LOCALIZATION OF SUCROSE AND IMPURITIES IN SUGARBEET ROOTS

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Sodium, potassium, amino acids, and reducing sugars are the major impurities in sugarbeet (*Beta vulgaris* L.) roots that interfere with sucrose extraction. Data showing the specific location of these impurities are limited. The objectives in this study were to determine, by analyzing specific tissues of the root, the effects of leaf removal, cultivars, and potassium fertilizer on the localized content of sucrose and various impurities. Weekly removal of older fully expanded leaves reduced the sucrose and amino acid content of the roots and increased the sodium level. Potassium content was decreased by removal of new leaves. Vascular rings near the epidermal surface of the root had the highest concentration of sucrose and the lowest level of all impurities. Pith tissue of the crown had the lowest content of sucrose and highest content of amino acids. The vascular tissue of the crown was similar in quality to the vascular tissue of the root. Cultivars and potassium fertilizers affected the sodium and potassium content of specific tissue. Impurity levels were affected by several parameters. Impurities were located in tissues where sucrose was low. Selecting genotypes with an increased amount of vascular tissue in the root and with less pith tissue in the crown should reduce the impurity levels and increase sucrose.

INTRODUCTION

Sugarbeet, *Beta vulgaris* L., roots differ in several morphological characteristics, e.g., number of anomalous cambiums (vascular rings), width of the central core (primary xylem and phloem), and ring density (ratio of total number of vascular rings divided by the radius of the beet) (1). Also, the crown tissue located above the lowest leaf scar is composed of vascular and parenchyma tissues. For the remainder of this paper the term "root" will include both the root and crown tissue. Fort and Stout (4) reported differences for several parameters among various parts of sugarbeet roots; however, their sectioning technique did not separate specific tissues. Teranishi *et al.* (10) observed differences in sucrose content of samples composed mainly of vascular tissue compared to parenchyma tissue. Artschwager (1) attempted to correlate internal root morphology with sucrose content, but was unsuccessful in finding any individual characteristic related to sucrose content.

Sucrose content of 50 individual roots that were harvested consecutively from one row in a commercial field varied from 4.4 to 17.2% (6). Carruthers and Oldfield (3) and Smith *et al.* (8) have shown that major impurities affecting sucrose extraction from sugarbeet roots were sodium, potassium, and nitrogenous compounds. However, those analyses were determined on pulp samples obtained from several roots. Data showing the location of these impurities in specific tissues of sugarbeet roots are limited. Crown tissue is generally lower in sucrose and higher in impurities than root tissue. Recent data have indicated that the difference in sucrose and impurity levels between root and crown tissue is affected by nitrogen fertilizer and by cultivars (5,12,13).

The objectives in this study were to analyze specific root tissues and determine the localized content of sucrose and various impurities as affected by leaf removal, potassium fertilizer, and cultivar.

MATERIALS AND METHODS

Experiment 1.

Sugarbeets were grown at Fargo, North Dakota, on a heavy clay soil in 1977 using seed of a commercial hybrid cultivar, "Bush Mono." The 4-row plots were 9.1 m long with six replications in a randomized complete block design. Three-leaf removal treatments were initiated on August 1: 1) no leaves were removed; 2) new leaves were removed twice weekly; 3) old fully expanded leaves were removed on a weekly basis. Four roots were harvested at random from the two center rows of each plot. Two roots were analyzed at harvest and two were stored for 120 days. Two replicates of the harvest samples and one replicate of the storage samples were lost during analysis. Thus, results are from four of the replicates at the time of harvest and from five replicates after the 120-day storage period.

From each fresh and stored root, a horizontal slice of tissue was removed near the mid-portion of the crown and from an area 1.5 cm below the lowest leaf scar. Each slice was 8-10 mm thick and was placed on a clear glass surface over a fluorescent light to facilitate removal of specific types of tissue. A sample of tissue was removed with a stainless steel cork borer (3 mm inside diameter) from specific locations in the root slice. Six locations

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(from center to exterior) were sampled in the root slice: 1) central core; 2) the first two vascular rings nearest the central core; 3) the first two intravascular parenchyma rings nearest the central core; 4) vascular tissue near the epidermal tissue (outer rings). Two locations were sampled in the crown slice: 1) vascular tissue; and 2) tissue from the center of the crown. The same procedure was used for the stored samples.

Each sample of tissue was weighed and extracted with glass-distilled water for 15 minutes in a boiling water bath. The extract was analyzed for reducing sugars (9), amino acids (7), and total carbohydrates (2). Sucrose content was calculated by correcting total carbohydrates for reducing sugars. Sodium and potassium were determined by atomic absorption spectrometry (emission mode). The data were expressed on a fresh weight basis.

Experiment 2.

Sugarbeet roots were obtained from a cultivar x potassium experiment in 1977 located near Gary, Minn. The experiment was located on a sandy textured soil deficient in potassium. Four cultivars ("ACH-14," "GW D2," "Beta 1934," and "ACH-17") were grown at three levels of potassium fertilization (0, 44, and 220 kg/ha). Nitrogen and phosphorus were applied at rates based on results of soil testing to a depth of 60 cm. The experimental design was a split-plot with cultivars as whole plots and potassium level as the sub-plot. The experiment was replicated four times. Plots were six rows wide and 9.1 meters long. Ten consecutive beets in either row 2 or 5 were manually harvested from the 0 and 220 kg/ha treatment. Four roots were selected at random from the 10 harvested and sectioned and analyzed as previously described.

RESULTS AND DISCUSSION

Experiment 1.

Removal of older leaves did not significantly reduce the sucrose percentage when averaged over all tissue sampling locations (Table 1). Reducing sugars of the control treatment did not differ significantly for either leaf removal treatment, but the old and new leaf removal treatments were significantly different. Removal of older leaves significantly reduced amino acid levels at harvest. Sodium was increased by both leaf removal treatments and potassium was decreased by removal of new leaves when averaged over all tissues.

Vascular tissues (outer rings) located near the epidermal surfaces of the sugarbeet root had the highest concentration of sucrose and lowest concentration of impurities (Table 2). Parenchyma cells located between vascular rings near the center of the roots contained only 65-70% of the sucrose in the vascular tissues. Sucrose concentrations of the crown vascular tissue and root vascular tissue were similar. Crown pith tissue had the lowest concentration of sucrose. Parenchyma cells located between the vascular rings had the highest concentration of reducing sugars and sodium. Potassium and amino acid concentrations were highest in the pith tissue of the crown. No differences were detected between vascular tissues of the crown and outer rings for sodium levels. Potassium levels of crown and root vascular tissues were equal. Quality of the vascular tissue of the crown was better than the quality of parenchyma tissue of the roots.

Distribution of sucrose and impurities after the 120-day storage period was essentially the same as at harvest. However, sucrose content of crown vascular tissue decreased by 17.8%, whereas the central core decreased by only 1.4% during the 120-day storage period. Wyse and Peterson (11) showed that crown tissue had a higher rate of respiration than root tissue which would explain the greater sucrose loss in crown tissue.

Experiment 2.

Potassium levels among tissue sampling locations differed with cultivar and K fertilizer level (Table 3). Sodium and potassium were concentrated in parenchyma and pith tissues. Sodium levels for the vascular tissue of the crown and roots were similar. Cultivars differed in the amounts of sodium and potassium in the roots (Table 3). Cultivar ACH-14 accumulated less sodium and potassium than did Beta 1934. Cultivar GW

Table 1. Effect of leaf removal on quality components in sugarbeet roots at harvest and after 120-days storage at 5 C.

Leaves Removed	Sucrose	Reducing sugars	Amino acids	Sodium	Potassium	Sodium Potassium ratios
	%	ppm	ppm	ppm	ppm	
			Harvest			
None	12.8 a*	1563 ab	9162 a	709 b	4096 a	0.21 b
New	12.3 a	1933 a	8995 a	1024 a	3518 b	0.33 a
Old	11.3 a	1104 b	7480 b	978 a	3786 ab	0.30 a
			After 120-Day Storage			
None	11.7 a	1744 ab	7448 a	962 b	3899 a	0.30 b
New	11.5 a	2041 a	7480 a	1001 ab	3696 ab	0.34 ab
Old	10.4 a	1375 b	8282 a	1121 a	3573 b	0.39 a

**Means followed by the same letter within a column at each sampling date are not significantly different according to Duncan's multiple range test at P = 0.05 level.*

Table 2. Localization of quality components within specific tissues of sugarbeet roots at harvest and after 120-days storage at 5 C.

Tissue	Sucrose	Amino acids	Reducing sugars	Sodium	Potassium	Sodium / Potassium ratio
	%	ppm				
Harvest						
Central core	13.8 b*	3971 d	751 c	867 b	2222 c	0.40 a
Vascular 1	14.1 b	4183 d	739 c	877 b	2145 c	0.43 a
Vascular 2	13.9 b	5165 cd	833 c	854 b	2233 c	0.40 a
Parenchyma 1	9.6 c	12034 b	3438 a	1529 a	6457 b	0.26 b
Parenchyma 2	9.0 c	14079 ab	4003 a	1465 a	6464 b	0.24 bc
Outer rings	16.5 a	4856 cd	357 c	317 c	1898 c	0.19 bc
Crown pith	5.2 d	16570 a	1689 b	1074 b	7209 a	0.18 bc
Crown vascular	15.1 b	7509 c	456 c	246 c	1773 c	0.16 c
120-Day Storage						
Central core	13.6 ab	3961 d	580 b	976 b	2219 c	0.47 b
Vascular 1	13.6 ab	3609 d	583 b	1000 b	2030 c	0.55 a
Vascular 2	13.7 ab	4071 d	794 b	1002 b	1918 c	0.55 a
Parenchyma 1	8.9 c	10041 b	3130 a	1680 a	6066 b	0.30 c
Parenchyma 2	8.4 c	10085 b	3715 a	1725 a	6065 b	0.31 c
Outer rings	14.4 a	6806 c	1137 b	423 c	1900 c	0.23 cd
Crown pith	4.4 d	17540 a	2915 a	1045 b	7593 a	0.14 e
Crown vascular	12.4 b	5780 cd	904 b	375 c	1990 c	0.18 de

**Means followed by the same letter within a column at each sampling date are not significantly different according to Duncan's multiple range test at P = 0.05 level.*

Table 3. Effect of tissue, cultivar and potassium fertilizer on sodium, potassium, and sodium:potassium ratio in sugarbeet roots.

Tissue	Sodium	Potassium	Sodium / Potassium Ratio
	ppm	ppm	
Central core	170 c*	1187 de	0.14 b
Vascular 1	148 c	1152 de	0.14 b
Vascular 2	143 c	1147 e	0.14 b
Parenchyma 1	442 b	2258 b	0.28 a
Parenchyma 2	391 b	1835 c	0.29 a
Outer rings	107 c	1057 e	0.11 b
Crown pith	634 a	6264 a	0.16 b
Crown vascular	127 c	1480 d	0.10 b
Cultivar			
ACH-14	201 b	1836 c	0.14 b
GW Mono-Hy D2	204 b	2087 ab	0.14 b
Beta 1934	406 a	2256 a	0.23 a
ACH-17 Hy 2B	270 b	2011 bc	0.18 ab
Potassium Fertilizer			
0	356 a	1645 b	0.25 a
200 lb/A	184 b	2450 a	0.09 b

**Means followed by the same letter in a column of main effects are not significantly different at the 0.05% level (Duncan's multiple range test).*

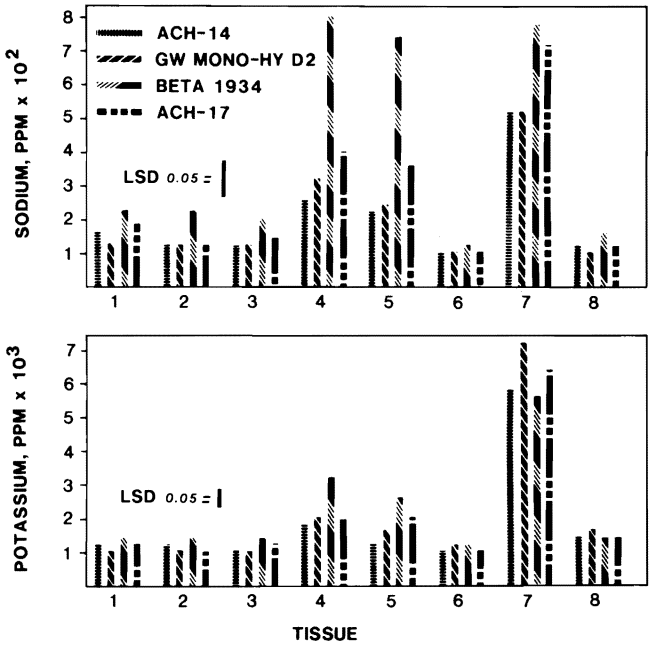
D-2 contained less sodium than Beta 1934 but potassium levels of these two cultivars were similar. Cultivar GW D-2 had more potassium than did ACH-14 but sodium levels were similar. Potassium fertilization increased potassium and reduced sodium levels in the roots (Table 3).

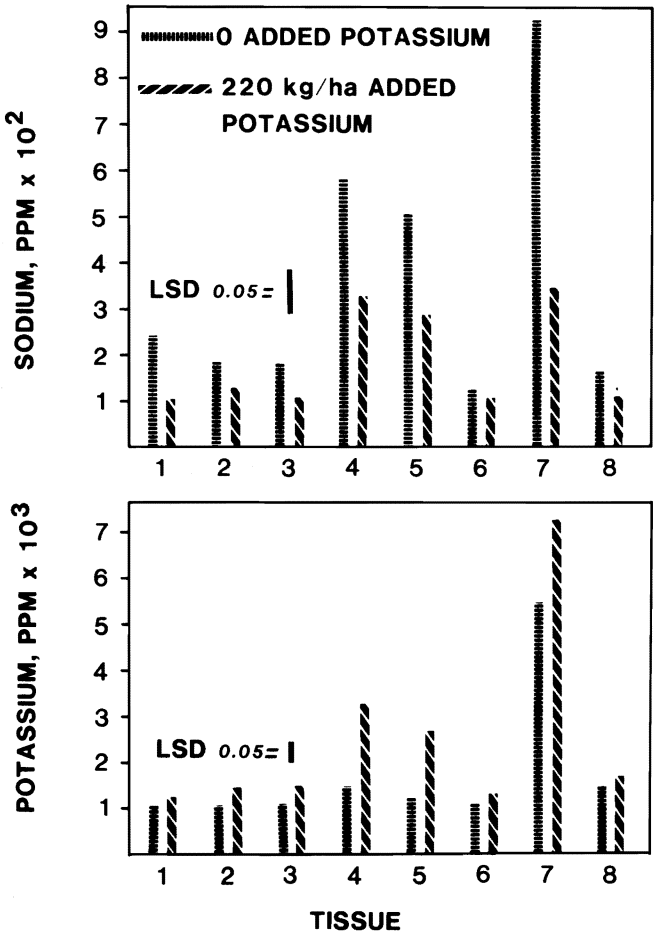
The cultivar by tissue interaction was significant for sodium and potassium (Fig. 1). Also, the tissue by fertilizer interaction was significant for both sodium and potassium (Fig. 2). Sodium contents of each tissue were reduced by the application of 220 kg/ha of potassium. The greatest reduction was noted in the crown pith tissue. Crown pith and parenchyma tissues showed the greatest increase in potassium when 220 kg/ha of potassium was added to the soil.

Fort and Stout (4) reported lower sucrose concentration in the central core, but their diagram indicated that the core included the first band of parenchyma tissue. Such an approach would lower the sucrose content of the core.

Sucrose is influenced by several cultural practices and environmental conditions, e.g., level of nitrogen, planting date, cultivars, row width, and plant populations. However, beets which have a higher proportion of vascular tissue would have a higher sucrose concentration and less impurities.

The data indicate that impurity levels are affected by several parameters and that impurities are located in tissues where sucrose is lowest. Selecting genotypes with an increased amount of vascular tissue in the root and with less pith tissue in the crown should reduce the impurity levels and increase sucrose.





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