EFFICACY OF FUNGICIDES FOR CONTROLLING CERCOSPORA LEAF SPOT ON SUGARBEET

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Cercospora leaf spot (CLS), caused by the fungus *Cercospora beticola* Sacc., is one of the most economically damaging foliar disease of sugarbeet worldwide and is listed as the most important issue for producers in Minnesota and North Dakota. The disease reduces root yield and sucrose concentration and increases impurity concentrations resulting in reduced extractable sucrose and higher processing losses (Smith and Ruppel, 1973; Khan and Smith, 2005). Roots of diseased plants do not store well in storage piles that are processed in a 7 to 9 month period in North Dakota and Minnesota (Smith and Ruppel, 1973). Cercospora leaf spot is managed by integrating the use of tolerant varieties, reducing inoculum by crop rotation and tillage, and fungicide applications (Khan et al; 2007). It is difficult to combine high levels of Cercospora leaf spot resistance with high recoverable sucrose in sugarbeet (Smith and Campbell, 1996). Consequently, commercial varieties generally have only moderate levels of resistance and require fungicide applications to obtain acceptable levels of protection against Cercospora leaf spot (Miller et al., 1994) under moderate and high disease severity. Since 2016, the pathogen has developed resistance to QoI fungicides and reduced sensitivity to several other modes of action.

The objective of this research was to evaluate the efficacy of fungicide mixtures used in rotation to control Cercospora leaf spot on sugarbeet.

MATERIALS AND METHODS

A field trial was conducted at Foxhome, MN in 2020. The experimental design was a randomized complete block with four replicates. Field plots comprised of six 30-feet long rows spaced 22 inches apart. Plots were planted on 4 May with a variety susceptible to Cercospora Leaf Spot. Seeds were treated with Tachigaren (45 g/kg seed), CruiserMaxx and Vibrance. Seed spacing within the row was 4.7 inches. Weeds were controlled with herbicide applications (Ethotron @ 6 pt) on 11 May, (Roundup Powermax @ 32 fl oz; Outlook @ 12 fl oz; Class Act 1%v/v; Interlock @ 4 fl oz per acre) on 29 May and (Roundup Powermax @ 32 fl oz; Outlook @ 12 fl oz; Class Act 1% v/v; Interlock @ 4 fl oz per acre; Stinger @ 2.5 fl oz) 16 June and (Roundup Powermax @ 32 fl oz; Outlook @ 12 fl oz; Class Act 1% v/v; Interlock 4 fl oz) on 29 June as well as hand weeding throughout the summer. Quadris (14.3 fl oz per acre) was applied on 5 June and 23 June to control *Rhizoctonia solani*. Plots were inoculated on 6 July with *C. beticola* inoculum.

Fungicide spray treatments were applied with a CO_2 pressurized 4-nozzle boom sprayer with 11002 TT TwinJet nozzles calibrated to deliver 17 gpa of solution at 60 p.s.i pressure to the middle four rows of plots. Most fungicide treatments were initiated on 22 July. Treatments included five fungicide applications on 20 July (application A), 31 July (application B), 12 August (application C), 24 August (application D) and 4 September (application E). Applications that were initiated just prior to row closure were treated starting on 7 July. Treatments were applied at rates indicated in Table 1.

Cercospora leaf spot severity was rated on the leaf spot assessment scale of 1 to 10 (Jones and Windels, 1991). A rating of 1 indicated the presence of 1- 5 spots/leaf or 0.1% disease severity and a rating of 10 indicated 50% or higher disease severity. Cercospora leaf spot severity was assessed five times during the season. The rating performed on 31 August is reported.

Plots were defoliated mechanically and harvested using a mechanical harvester on 30 September. The middle two rows of each plot were harvested and weighed for root yield. Twelve to 15 representative roots from each plot, not including roots on the ends of the plot, were analyzed for quality at the American Crystal Sugar Company Quality Tare Laboratory, East Grand Forks, MN. The data analysis was performed with the ANOVA procedure of the Agriculture Research Manager, version 2019.4 software package (Gylling Data Management Inc., Brookings, South

Dakota). The least significant difference (LSD) test was used to compare treatments when the F-test for treatments was significant.

RESULTS AND DISCUSSIONS

The area around the Foxhome site received measurable amounts of rainfall for 48 of the 95 days of the crop (over 14.5 inches). As a result, crop growth was slow and row closure occurred around mid-July. Inoculation was done on July 6 and the first fungicide application for some treatments (indicated by and asterisk (*) started on July 7. Lesion development was slow and occurred about 14 days after inoculation. Most fungicide applications started at first symptoms on July 20. Subsequent fungicide applications were reduced to 10 to 12 days interval instead of 14 days because of regular rainfalls that were washing off the fungicides. Disease development then increased rapidly with economic damage occurring in early August and most plants in the non-treated check losing their oldest leaves with regrowth starting by the end of August. All fungicide treatments were effective at reducing disease severity below the economic threshold when evaluations were done in mid-August. However, by the end of August, most fungicide treatments were becoming less effective at reducing disease severity. In September, there was less days with rainfall than the preceding months and disease severity rapidly increased across all fungicide treatments resulting in leaf loss of mature leaves and regrowth by September 15.

The inoculum used was obtained from nearby (Andrea and Foxhome, MN) CLS infected fields. The *C. beticola* population was resistant to QoI fungicides and had the G143A mutation. The use of fungicide mixtures in a rotation program applied at 10 to 12-day intervals effectively controlled CLS until mid-August to late August, especially those treatments that were initiated just prior to row-closure. The non-treated check had significantly higher CLS ratings compared to the fungicide treatments by early August (Table 1). All fungicide treatments resulted in significantly higher tonnage, sugar concentration, recoverable sucrose per ton and recoverable sucrose per acre compared to the non-treated check. Severe CLS in the non-treated check resulted in a 28% reduction in tonnage, 46% reduction in sucrose concentration, and 57% reduction in recoverable sucrose compared to the most effective fungicide treatment. Whereas similar fungicide treatments using the same variety and inoculum source resulted in effective disease control as measured by the leaf spot ratings through harvest in 2019, the pathogen was not effectively controlled in 2020. Wet conditions in 2020 adversely impacted tonnage but drier conditions in September resulted in higher sugar concentration for the fungicide treatments compared to 2019. It should be noted that the same variety used in 2019 when protected effectively with fungicides resulted in 8,534 pounds of recoverable sucrose which was 40% higher than the best fungicide treatment in 2019. It should also be noted that at the research site, improved CLS varieties had yields of over 28 tons per acre and more than 9,000 pounds of recoverable sucrose when disease severity was reduced as a result of genetics and fungicides in the same environmental conditions.

Over the past two decades, we have used our most susceptible CLS varieties in fungicide efficacy trials. Our assumption was that if we can control CLS with fungicides with these susceptible varieties where we inoculate to ensure the pathogen is present, that growers, when using our fungicide recommendation with more tolerant varieties and in non-inoculated conditions, will be successful at reducing disease severity. This has proven true in most years. What we observed in our 2016 and 2020 fungicide efficacy trials, was that when frequent rainfall washed off fungicides soon after applications with our more susceptible varieties compounded by the fact that some fungicides were less effective because of fungicide resistance, disease severity increased rapidly and adversely impacted yield and quality. Since *C. beticola* population with resistance to several fungicides has become widespread over our over 300 miles stretch of sugarbeet production area, and rainfall has become more frequent, it may be prudent for growers to use improved CLS tolerant varieties that can better withstand the disease when fungicides become ineffective because of resistance and or rainfall wash-off.

Our research over the past five years indicated that when conditions are favorable for applications that fungicide mixtures applied starting promptly at first symptoms of CLS and continued during the season will result in low disease severity. However, in years when there are frequent rainfall that washes off the fungicides or delay applications, it becomes impossible to control the disease in susceptible varieties. As under such conditions, applications that start at or just prior to row closure typically result in lower disease severity. Consequently, our current recommendation is to use improved CLS tolerant varieties, start fungicide applications at or just prior to row closure at 10 to 14 day intervals for most effective control of CLS.

General comments for Cercospora leaf spot control in growers' fields in North Dakota and Minnesota where inoculum levels will probably be high in 2021 and CLS tolerant (KWS ratings of 5.2 and less) varieties are grown:

1. The first fungicide application should be made when disease symptoms are first observed (which entails scouting) or just prior to row closure especially if the crop was planted early and environmental conditions were favorable for good crop growth. If the first application is late, control will be difficult (and probably impossible with more susceptible varieties) all season.
2. Since the pathogen population is very high, especially from the central Red River Valley going south, fungicide applications should be made at regular intervals (14 or 10 to 12 days during periods with more rainfall).
3. Use mixtures of fungicides that are effective at controlling Cercospora leaf spot in an alternation program.
4. Use the recommended rates of fungicides to control Cercospora leaf spot.
5. During periods of regular rainfall, shorten application interval from 14 days to 12 or 10 days; use aerial applicators during periods when wet field conditions prevent the use of ground rigs.
6. Limit or avoid using fungicides to which the pathogen population has become resistant or less sensitive.
7. Only one application of a benzimidazole fungicide (such as Topsin M 4.5F) in combination with a protectant fungicide (such as Super Tin). The use of multi-site fungicides such as TPTH, Copper, and EBDCs mixed with a QoI or DMI fungicides will increase the effectiveness of the QoIs and DMIs.
8. Avoid using fungicides in an area where laboratory testing shows that the fungus has developed resistance or reduced sensitivity to that particular fungicide or particular mode of action.
9. Use high volumes of water (15 to 20 gpa for ground-rigs and 3 to 5 gpa for aerial application) with fungicides for effective disease control.
10. Based on the 2020 *C. beticola* population and sensitivity testing, CLS spray applications should start at disease onset or just prior to row closure, or when symptoms are first observed in the field, factory district, sentinel plants or in CLS inoculated trials.

The following fungicides in several classes of chemistry are registered for use in sugarbeet:

Strobilurins	**Sterol Inhibitors**	**Ethylenebisdithiocarbamate (EBDC)**
Gem	Eminent/Minerva	Penncozeb
(Priaxor)	Inspire XT	Manzate
	Proline	Mancozeb
	Provysol	Maneb
	Enable	(Mankocide)
	Topguard	

Benzimidazole	**TriphenylTin Hydroxide (TPTH)**	**Copper**
Topsin	SuperTin	Kocide 2000 and 3000
	AgriTin	Badge SC, Badge X2
		ChampION, Champ DP and WG
		Cuprofix Ultra 40 Disperss
		MasterCop

Products with multiple modes of action include Priaxor, Minerva Duo, Acropolis, Lucento, Mankocide, ProPulse, Delaro, Dexter Max, and Brixen. See publication PP622-20 for more details.

Products within ( ) indicate that they comprise of more than one mode of action.

Table 1. Effect of fungicides on Cercospora leaf spot control and sugarbeet yield and quality near Foxhome, MN in 2020.

Treatment and rate/A	CLS*	Root yield	Sucrose concentration	Recoverable sucrose		Returns**
	1-10	Ton/A	%	lb/Ton	lb/A	$/A

Super Tin 8 fl oz + Badge SC 2 pt***/ Inspire XT 7 fl oz + Badge SC 2 pt/ Super Tin 8 fl oz + Badge SC 2 pt/ Proline 5.7 fl oz + NIS 0.125 % v/v + Manzate Max 1.6 qt/ Super Tin 8 fl oz + Manzate Max 1.6 qt/ Badge SC 4 pt	5.5	17.78	15.39	290.5	5,167	456
Super Tin 8 fl oz + Manzate Max 1.6 qt***/ Inspire XT 7 fl oz + Manzate Max 1.6 qt/ Super Tin 8 fl oz + Badge SC 2 pt/ Proline 5.7 fl oz + NIS 0.125 % v/v + Manzate Max 1.6 qt/ Super Tin 8 fl oz + Manzate Max 1.6 qt §	5.5	16.18	14.88	280.9	4,541	354
Priaxor 6.7 fl oz + Badge SC 2 pt***/ Provysol 4 fl oz + Badge SC 2 pt/ Super Tin 8 fl oz + Manzate Max 1.6 qt/ Proline 5.7 fl oz + NIS 0.125 % v/v + Badge SC 2 pt/ Super Tin 8 fl oz + Manzate Max 1.6 qt/ Badge SC 4 pt ¥	6.3	15.50	15.04	281.6	4,371	313
Provysol 4 fl oz + Manzate Max 1.6 qt***/ Super Tin 8 fl oz + Topsin 20 fl oz/ Proline 5.7 fl oz + NIS 0.125 % v/v + Manzate Max 1.6 qt/ Manzate Max 1.6qt/ Super Tin 8 fl oz + Priaxor 6.7 fl oz	6.0	15.35	14.70	277.3	4,248	302
Minerva Duo 16 fl oz + Badge SC 2 pt/ Super Tin 8 fl oz + Manzate Max 1.6 qt/ Inspire XT 7 fl oz + Badge SC 2 pt/ Super Tin 8 fl oz + Manzate Max 1.6 qt/ Proline 5.7 fl oz + NIS 0.125 % v/v + Badge SC 2 pt	6.5	13.43	14.74	277.9	3,719	249
Super Tin 8 fl oz + Manzate Max 1.6 qt + Topsin 20 fl oz/ Inspire XT 7 fl oz + Manzate Max 1.6 qt/ Super Tin 8 fl oz + Badge SC 2 pt/ Proline 5.7 fl oz + NIS 0.125 % v/v + Badge SC 2 pt/ Super Tin 8 fl oz + Badge SC 2 pt	6.5	14.70	14.21	265.4	3,904	243
Inspire XT 7 fl oz + Manzate Max 1.6 qt***/ Super Tin 8 fl oz + Topsin 20 fl oz/ Proline 5.7 fl oz + NIS 0.125 % v/v + Manzate Max 1.6 qt/ Manzate Max 1.6 qt/ Super Tin 8 fl oz + Priaxor 6.7 fl oz β	6.5	13.98	14.53	271.6	3,800	237
Manzate Max 1.6 qt + Badge SC 2 pt/ Super Tin 8 fl oz + Badge SC 2 pt/ Manzate Max 1.6 qt + Badge SC 2 pt/ Super Tin 8 fl oz + Manzate Max 1.6 qt/ Super Tin 8 fl oz + Badge SC 2 pt	6.8	12.43	14.46	271.7	3,385	234
Super Tin 8 fl oz + Badge SC 2 pt/ Inspire XT 7 fl oz + Manzate Max 1.6 qt/ Super Tin 8 fl oz + Manzate Max 1.6 qt/ Proline 5.7 fl oz + NIS 0.125 % v/v + Manzate Max 1.6 qt/ Super Tin 8 fl oz + Badge SC 2 pt	6.5	12.98	14.43	272.3	3,539	226
Provysol 4 fl oz + Manzate Max 1.6 qt***/ Proline 5.7 fl oz + NIS 0.125 % v/v + Manzate Max 1.6 qt/ Manzate Max 1.6 qt + Badge SC 2 pt/ Super Tin 8 fl oz + badge SC 2 pt/ Super Tin 8 fl oz + Priaxor 6.7 fl oz	6.8	14.03	14.59	271.7	3,804	223
Super Tin 8 fl oz + Badge SC 2 pt/ Manzate Max 1.6 qt + Badge SC 2 pt/ Super Tin 8 fl oz + Manzate Max 1.6 qt/ Manzate Max 1.6 qt + Badge SC 2 pt/ Super Tin 8 fl oz + Badge SC 2 pt	6.5	12.60	14.26	267.4	3,372	221
Provysol 4 fl oz + Manzate Max 1.6 qt/ Super Tin 8 fl oz + Topsin 20 fl oz/ Manzate Max 1.6 qt + Badge SC 2 pt/ Proline 5.7 fl oz + NIS 0.125 % v/v + Manzate Max 1.6 qt/ Manzate Max 1.6 qt + Badge SC 2 pt/ Super Tin 8 fl oz + Priaxor 6.7 fl oz	7.3	14.33	13.94	260.5	3,725	196
Super Tin 8 fl oz + Topsin 20 fl oz/ Manzate Max 1.6 qt + Badge SC 2 pt/ Super Tin 8 fl oz + Manzate Max 1.6 qt/ Proline 5.7 fl oz + NIS 0.125 % v/v + Badge SC 2 pt/ Super Tin 8 fl oz + Badge SC 2 pt	7.5	12.08	14.20	264.9	3,189	186

Proline 5.7 fl oz + NIS 0.125 % v/v + Manzate Max 1.6 qt/ Super Tin 8 fl oz + Topsin 20 fl oz/ Manzate Max 1.6 qt + Badge SC 2 pt/ Provysol 4 fl oz + Manzate Max 1.6 qt/ Manzate Max 1.6 qt + Badge SC 2 pt/ Super Tin 8 fl oz + Priaxor 6.7 fl oz	6.8	13.98	13.98	259.5	3,622	184
Inspire XT 7 fl oz + Manzate Max 1.6 qt***/ Proline 5.7 fl oz + NIS 0.125 % v/v + Manzate Max 1.6 qt/ Manzate Max 1.6 qt + Badge SC 2 pt/ Super Tin 8 fl oz + Badge SC 2 pt/ Super Tin 8 fl oz + Priaxor 6.7 fl oz	7.0	11.85	14.40	270.5	3,226	167
Untreated Check	9.8	9.68	12.78	235.9	2,271	166
LSD (P=0.10)	**0.8**	**2.0**	**0.41**	**8.6**	**538**	**73.5**

*Cercospora leaf spot measured on 1-10 scale (1 = 1- 5 spots/leaf or 0.1% severity and 10 = 50% severity) on 31 August.
**Returns based on American Crystal payment system and subtracting fungicide costs and application.
***Treatment started just prior to row closure on July 7.
§, ¥, and β treatments are typically recommended by Southern Minnesota Beet Sugar Cooperative, Minn-Dak Farmers Cooperative, and American Crystal Sugar Company, respectively.

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