Sucrose Content, Clear Juice Purity and Storage Rot of Sugarbeet*

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Received for Publication December 9, 1985

INTRODUCTION

The sucrose content of sugarbeet juice at harvest has been suggested as an indicator of how well roots might store. Slices from roots with a higher sucrose content were more resistant to rot caused by *Phoma beta* (Oud.) Frank (teleomorph: *Pleospora bjoerlingii* Byford) than roots with lower sucrose content (1,8). Roots did not store well when their sucrose content was lowered because of leaf damage caused by *Cercospora beticola* (10). Cell walls of roots with high sucrose content were more resistant to maceration and elicited a lower production of endopolygalacturonate transeliminase by *P. betae* than walls from roots with lower sucrose contents (1). We were able to gain more information on the relationship of juice quality and storage rot because of distinct gradients in juice quality and sucrose content that was associated with the location of plots within our replicated field trial. This provided a unique opportunity to measure the degree of association of sucrose content and juice purity with storage rot. The results are reported here.

MATERIALS AND METHODS

This test was made in Fargo clay-loam soil at the

*Cooperative investigation of the U.S. Department of Agriculture, Agricultural Research Service, and the North Dakota Agricultural Experiment Station. Published with the approval of North Dakota Agricultural Experiment Station as Journal Article No. 1435. The authors are Research Plant Pathologist and Research Plant Physiologist, respectively, USDA, ARS, Fargo, ND 58105.

North Dakota Agricultural Experiment Station, Fargo, ND. Two seed lots of cultivar US H20 of *Beta vulgaris* L. were used. Both were naturally infected with *P. betae*. Over 95% of the seed in one lot was infected, and 25% in the other.

Seeds from each lot were treated with five fungicidal seed treatments for the purpose of examining the effect of seed treatments on storage rot. The storage rot results have been reported elsewhere (2). Seeds from each lot also were left untreated for a total of six seed treatments.

Treatments were replicated 16 times and arranged in a randomized complete block design for a total of 192 plots. Each replicate consisted of 12 treatments and occupied an area of 3.9 m x 61.5 m. The entire plot area was 61.5 x 73.1 m. Each treatment plot was four rows wide and 9 m long. Rows 1 and 4 were buffer rows of a commercial cultivar, and rows 2 and 3 were test rows. The experimental site was sampled for soil fertility in the spring, and enough ammonium nitrate was applied to bring the available nitrogen level up to 167 kg/ha in the top 60 cm.

Roots were harvested by first removing leaves with a mechanical flail defoliator, then raising the roots in the soil with a two-row lifter. The roots were removed from the soil by hand and bagged. Thirty roots from each of the 192 plots were divided into three samples of 10 roots each. Sample one was processed immediately for harvest quality. Sample two was dipped into a 1,500 µg/ml suspension of thiabendazole. Sample three was not treated. Samples two and three were stored in perforated plastic bags at 4-6 C and 100% relative humidity for 150 days. After storage, rotted tissue was excised, weighed, and expressed as percentage of the entire fresh weight of the roots per plot.

Quality parameters of the juice that were measured at harvest and after storage were sucrose content, clear juice purity (CJP), raffinose, and invert sugars. The recoverable white sugar per metric ton of roots (RWST) was

calculated with an assumed factory loss of 0.3%, and a molasses purity of 62.5% (11). Sucrose was measured with a polarimeter after the cold digestion method of juice preparation with aluminum sulfate as the clarifying agent (3). The CJP was determined with the method described by Dexter et al. (4). Purity was 100 x sucrose content/dry substance (by refractometry) of root extract that had been clarified with CaO and filtered. We measured raffinose in juice from stored roots by using an enzyme system (galactose oxidase) developed by Yellow Springs Instrument Co., Yellow Springs, OH 45387. The enzyme was immobilized in a polycarbonate membrane fitted on a silver and platinum electrode within a small reaction chamber. The clarified juice (25 µl) was injected into the reaction chamber. The instrument was calibrated with a raffinose standard. Raffinose accumulates in sugarbeets at storage temperatures below 5 C (11) and causes false polariscope readings for sucrose determinations. The raffinose values were used to adjust the polariscope values of juice from stored sugarbeets to give accurate sucrose values. Invert sugars were determined by the 3,5-dinitrosalicylic acid method (7). This value was used to adjust the polarimetric values.

RESULTS AND DISCUSSION

The analyses of variance showed that the *P. beta* content of the two seed lots and the use of thiabendzole for storage rot control had no effect on the sucrose content, CJP, RWST, or storage rot, so this data was combined over seed lots and thiabendazole for the correlation and regression analyses.

Variability in harvest sucrose content tended to be associated with the location of replicates, but variability in sucrose content of the stored roots definitely was associated with replicate location (Table 1). Lower sucrose content was most evident in replicates 9 through 16. The situation was similar with CJP; there was a tendency for harvest CJP to be associated with replicate location, but there was a definite association of storage

Table 1. Sucrose content, clear juice purity (CJP), recoverable white sugar per metric ton (RWST), and storage rot for each of 16 replicates of a field experiment planted to sugarbeets.

Replicate*	Harvest			After 105 Days Storage			
	Sucrose content (w/w)	CJP	RWST	Sucrose Content	CJP	RWST	Rot (w/w)
	%	%	kg	%	%	kg	%
1	12.7	88.8	96	10.3	88.2	77	3
2	13.9	90.1	109	10.9	87.8	83	5
3	12.9	89.5	100	10.3	88.3	77	6
4	12.7	90.1	100	9.9	88.3	74	7
5	12.6	90.3	100	10.6	88.9	81	5
6	12.8	90.5	102	10.3	87.0	74	6
7	13.0	89.2	100	10.0	85.7	69	8
8	13.1	90.2	103	10.1	87.2	73	7
9	12.9	89.8	100	9.7	86.5	69	8
10	13.0	90.2	103	9.5	86.0	59	9
11	12.6	89.0	96	8.7	85.3	45	11
12	12.6	88.3	94	7.6	81.8	45	17
13	12.8	87.6	95	7.3	83.0	46	16
14	12.2	87.1	89	6.8	81.5	40	18
15	12.2	87.0	88	6.7	81.3	40	19
16	12.4	87.4	90	7.3	80.8	42	17

*Each replicate was 3.9 x 73.1 m (total plot size, 61.5 x 73.1 m). The gradients were west-east on the long axis of the plot. Data for each replicate are means of 12 observations.

CJP with replicate location. The gradient in RWST for stored roots was very evident. The amount of RWST in replicates 11 through 16 was only 58% of that in replicates 1 through 6. The amount of storage rot varied from 3 to 19% and was associated with replicate location in a directional gradient similar to the quality values.

When storage rot was correlated with harvest data for each of the 16 replicates, the correlation coefficients were negative and significant ($P = 0.05$): sucrose content, $r = -0.63$; CJP, $r = -0.87$; and RWST, $r = -0.76$. A high correlation ($r = -0.98$) was shown between storage rot and sucrose content after storage, as would be expected, because fungal development would reduce the sucrose content of the rotted root tissue.

A regression of 192 plot means (two observations per plot) for storage rot and sucrose content at harvest showed that each 1% increase in sucrose content was associated with a 1.8% decrease in storage rot ($r = -0.22$, $n =$

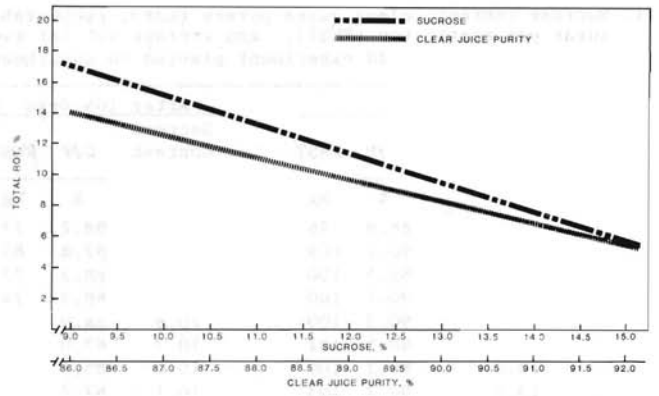

Figure 1. Regression for 192 plots of sugar beet at two observations per plot for percent sucrose content and clear juice purity of roots at harvest, and percent storage rot (w/w) of roots after 150 days' storage at 5 C.

192); each 1% increase in CJP was associated with a 1.4% decrease in storage rot (r = -0.41, n = 192) (Figure 1). The low negative correlation (r = -0.22) between sucrose content at harvest and total storage rot development supports an earlier report (r = -0.41 to -0.46) (1) that sucrose content alone does not account for resistance to *P. betae*. Our data show a more negative association of storage rot development with CJP than with sucrose content at harvest. This would suggest that higher concentrations of nonsucrose dissolved solids in roots with a low CJP in this experiment stimulated increased aggressiveness of storage pathogens, or interfered with the sugarbeet's defense mechanisms.

The environmental factors that could have caused the variability of juice purity in this experiment are not known, but numerous reports in the literature show that excess soil nitrogen causes reduced sucrose yield and a lowering of CJP (5). The soil in our experimental area was sampled 60 cm deep, and the nitrogen level was raised to 167 kg/ha with added fertilizer in accordance with recommendations for maximum sugar yield and quality. Higher levels of nitrogen might have been present below

the 60-cm depth, however, even in the plots that had grown corn, a high nitrogen user. Recent measurements have shown very high levels of soil nitrogen as deep as 2.1 m (9).

Low soil moisture during the growing season may reduce the sucrose content and juice purity of roots, and this effect can be modified by the genotype of the sugarbeet (6). The plants in our test never showed signs of nitrogen depletion or moisture stress. In fact, nothing unusual was apparent until the roots were evaluated for rot development, and the data on juice quality were assembled.

This experimental area was cropped the previous year to wheat, except for that portion comprised of replicates 13, 14, and 15 which was planted to corn. Replicates 13 through 16 had the lowest CJP at harvest (Table 1). The high moisture requirement of corn could have reduced soil moisture to a level that lowered juice purity and stimulated storage rot, but not low enough to have induced noticeable wilt of the sugarbeet.

Regardless of whether the cause of poor storability was due to excess nitrogen, moisture stress, or a combination of both, dramatic variability in storage rot and sucrose loss occurred in roots of US H20 that were produced within a research area of 4,500 m^2. The average CJP at harvest varied only 3.5% from the highest to the lowest plot mean, but this variation was associated with a 50% loss in RWST during storage. This finding suggests an association of storage rot development with CJP. If a small variation in CJP can affect a significant change in susceptibility to storage rot, then measures to ensure uniformity of the soil environment takes on new and increased importance, especially if goals involve improved storability and storage rot resistance through breeding.

SUMMARY

A research plot was planted with sugarbeets. Sucrose contents and clear juice purities (CJP) of juice expressed from roots were measured at harvest and after root storage of 150 days at 5 C. A gradient along the east-west axis

of the plot showed a decrease in sucrose content and CJP at harvest and after storage, and an increase in rot and loss of recoverable white sugar per metric ton of roots during storage.

The cause of the gradient at harvest is not known, but the replicates that contributed most toward the gradient were located on land cropped to corn the previous year. The remaining land had been cropped to wheat. These results emphasize the necessity of a uniform soil environment within research plots intended for all sugarbeet research. The appearance of the growing crop or the harvested roots gave no indication that poor storability could be anticipated. The data, however, did provide evidence to suggest that low CJP was associated with an increase in storage rot development. Roots with high CJP were more resistant to storage rot than roots with low CJP.

LITERATURE CITED

1. Bugbee, W. M. 1973. Sucrose and cell walls as factors affecting Phoma storage rot of sugar beet. Phytopathology 63:480-484.

2. Bugbee, W. M. and D. F. Cole. 1981. The effect of seed infected with *Phoma betae* on rot and sucrose yield of stored sugar beet. Phytophathology 71:357-359.

3. De Whalley, H. C. S., ed. 1964. ICUMSA Methods of Sugar Analysis. Elsevier Publishing Co., Amsterdam, Holland. 153 pp.

4. Dexter, S. T., M. G. Frakes and F. W. Snyder. 1967. A rapid and practical method of determining extractable white sugar as may be applied to the evaluation of agronomic practices and grower deliveries in the sugar beet industry. J. Am. Soc. Sugar Beet Technol. 14:433-454.

5. Hills, F. J. and A. Ulrich. 1971. Nitrogen nutrition. Pages 111-135 in: Advances in Sugarbeet Production. R. T. Johnson, J. T. ALexander, G. E. Rush and G. R. Hawkes, eds. Iowa State University Press, Ames. 470 pp.

6. James, D. W., D. L. Doney, J. C. Theurer and R. L. Hurst. 1978. Sugarbeet genotype, N, and soil moisture availability interactions in components of beet yield and quality. Agron. J. 70:525-531.

7. Miller, G. L. 1959. Use of dinitrosalicylic acid reagent for determination of reducing sugar. Anal. Chem. 31:426-428.

8. Nelson, R. T. and R. K. Oldemeyer. 1952. Preliminary studies applicable to selection for low respiration and resistance to storage rots of sugar beets. J. Am. Soc. Sugar Beet Technol. Proc. 7:400-406.

9. Peterson, G. A., F. N. Anderson, G. E. Varvel and R. A. Olson. 1979. Uptake of ^{15}N-labeled nitrate by sugar beets from depths greater than 180 cm. Agron. J. 71:371-372.

10. Smith, G. A. and E. G. Ruppel. 1971. Cercospora leaf spot as a predisposing factor in storage rot of sugar beet roots. Phytopathology 61:1485-1487.

11. Wyse, R. E. and S. T. Dexter. 1971. Sucrose of recoverable sugar losses in several sugarbeet varieties during storage. J. Am. Soc. Sugar Beet Technol. 16:390-398.