IMPACT OF CERCOSPORA LEAF SPOT DISEASE SEVERITY ON SUGARBEET ROOT STORAGE

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Cercospora leaf spot (CLS), caused by the fungus *Cercospora beticola* (Crous et al., 2001), is the most damaging foliar disease of sugarbeet in North Dakota and Minnesota (Khan and Hakk, 2016). Historically, the disease has been controlled using fungicides. However, with developing tolerance of *C. beticola* to several classes of fungicides, it is increasingly likely that disease symptoms will develop during production and that roots harvested from CLS-diseased plants will be incorporated into storage piles.

In Minnesota and North Dakota, sugarbeet roots are stored in ventilated or frozen piles for up to eight months. While other production diseases such as Aphanomyces root rot, Fusarium yellows, rhizomania, and rhizoctonia root and crown rot, are known to have a negative impact on storage (Campbell and Klotz, 2006; Campbell and Klotz, 2008; Klotz and Campbell, 2009; Campbell et al., 2011; Campbell et al., 2014), the effects of CLS on sugarbeet root storage properties are not known. It is suspected that roots harvested from CLS-diseased plants do not store as well as healthy roots. However, the effects of CLS on storage properties such as respiration rate, sucrose loss, losses in recoverable sugar, and the accumulation of invert sugars and other impurities that increase sucrose loss to molasses have not been determined.

Research was initiated in 2018 to determine the impact of different levels of CLS disease severity on sugarbeet root storage properties after short-term and long-term storage. In a three-year study, roots with varying levels of CLS disease severity were obtained from field plots that were inoculated with *C. beticola* and received different fungicide treatments, and the storage properties of these roots were evaluated during storage. In studies initiated in 2018 and 2019, roots from plots with very low, low, moderate, and severe CLS disease ratings were used for evaluating storage properties after 30, 90 and 120 days in storage. In 2020, roots from plots with low, moderate, moderately-severe and severe CLS disease ratings were used in this study due to higher CLS disease incidence in the field. A summary of the 2018 storage study can be found in last year's Sugarbeet Research and Extension Report (Fugate et al., 2020). A summary of the 2019 storage study and initial results from the ongoing 2020 storage study are presented here.

MATERIALS AND METHODS

Sugarbeet plants were produced in 2019 and 2020 in fields near Foxhome, MN using a randomized complete block design with four replicates. Plots were six-rows wide (11 ft wide by 30 ft long) with 22 inches between rows and 4.7-inch spacing within rows. In 2019, plots were planted with Seedex Cruze hybrid seed on 14 May. In 2020, plots were planted with Hilleshög HM4448RR on 4 May. Plants were produced using recommended agronomic practices (Khan, 2019). On 12 July and 6 July in 2019 and 2020, respectively, field plots were inoculated with 5 lb ac^{-1} dried *C.*

Table 1: Fungicide treatments and application dates used to obtain plants with varying severity of Cercospora leaf spot symptoms.

/Disease Severity	2019 Production Year		2020 Production Year	
	Fungicide Treatment	**Application Date**	**Fungicide Treatment**	**Application Date**
Group 1 (lowest severity)	Super Tin + Proline + NIS	07/22	Super Tin + Proline + NIS	07/20
	Super Tin + Proline + NIS	08/01	Super Tin + Proline + NIS	07/31
	Super Tin + Proline + NIS	08/14	Super Tin + Proline + NIS	08/12
	Super Tin + Proline + NIS	08/28	Super Tin + Proline + NIS	08/24
Group 2	Super Tin + Manzate Max + Topsin	07/22	Proline + NIS + Badge SC	07/20
	Super Tin + Manzate Max + Topsin	08/01	Proline + NIS + Badge SC	07/31

	Super Tin + Manzate Max + Topsin	08/14	Proline + NIS + Badge SC	08/12
	Super Tin + Manzate Max + Topsin	08/28	Proline + NIS + Badge SC	08/24
Group 3	Gem	07/22	Inspire XT + Badge SC	07/20
	Gem	08/01	Inspire XT + Badge SC	07/31
	Gem	08/14	Inspire XT + Badge SC	08/12
	Gem	08/28	Inspire XT + Badge SC	08/24
Group 4 (highest severity)	untreated		Topsin	07/20
			Topsin	07/31
			Topsin	08/12
			Topsin	08/24

beticola-infected leaves. Plots were treated with the fungicide treatments described in **Table 1** to achieve different levels of disease symptom severities, with all fungicides applied at their full rate to the middle four rows of each plot. CLS disease severity was rated using a 1 – 10 scale with 1 indicative of an absence of disease symptoms and 10 describing plants that experienced complete defoliation and leaf regrowth.

The middle two rows of each plot were harvested on 10 September and 11 September in 2019 and 2020, respectively. Roots were washed, and roots within a plot were randomly assigned to 10-root samples which served as the experimental unit for the storage study. A 10-root sample from each plot was ground to brei after harvest for determining sucrose content, loss to molasses, invert sugar concentration, impurity concentrations, and recoverable sugar per ton prior to storage. The remaining 10-root samples were stored at 5°C (41°F) and 95% humidity. Respiration rates of samples were determined after 30, 90, and 120 days in storage using a Licor infrared CO_2 analyzer (Campbell et al., 2011). Samples were then ground into brei for determining sucrose content, loss to molasses, invert sugar concentration, impurity concentrations, and recoverable sugar per ton.

PROGRESS REPORT

2019-2020 Storage Study

At harvest, root yield and recoverable sugar per acre were significantly reduced in plots with moderate or severe CLS disease symptoms **(Table 2**). Sucrose concentration was also reduced in these plots although the reduction was only statistically significant for roots harvested from plants with severe disease symptoms (**Table 3**). Impurities that cause sucrose loss during processing were also greater in roots from plots with moderate to severe CLS symptoms as evidenced by higher values for sucrose loss to molasses and lower values for recoverable sugar per ton for these roots (**Table 3**).

Table 2: Root yield and recoverable sugar per acre for plants with varying levels of disease symptoms due to Cercospora leaf spot in 2019. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with α = 0.05 (n = 4).

CLS severity class	Disease rating	Yield (tons acre^{-1})	Recoverable sugar (lbs acre^{-1})
Group 1 (lowest)	3.0 c	31.7 a	8709 a
Group 2 (low)	3.5 c	30.3 a	8171 a
Group 3 (moderate)	5.8 b	25.9 b	6753 b
Group 4 (severe)	8.8 a	21.5 c	5467 b

After storage for 30, 90 or 120 days, sucrose concentration and recoverable sugar per ton (RST) were lower in roots from plants with moderate and severe CLS relative to roots from plants with the lowest CLS ratings (**Table 3**). Some, but not all of these reductions were statistically significant. The reductions in sucrose concentration and RST in stored roots, however, were reflections of the lower values for these traits at harvest and were not the product of accelerated sucrose loss in roots with either disease ratings. Similarly, disease severity had no significant effect on root respiration rate after 30, 90, or 120 days in storage (**Table 4**) or invert sugar concentration at harvest or after 30, 90 or 120 days in storage (**Table 3**).

2020-2021 Storage Study

The severity of Cercospora leaf spot was greater in 2020 than in 2018 or 2019. Because of this, no roots with low levels of CLS were available and all roots had moderate to severe disease symptoms. Within the four CLS severity classes used for the 2020 storage study, disease ratings ranged from 5.5 to 10 (**Table 5**). For these roots, no significant differences in root yield, sucrose content, sucrose loss to molasses or recoverable sugar per acre at harvest were found (**Table 5**). At the writing of this report, only respiration rate determinations for roots stored for 30 and 90 days are available, as roots have yet to be stored for 120 days. Data for sucrose concentration, invert sugar concentration, and impurity concentrations will be determined after 120 d when all tissue samples have been collected. For roots stored for 30 and 90 days, however, CLS disease severity had no significant effect on root respiration rate (**Table 6**).

Table 3: Sucrose concentration, sucrose loss to molasses, recoverable sugar per ton, and invert sugar concentration at harvest and during storage for roots obtained from plants with varying levels of disease symptoms due to Cercospora leaf spot in 2019. Roots were stored at 5°C and 95% relative humidity. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with α = 0.05 (n = 4). DIS = days in storage.

CLS	Sucrose concentration				Sucrose loss to molasses				Recoverable sugar per ton				Invert sugar concentration			
severity	0 DIS	30 DIS	90 DIS	120 DIS	0 DIS	30 DIS	90 DIS	120 DIS	0 DIS	30 DIS	90 DIS	120 DIS	0 DIS	30 DIS	90 DIS	120 DIS
	- - - - - - - - - - - - - - (%) - - - - - - - - - - - - -				- - - - - - - - - - (%) - - - - - - - - - -				- - - - - - - ($lbs\ ton^{-1}$) - - - - - - -				- - - (g per 100 g sucrose) - - -			
Group 1	14.5 a	14.4 a	14.2 a	14.5 a	0.90 b	0.80 b	0.77 b	1.18 a	271 a	271 a	269 a	267 a	0.77 a	0.88 a	1.03 a	2.14 a
Group 2	13.6 ab	14.0 ab	13.9 a	14.1 a	0.87 b	0.92 ab	0.88 ab	1.20 a	254 ab	262 ab	261 ab	258 a	0.87 a	1.04 a	1.09 a	1.18 a
Group 3	13.5 ab	13.6 b	13.7 a	13.8 ab	1.17 a	0.86 ab	1.01 ab	1.33 a	247 b	255 b	253 b	250 ab	0.80 a	0.84 a	0.90 a	1.30 a
Group 4	12.8 b	13.1 c	12.7 a	13.2 b	1.16 a	1.04 a	1.03 a	1.37 a	232 b	241 c	233 c	237 b	0.84 a	0.88 a	1.22 a	1.22 a

Table 4: Respiration rate during storage for roots obtained from plants with varying levels of disease symptoms due to Cercospora leaf spot in 2019 study. Roots were stored at 5°C and 95% relative humidity. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with α = 0.05 (n = 4). DIS = days in storage.

	Respiration rate		
CLS severity class	30 DIS	90 DIS	120 DIS
	- - - - - - - - - - ($mg\ kg^{-1}\ h^{-1}$) - - - - - - - - - - -		
Group 1 (lowest)	2.18 a	3.66 a	4.16 a
Group 2 (low)	2.55 a	3.55 a	3.70 a
Group 3 (moderate)	2.72 a	3.39 a	3.64 a
Group 4 (severe)	2.94 a	3.48 a	4.22 a

Table 5: Root yield and recoverable sugar per acre for plants with varying levels of disease symptoms due to Cercospora leaf spot in 2020. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with α = 0.05 (n = 4).

CLS severity class	Disease rating	Sucrose content (%)	Loss to molasses (%)	Yield (tons acre^{-1})	Recoverable sugar (lbs acre^{-1})	Recoverable sugar (lbs ton^{-1})
Group 1 (lowest/moderate)	5.5 c	15.3 a	0.91 a	14.9 a	4281 a	287 a
Group 2 (moderate)	6.5 bc	14.7 a	0.91 a	10.5 a	2864 a	276 a
Group 3 (moderately severe)	8.0 b	15.0 a	0.94 a	12.7 a	3530 a	282 a
Group 4 (severe)	10.0 a	14.1 a	0.90 a	14.3 a	3800 a	264 a

Table 6: Respiration rate after 30 and 90 days in storage for roots obtained from plants with varying levels of disease symptoms due to Cercospora leaf spot in 2020. Roots were stored at 5°C and 95% relative humidity. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with α = 0.05 (n = 4). DIS = days in storage.

CLS severity class	Respiration rate (mg kg^{-1} h^{-1})	
	30 DIS	90 DIS
Group 1 (lowest/moderate)	2.85 a	2.38 a
Group 2 (moderate)	2.94 a	3.14 a
Group 3 (moderately severe)	2.79 a	2.41 a
Group 4 (severe)	3.08 a	2.87 a

CONCLUSIONS

Data from the 2019-2020 storage study and the ongoing 2020-2021 storage study suggest that Cercospora leaf spot, at any severity level, has no effect on sugarbeet root storage properties. This is consistent with results from the 2018-2019 storage study (Fugate et al., 2020). These conclusions, however, should be considered preliminary until all data from the 2020-2021 storage study are collected and analyzed, and a multiyear analysis of data is completed.

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