Mineral Composition of Sugarbeet Plants as Affected by Varieties and Genotypes[1]

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Haddock and Stuart (3)[3] demonstrated in nutrient culture studies that a specific monogerm sugarbeet variety, SLC 126, can be characterized for high yield and quality by a narrow seasonal range in chemical quality factors. If the wide variety of sugarbeet plants now being grown commercially, and those likely to be developed in the future, could be characterized nutritionally by reference to this same narrow range in chemical composition, rapid progress could be made in adjusting fertilizer practice to obtain high yield and quality of sugarbeets.

Ulrich et al. (8) concluded from a widely distributed geographic study in 1958 that low sugar yields may be more closely related to inadequacies in nutrition than to climatic limitations.

If a wide variation in chemical composition of plant tissue exists among varieties of commercial sugarbeets when grown under the same soil fertility conditions, it may not be possible to establish satisfactory chemical composition reference standards based on one variety which would apply to all other varieties.

Methods and Procedure

In 1966, we planted 48 sugarbeet genotypes on Millville silt loam in a variety testing program. We selected 21 of the widely varying genotypes for chemical study. The source of the genetic material for the 19 four-way sugarbeet hybrids used are shown in Table 1. In addition to the 19 hybrids, which included several with common male and female parents, two current commercial varieties were used as checks.

The Millville silt loam on which these varieties were grown is a deep, well-drained, calcareous soil derived from dolomitic limestone. The profile is relatively uniform in texture to a depth of more than 20 feet. The pH of the soil varies from 7.9 to 8.2 and contains 45 to 70% calcium carbonate equivalent. The average moisture at 1/3-atmosphere tension is 21%, and at 15 atmospheres it is 8.7%. The electrical conductivity (EC $\times$ 10^3

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[3] Numbers in parentheses refer to literature cited.

Table 1.—Lines selected in 1966 variety test I for leaf-petiole and leaf-blade chemical composition study.

Code No.	Description	Comparisons										
		Common ♂ parent			Common ♀ parent				Local sources of lines			
		CT9	129	515	308	3611	OV. 3	00.5	0%	25%	50%	75%
101	1114 Check											
104	(308 × 00.5) × (F.C. 503 × Rf)				X			X	X			
107	(129 × OV.1) × (CT9 × Rf)	X								X		
108	(308 × 00.5) × (CT9 × Rf)	X			X			X				
109	(308 × 129) × (CT9 × Rf)	X			X							X
111	(129 × 3611) × (CT9 × Rf)	X				X					X	
112	(308 × CT5B) × (CT9 × Rf)	X			X							X
113	(128 × OV. 3) × (CT9 × Rf)	X					X					X
114	(AI-1 × OV. 3) × (CT9 × Rf)	X					X				X	
115	(308 × 00.5) × (128 × Rf)				X			X		X		
117	(308 × 3611) × (128 × Rf)				X	X					X	
122	(308 × CT5B) × (129 × Rf)		X		X							X
123	(AI-1 × OV. 3) × (129 × Rf)		X				X				X	
127	(CT9 × OV. 3) × (129 × Rf)		X				X					X
128	(308 × CT9A) × (129 × Rf)		X		X							X
134	(AI-1 × OV. 3) × (C515 × Rf)			X			X			X		
135	(AI-1 × 503) × (C515 × Rf)			X					X			
141	(AI-1 × 3611) × (C515 × Rf)			X		X			X			
144	(308 × 00.5) × (AI-1 × Rf)				X			X				
148	UI Commercial check											
149	TASCO commercial check											

at 25 C) of the saturated extract varies from 0.35 to 0.52 millimhos per cm. The cation exchange capacity is 13.3, with calcium and magnesium constituting 12.4, sodium 0.4 and potassium 0.5 milliequivalents per 100 g of soil. The irrigation water contains 1,10,85 and 240 lb of K, Na, Mg and Ca, respectively, per 24 acre-inches of water. The soil and water environmental conditions are therefore very favorable to the growing of sugarbeets.

The soil was fertilized with 40 lb of nitrogen and 50 lb of P_2O_5 per acre. Beets were planted May 2, 1966, and sprinkled for 6 hours immediately thereafter. The varieties were planted in two-row plots 36 feet long and 22 inches apart. Individual beets were spaced 12 inches apart. Successive sprinkler irrigations were applied May 30, June 8 and at weekly intervals thereafter until harvest. Beets were thinned on June 6 and harvested on October 10. It was cold and dry early, and remained dry throughout the season. No external nutrient deficiencies were observed during the growing season.

Sampling Procedure

Leaf and petiole samples were obtained on August 15 (the period of most rapid growth) in order to have the plants under highest possible stress for nutrient absorption. Eighteen recently mature blades and petioles were selected from each plot, washed in deionized water, dried in a forced draft oven at 70 C and ground in a stainless steel mill to pass a 40-mesh screen.

One gram of finely ground leaf petioles was extracted with 100 ml of 2% acetic acid solution. Sodium was determined on diluted aliquots by flame photometry. Soluble organic-nitrogen plus ammonia-nitrogen was obtained by the micro-kjeldahl method using 20 ml of solution. Nitrate-nitrogen was obtained from the extract by the spot-plate diphenylamine-color method. Total soluble nitrogen is the sum of soluble organic, ammonia and nitrate-nitrogen.

Leaf blades were wet-digested with HNO_3 followed by $HClO_4$ acid after the method of Gerritz (2). Phosphorus was determined by Barton's (1) procedure. Potassium was determined on a diluted aliquot of the above described digest by means of atomic absorption. Kjeldahl nitrogen (excluding nitrate-nitrogen) was obtained on 0.2 g of finely ground (< 40 mesh) plant material by means of micro-kjeldahl digestion distillation and titration procedure.

Sugarbeet pulp samples were dried in a forced-draft oven at 70° C, ground to pass a 40 mesh screen and analyzed for nitrogen,

phosphorus and potassium. Nitrogen was determined on a 0.5 g sample of dried pulp using the micro-kjeldahl procedure. Nitrate-nitrogen was not included in this determination. Phosphorus was determined by Barton's (1) procedure and potassium was determined by atomic absorption techniques from a diluted aliquot from a HNO_3 - $HClO_4$ digest of 2 g of dried pulp.

Experiment Results

Yield of gross sugar is shown (arranged in descending order) in Table 2 for the 21 varieties used in this study. This arrangement is maintained in Table 2 and Figures 1 to 3 which indicate the relation of other composition factors to yield of sugar. The mean value for the two commercial varieties used as checks is indicated by the broken horizontal line in Figures 1 to 3. It will be observed in Table 2 that there are three varieties significantly higher in sugar yield than the commercial check. It will also be noted in Table 2 that yield of gross sugar is closely related to yield of roots. Five of the varieties are significantly

Table 2.—Yield and quality of sugarbeet roots and chemical composition of petioles as influenced by genotypes, 1966.

Treatment No.	Gross sugar lbs/A	Yield roots T/A	Sucrose (percent)	Aug. sampling of petioles PPM	
				Soluble - N	Soluble Na
101	7810	26.01	15.02	8850	6600
117	7764	25.10	15.50	9963	5313
128	7655	26.10	14.68	7088	6638
127	7435	24.93	14.89	6763	5513
115	7359	25.52	14.37	6975	7000
108	7152	26.11	13.66	7413	5888
113	6995	23.76	14.72	6813	5863
114	6978	22.24	15.02	8238	6225
109	6956	23.51	14.82	7738	6875
112	6951	23.13	14.99	8038	6588
123	6883	22.44	15.34	7075	6575
141	6839	21.75	15.74	7650	7675
107	6801	22.98	14.77	7900	6713
122	6800	23.49	14.41	6263	5988
104	6646	23.54	14.16	6338	7213
111	6602	20.59	15.87	5938	7825
148	6598	22.24	14.85	9088	8925
149	6539	21.51	15.16	6450	6550
135	6390	20.53	15.55	6838	6225
134	6382	20.89	15.23	7913	6463
144	6299	22.30	14.12	7000	6663
Mean	6932	23.27	14.91	7444	6534
S.E. of M	334	1.08	0.22	686	530
Sig. @ .05	933	3.00	0.60	1915	1482
C. V.	13.62	13.07	4.10	26.00	13.70
F - Value	1.71	2.74	6.96	2.16	4.48

higher in root yield than the commercial checks, but 14 are not different in yield.

It is evident from the tabular data in Table 2 that there is no positive relation between sucrose percentage and yield of sucrose or yield of roots. There are two varieties significantly different from the commercial checks, numbers 111 higher and 108 lower.

Data shown in Table 2 indicate that nitrogen concentration in petioles in August is not related to yield of gross sugar in October. Two varieties are significantly different from the checks; number 111 is lower in nitrogen and number 117 is higher.

Statistically, the sodium concentration in petioles shown in Table 2 is positively associated with gross sugar yield. (It is difficult to see this relationship from the tabular data in Table 2). Number 117 is the only variety significantly different from the commercial checks in sodium concentration in petioles.

The quantity factor proposed by Haddock and Stuart (3) as optimum for sugarbeet leaf blades is 450. None of the genotypes that we used reached this value. However, one variety, number 104, varied significantly from the commercial checks in this measurement (Figure 1).

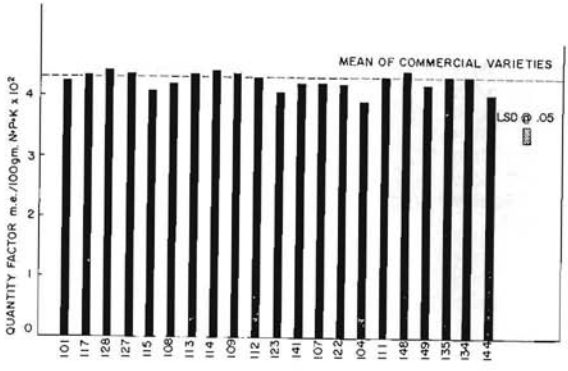

Figure 1.—Quantity factor of sugarbeet blades as influenced by genotypes, 1966.

The optimum nitrogen quality factor for sugarbeet leaf blades is 65. The mean value for the two commercial checks was 71.3. Nevertheless only number 122 was significantly below the checks (Figure 2).

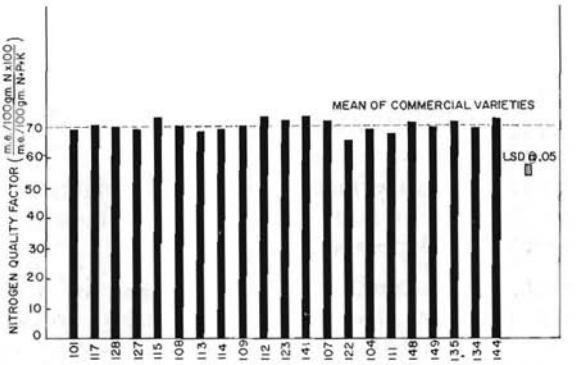

Figure 2.—Nitrogen quality factor of sugarbeet leaf blades as influenced by genetypes, 1966.

The nitrogen quality factor proposed as optimum for sugarbeet pulp is 63.2. This is considerably below the mean shown in Figure 3 for the commercial check sugarbeet roots. Note that three varieties are significantly below the mean for the commercial checks in Figure 3 (i.e., 108, 109 and 122).

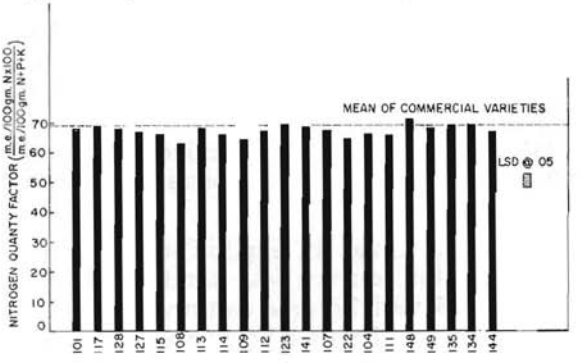

Figure 3.—Nitrogen quality factor for sugarbeet pulp as influenced by genotypes, 1966.

Discussion

We expected to find wide variation in chemical composition among the varieties studied. However, it is obvious (Table 2 and Figures 1 to 3) that variation is small. Roboz (6) stated that the quantity of harmful nitrogen in beet roots varies with the variety. She showed that 50% of a lot of 300 beets were from 50 to 100% higher in harmful nitrogen than the low nitrogen beets. Payne et al. (5) found no difficulty in showing a range of 40% in the sodium and potassium content of thin juice in their study of 20 varieties. Ryser et al. (7) found significant differences among nine genotypes for root composition of amino N, sodium, potassium and for petiole composition of nitrate-nitrogen.

There were significant differences among the 21 genotypes in almost every chemical studied, but these differences were very small for the diversity of genotypes examined. The coefficient of variation is modest for biological field material varying mostly from 5 to 15%.

The quantity-quality factors show less variation than shown for the specific concentration of a particular element; e.g., nitrogen, phosphorus and potassium.

There are, undoubtedly, sources of genetic material which would show a greater divergence of chemical composition than the material used in this study. The 18 four-way hybrids were each made up of diverse genetic material; however, they all had the same pollen restorer inbred parent. All but two entries had an Ovana parent (308, Ov 1 or Ov 3). In addition, several of the hybrids had one or two other parents in common (Table 1). Inbred lines could be produced which would consistently show higher or lower values in specific chemical constituents than the commercial beets used as check plants.

Although the 21 genotypes were quite diverse in genetic origin, they did not show great variability in yield, quality or chemical composition of leaf-blades, roots or petioles. The limited range of genetic material suggests that neither macro- nor micronutrients would be altered markedly by a breeding and selection program. However, other hybrids derived from inbreds with a broader genetic base for chemical constituents may have shown greater variation.

From the limited range of genetic material studied to date there is little basis for concern lest standards of nutritional adequacy used in 1968 will become outmoded by new releases of commercial varieties to be used in 1988. Of greater concern is the danger that sugarbeet growers will fail to use, to their advantage, standards of nutritional adequacy now available to them.

Summary

Twenty-one sugarbeet varieties were grown on the same soil and analyzed for various plant nutrients. Statistically significant differences were obtained among the 21 genotypes for each nutrient element studied. The range in chemical composition, while statistically significant, was relatively small. This suggests that it is feasible to use a standard chemical analysis for critical levels (and more particularly to use quantity-quality factors) in appraising the nutritional status of newly released commercial varieties, without danger of being misguided in the use of fertilizer or soil amendments.

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