IMPACT OF DROUGHT STRESS ON SUGARBEET STORAGE PROPERTIES

Karen K. Fugate[1], Abbas M. Lafta[2], John D. Eide[1], and Mohamed F. R. Khan[2,3]

[1]USDA-ARS, Edward T. Schafer Agricultural Research Center, Fargo, ND
[2]Department of Plant Pathology, North Dakota State University, Fargo, ND
[3]University of Minnesota Extension Service, St. Paul, MN

Sugarbeet roots in Minnesota and North Dakota are largely produced without irrigation and rely on natural precipitation to meet their water needs. For a large portion of the crop, water stress is, therefore, inevitable when rainfall is insufficient. Drought stress reduces root and sucrose yields, reduces root water content, and increases amino-nitrogen, sodium and potassium concentrations, and sucrose loss to molasses at harvest (Clover et al., 1999; Choluj et al., 2004; Bloch et al., 2006; Hoffmann, 2010). It is expected that drought stress prior to harvest is also detrimental to storage. Information regarding the effects of inadequate water availability during the production season on sugarbeet root storage properties, however, is limited. Kenter and Hoffmann (2008) reported that severely drought-stressed roots accumulated greater concentrations of invert sugars and amino-nitrogen during storage relative to unstressed roots. The effect of minor or moderate drought conditions on these properties, however, is unknown. Because dehydration during storage increases root respiration rate and susceptibility to storage rots (Gaskill, 1950; Lafta and Fugate, 2009), it is likely that preharvest drought stress increases storage respiration rate and the incidence of storage diseases. However, no research has examined the effects of preharvest water stress on postharvest respiration rate or susceptibility to storage diseases.

Research was conducted to investigate the effect of inadequate water availability on sugarbeet root storage properties. Since controlling water availability is difficult with field grown plants due to the unpredictability of rainfall, research was conducted using greenhouse plants. Storage properties evaluated include root respiration rate, sucrose loss, invert sugar accumulation, and susceptibility to storage rots. These investigations are incomplete at the time this report was written. Therefore, all data reported here should be viewed as preliminary.

MATERIALS AND METHODS

Sugarbeet plants were produced in 15 L pots in a greenhouse. Plants were grown with supplemental light using a 16-hour light/8-hour dark regime and were watered with an automated drip irrigation system that delivered 1.0 L water per day to each pot. Watering treatments were created by removing irrigation drip tubes from plants at 0, 1, or 3 weeks prior to harvest to generate plants with no, mild, and severe water stress. Roots from all treatments were harvested 18 weeks after planting, and the harvested roots within a treatment were randomized. On the day of harvest, tissue samples were collected from five replicate roots from each watering treatment. An additional five roots from each watering treatment were stored at 10°C and 90% relative humidity for up to 12 weeks. Six roots from each watering treatment were inoculated with the storage pathogen, *Botrytis cinerea* using the protocol of Fugate et al. (2012). An additional six roots were inoculated with *Penicillium claviforme*. Inoculated roots were stored at 20°C and 90% relative humidity for 28 days.

Respiration rates of individual roots were measured on stored roots after 3, 6, 9, and 12 weeks of storage using the protocol of Haagenson et al. (2006). Tissue samples of these roots were collected after 12 weeks in storage for sucrose and invert sugar determinations. Inoculated roots were assessed for disease progression after 28 days in storage by determining the weight of rotted tissue for each root (Fugate et al., 2012).

PROGRESS REPORT

Restricting water for 1 or 3 weeks prior to harvest caused minor and severe drought stress and reduced the water content of roots harvested from plants that had not received water for 1 or 3 weeks by 1.7 and 6.9%, respectively (Table 1). Storage respiration rates were elevated for roots harvested from severely drought-stressed plants, and roots from the 3-week drought-stress treatment had respiration rates after 3, 6, 9, and 12 weeks in storage that were 2.0, 3.2, 5.2, and 6.2 mg CO_2/kg·h greater than controls, respectively (Table 1). No differences in sucrose concentration that were related to drought stress, however, were noted at harvest or after 12 weeks in storage (Table 2). Sucrose content of roots from all watering treatments, however, declined in storage. The concentration of invert sugars in roots at harvest or after 12 weeks of storage was also not affected by watering treatments, although invert sugar concentrations

increased significantly during storage for roots from all watering treatments (Table 2). Susceptibility to two common storage rots was increased by severe water stress. (Table 3). Roots inoculated with *Botrytis cinerea* or *Penicillium claviforme* and stored for 28 days had approximately three-fold more rotted tissue than similarly treated roots from well-watered plants.

Table 1: Root water content at harvest and storage respiration rate of roots subjected to drought stress prior to harvest. Water was withheld from plants 1 week or 3 weeks prior to harvest. Controls were watered until the day of harvest. Respiration rate was measured on the same roots after 3, 6, 9, or 12 weeks in storage at 10°C and 90% relative humidity. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with $\alpha = 0.05$ (n = 5).

Water treatment	Root water content (%)		Respiration rate (mg CO_2/kg·h)							
			3 weeks		6 weeks		9 weeks		12 weeks	
control	77.0	a	3.1	a	2.9	a	5.3	a	8.5	a
1 week	75.3	a	2.5	a	2.6	a	4.3	a	7.9	a
3 weeks	70.1	b	5.1	b	6.1	b	10.5	b	14.7	b

Table 2: Concentration of sucrose and invert sugars at harvest and after 12 weeks in storage of roots subjected to drought stress prior to harvest. Water was withheld from plants 1 week or 3 weeks prior to harvest. Controls were watered until the day of harvest. Roots were stored at 10°C and 90% relative humidity. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with $\alpha = 0.05$ (n = 5).

Water treatment	Sucrose concentration (mg/g dry wt)				Invert concentration (mg/g dry wt.)			
	at harvest		after storage		at harvest		after storage	
control	441	a	429	a	7.0	a	9.0	a
1 week	440	a	435	a	6.4	a	9.3	a
3 weeks	444	a	425	a	6.5	a	8.3	a

Table 3: Relative weight of rotted tissue in roots subjected to drought stress prior to harvest and inoculated with *Botrytis cinerea* or *Penicillium claviforme* on the day of harvest. Water was withheld from plants 1 week or 3 weeks prior to harvest. Controls were watered until the day of harvest. After inoculation, roots were stored at 20°C and 90% relative humidity for 28 days. Means within a column followed by different letters are significantly different based upon Fisher's LSD, with $\alpha = 0.05$ (n = 6).

Water treatment	Relative Weight of Rotted Tissue (% of control)			
	Botrytis		*Penicillium*	
control	100	a	100	a
1 week	99	a	85	a
3 weeks	315	b	290	b

ACKNOWLEDGEMENTS

The authors thank the Sugarbeet Research & Education Board of MN & ND for partial financial support of this research. Mention of trade names or commercial products is solely for the purpose of providing specific information

and does not imply recommendation or endorsement by the U.S. Department of Agriculture. USDA is an equal opportunity provider and employer.

REFERENCES

Bloch, D., Hoffmann, C.M., and Märländer, B. (2006). Solute accumulation as a cause for quality losses in sugar beet submitted to continuous and temporary drought stress. J. Agron. Crop Sci. 192:17-24.

Choluj, D., Karwowska, R., Jasińska, M., and Haber, G. (2004). Growth and dry matter partitioning in sugar beet plants (*Beta vulgaris* L.) under moderate drought. Plant Soil Environ. 50:265-272.

Clover, G.R.G., Smith, H.G., Azam-Ali, S.N., and Jaggard, K.W. (1999). The effects of drought on sugar beet growth in isolation and in combination with beet yellows virus infection. J. Agricul. Sci., Cambridge 133:251-261.

Fugate, K.K., Ferrareze, J.P., Bolton, M.D., Deckard, E.L., Campbell, L.G. (2012). Postharvest jasmonic acid treatment of sugarbeet roots reduces rot due to *Botrytis cinerea*, *Penicillium claviforme*, and *Phoma betae*. Postharvest Biol. Technol. 65:1-4.

Gaskill, J.O. (1950). Effects of wilting, drought, and temperature upon rotting of sugar beets during storage. Proc. 6th Gen. Meeting Amer. Soc. Sugar Beet Technol. 653-659.

Haagenson, D.M., Klotz, K.L., Campbell, L.G., Khan, M.F.R. (2006). Relationships between root size and postharvest respiration rate. J. Sugar Beet Res. 43:129-144.

Hoffmann, C.M. (2010). Sucrose accumulation in sugar beet under drought stress. J. Agron. Crop Sci. 196:243-252.

Kenter, C., and Hoffmann, C.M., 2008. Influence of drought stress on quality and storage properties of sugarbeet. Zuckerindustrie 133:155-160.

Lafta, A.M., and Fugate, K.K. (2009). Dehydration accelerates respiration in postharvest sugarbeet roots. Postharvest Biol. Technol. 54:32-37.