2.6 was used for all treatments; fungicides and application dates for each program are listed in Table 1.
[w] 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.
[x] The coefficient of variation (CV) was calculated as (SD/mean) × 100. Higher CV values indicate greater experimental variability
[x] Least significant difference (LSD) was calculated from mixed-model EMM pairwise comparisons.
[y] 'Standard 5-spray program' consisting of 5 applications with approximately 14-day intervals initiated prior to row closure on 08 July.
[z] 'Standard 4-spray program' consisting of 4 applications with approximately 14-day intervals initiated at disease onset.

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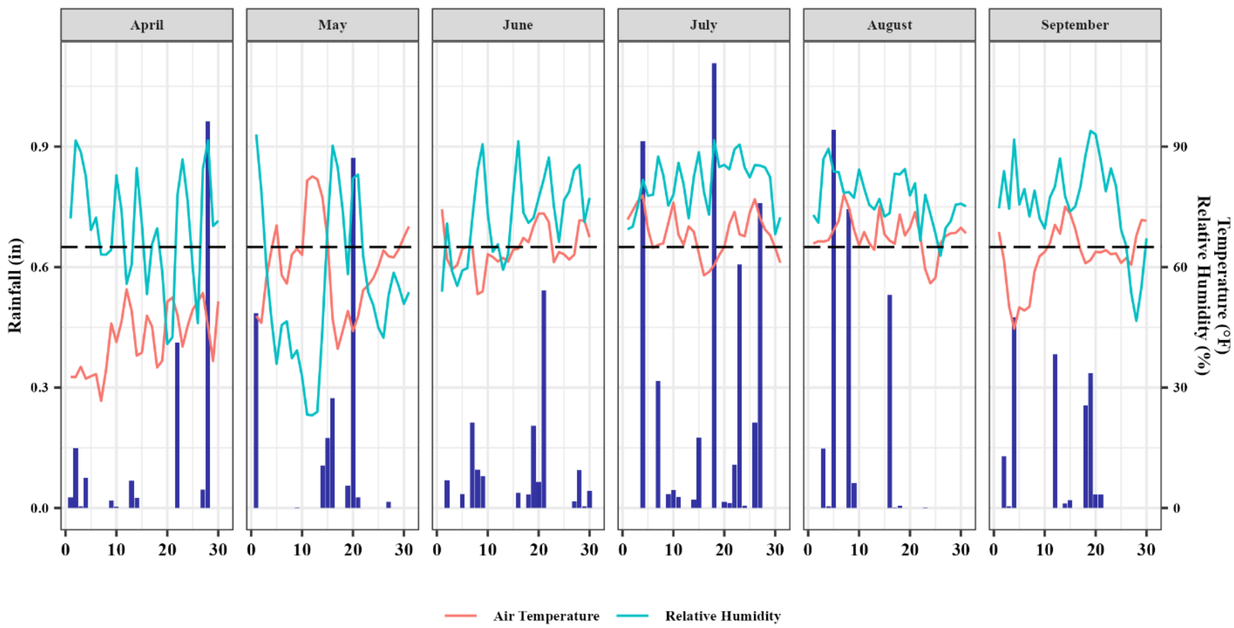
SUPPLEMENTARY WEATHER TABLE AND FIGURE

Supplementary Table S1. Weather data for the 2025 growing season compared to the normal (30-year average). Data was retrieved from the Crookston Minnesota Agricultural Weather Network station (47.823333, -96.620556), located approximately 0.63 miles north-northwest of the research plots maintained by the Northwest Research and Outreach Center (NWROC), Crookston, MN.

Month	Total Rainfall (inch)		Average Air Temperature (°F)	
	2025	Normal [z]	2025	Normal [z]
April	1.79	1.27	41.8	40.8
May	2.01	2.75	59.8	54.7
June	1.52	4.15	63.6	65.2
July	4.36	3.27	67.6	69.1
August	2.44	2.97	68.2	67.4
September	1.68	2.6	62.8	58.2
Growing Season	**13.80**	**17.01**	**60.6**	**59.2**

[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 (bars) and daily mean air temperature (red line), and daily mean relative humidity (blue line) for the 2025 growing season recorded 0.63 miles north-northwest of research plots in Crookston, MN. The dotted horizontal line represents 65°F.