Some Chemical and Physiological Characteristics of Inbred Lines of Sugar Beets

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Previous to 1952, sugar beet lines possessing both high sucrose percentage and curly-top resistance had not been fully developed. Selection from a broad self-fertile genetic base at Salt Lake City in 1953 and 1954, followed by progeny tests in 1955 and 1956, resulted in the development of some high-sugar, curly-top-resistant lines. These self-fertile lines were utilized for a study of chemical and physiological characters, with emphasis on nitrogen determinations of petioles and sodium content of roots in relation to sucrose percentage and other quantitative measurements. A statistical study of some of these quantitative measurements was made in the hope of finding better methods of identifying superior genotypes, and extensive correlation coefficients were calculated to determine possible relationships between the different characters.

Materials and Methods

Well drained, highly productive Taylorsville loam (2)[2] soils were chosen for selection and evaluation work in 1954, 1955 and 1956. The fields were located at Granger, Utah. A long-time crop rotation plus regular applications of manure and phosphate fertilizer, maintained a yielding capacity of sugar beets approaching and often exceeding 30 tons per acre on the experimental sites. In spite of this highly productive soil, petiole samples taken at an early harvest date in 1954 showed low nitrate-nitrogen content. One small-scale test employing a late nitrogen fertilizer application was made in 1954 (see Table 2). In 1955 and 1956 liberal applications of nitrogen fertilizer were made over a chosen portion of the replicated plots of each field during the growing season.

The test in 1954 was devoted to a collection of inbred lines of sugar beets for preliminary selection work. Some lines were grown only in single plots while others appeared in a second replication. An early harvest, September 21, was made of approximately twenty individual beets from each of the inbred lines. Fifteen measurements were made or calculated on each beet in each line. Petiole samples from five recently matured leaves per beet (9) were taken at harvest. For the small-scale

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[2] Numbers in parentheses refer to literature cited.

test with the heavy late nitrogen application, variety 342.400, representing the broad, self-fertile genetic base, was utilized, and individual beets were harvested and petiole samples taken November 2.

In 1955 five inbred lines were selected for further study of differences from the standpoint of sucrose percentage, amino N and sodium content. These varieties were planted in randomized blocks with 40 ft. plots at two levels of fertility, normal and high, with three replications at each level. The high-fertility level was obtained by adding two applications of ammonium nitrate at the approximate rate of 120 pounds of nitrogen per acre July 20 and again on August 27. A composite sample of ten roots was taken from each plot October 3 and another sample on November 4. Five additional individual beets, selected for uniformity of size and shape, were taken from each plot November 4. Petiole samples were taken from each selected plant for nitrate-nitrogen analysis.

In the 1956 test there were two nitrogen levels with six varieties replicated three times in 4-row plots. The high-fertility level received two supplemental applications of ammonium nitrate; one at the rate of 75 pounds nitrogen per acre on June 20, the other at the rate of 90 pounds nitrogen per acre on July 26. Two hundred pounds per acre of 24-20-0 fertilizer were applied to all plots before planting. Twenty consecutive beets were taken from the row with the best competitive stand in each 4-row plot. The early harvest date, September 24, was chosen in order to obtain a higher nitrate-nitrogen content in the petioles.

The lines tested in 1955 and 1956 resulted from the intensive selection work done in 1954, except for the commercial variety US 41 used as a check in 1956. The list of varieties was as follows:

US 41	Intermediate sugar-type commercial variety
Line 163	Low-sugar type
Line 163A	Higher in sugar than line 163
SLC 117	A monogerm inbred, intermediate-sugar type
CT9	Yield type with proven combining ability (3)
CT5	Intermediate-sugar type
CT5 subline	Similar to CT5 but more uniform
CT8	High-sugar type
CT7	Low-sodium, high-sugar type

Petiole nitrate-nitrogen analyses were made on dried samples at the University of California, Berkeley, California, by methods previously described (9). Other chemical analyses were made at the US Department of Agriculture field laboratory in Salt

Lake City, Utah, by methods also described (7). Amino N in the beet, as glutamine, was determined on clear filtrate (26 grams pulp digested in 177 ml. H_2O and 0.7 grams Hornes dry lead), by the Stanek-Pavlas method using the spectrophotometer as the absorption instrument. Na and K in the beet were determined on part of same filtrate by use of the flame spectrophotometer. Respiration measurement is reported in milligrams (mg.) of CO_2 per kilogram (kg) (fresh weight) per hour using a fresh 10-gram cylindrical beet root section. Total nitrogen in each dried petiole sample was determined by the Kjeldahl method. Percent purity as reported is the ratio of sucrose to total soluble solids, often referred to as apparent purity. Percentage of total soluble solids was determined with a dipping-type refractometer. Percent sucrose was obtained by direct polarization of clear filtrate.

All information was punched on IBM cards (5). The cards were punched locally and sent to the Computing Laboratory, Biometrics Services, Agricultural Research Center, Beltsville, Maryland, where means, standard deviations, and correlation coefficients were calculated by machine processing. Variance analyses and coefficients of variability were completed by hand calculation.

Experimental Results

Means of Quantitative Measurements

Yearly means of all measurements for 1954, 1955, and 1956 are shown in Table 1. The data in Table 1 for the year 1954 are those obtained at the early harvest date, September 21,

Table 1.—Yearly Means, All Measurements, with Varieties and Fertility Levels Combined.

Code	Measurement	Year 1954	1955	1956
1.	Beet weight in grams	1150	1480	1310
2.	Percent sucrose	14.6	17.1	14.2
3.	Amino N in beets, p.p.m.	3600	3700	7600
4.	Na in beets, p.p.m.	275	270	230
5.	Respiration rate CO_2/kg/hr (mg)	112		
6.	K in beets, p.p.m.	3060	2630	3110
7.	Sugar content, grams (beet wt. × percent sucrose)	165	252	182
8.	Percent solids		19.2	16.6
9.	Nitrate-nitrogen in petiole, p.p.m.	520	865	4084
10.	Percent purity		89.1	85.0
10A.	Top weight, grams (1954)	743		
11.	Number of leaves (based on weight of 5 leaves)	43		
12.	Ratio of petiole to top weight	51.7		
12A.	Total N in petiole, p.p.m.		13,800	
13.	Length of petiole, cm.	22.7		
14.	Space code (rated 1 to 9)	2.2		
	Number of observations (individual beets)	530	150	720

on normal-fertility plots. The nitrate-nitrogen in the petioles was only 520 p.p.m. which is considered rather low for an early harvest date.

Table 2.—Effect of Heavy Late Application of Nitrogen on Sugar Beet Analyses, 1954.

Fertility Level	Number Beets	Root Analyses						Petiole Analyses
		Beet Weight	Sucrose	Amino N	Na	K	Purity	NO_3-N
		Lbs.	Percent	PPM	PPM	PPM	Percent	PPM
Heavy Nitrogen[1]	20	3.15	14.98	5600	427	3318	84.6	4539
Normal	20	3.21	17.72	2300	197	2369	89.8	185

[1] Nitrogen applied August 27, 300 lbs. per acre of ammonium sulphate, and September 10, 300 lbs. per acre of ammonium nitrate, harvested November 4, 1954.

Table 2 shows spectacular effects from a late, heavy application of nitrogen in 1954 with the beets harvested November 2. The sucrose dropped from 17.72 percent on the normal-fertility level to 14.98 percent on the high-fertility level, with a corresponding drop from 89.8 to 84.6 in percent purity. The late, heavy application of nitrogen resulted in high increases of amino N, Na, and K in the beet roots and a tremendous increase in nitrate-nitrogen in the petioles, from 185 p.p.m. on normal fertility to 4539 p.p.m. on the high-fertility level. Beets grown at normal fertility also decreased in petiole nitrate from 520 p.p.m. on September 21 to 185 p.p.m. on November 2.

Table 3 gives the means of varieties for 1955 and 1956. In both years line CT7 proved to be different from other lines because of its low Na (Figure 1) and K content in the root, a surprisingly low nitrate-nitrogen content in the petioles, but high amino nitrogen in the roots (Figure 2) and high total nitrogen in the petioles.

The 1955 data shown in Table 4 are from individual beets. Data from ten-beet composite samples taken from the same plots in 1955 are shown in Table 5. Here the striking effect of harvest date and fertility level are easily seen. The lowest sucrose was obtained at the early harvest, October 3, with high nitrogen fertilization. The highest sucrose was obtained at the late harvest, November 4, with normal fertility. The striking behavior of CT7 with low Na but high amino N content is again illustrated.

Table 3.—Variety Means.

Variety	No. Beets	Root Analyses								Petiole Analyses	
		Beet Weight	Sucrose	Amino N	Na	K	Sugar Content	Solids	Purity	NO_3-N	Total N
		Grams	Percent	PPM	PPM	PPM	Grams	Percent	Percent	PPM	PPM
1955 Test											
Line 163A	30	1650	17.0	2600	410	3020	278	18.9	89.5	1130	12300
CT9	30	1420	16.7	3600	310	2690	238	18.7	89.3	740	13300
SLC 117 mm	30	1670	17.1	3100	290	2480	282	19.1	89.7	870	12600
CT8	30	1490	18.0	3000	220	2530	266	20.0	89.8	1070	14700
CT7	30	1150	16.9	6200	110	2450	194	19.3	87.2	520	16000
MEAN, all varieties	150	1480	17.1	3700	270	2630	252	19.2	89.1	870	13800
LSD 5% point		250	0.72	1220	81	243	38	0.72	1.33	NS	1330
1956 Test											
US 41	120	1390	13.1	7700	480	3800	181	15.7	83.1	6075	
Line 163	120	1580	12.0	10700	200	3700	189	14.7	81.4	4949	
CT5	120	1280	14.7	6400	250	2860	186	17.0	86.2	4185	
CT5 subline	120	1250	14.4	6100	150	2970	179	16.6	86.7	4170	
CT8	120	1270	15.8	5700	200	2810	197	18.1	87.2	3218	
CT7	120	1080	15.1	9100	103	2520	161	17.6	85.7	1934	
MEAN, all varieties	720	1310	14.2	7600	230	3110	182	16.6	85.0	4084	
LSD 5% point		210	0.80	1660	68	255	NS	0.80	1.91	1227	

Table 4.—Effect of Fertility Level, 1955.

			Root Analyses								Petiole Analyses	
Variety	Fertility	No. Beets	Beet Weight	Sucrose	Amino N	Na	K	Sugar Content	Solids	Purity	NO_3-N	Total N
			Grams	Percent	PPM	PPM	PPM	Grams	Percent	Percent	PPM	PPM
			Mean for variety at each fertility level									
Line 163A	Normal	15	1630	17.9	2200	280	2800	291	19.9	90.3	660	11400
	High	15	1670	16.0	3000	540	3230	265	18.0	88.8	1610	13100
CT9	Normal	15	1500	17.3	2900	280	2710	257	19.2	90.1	400	12300
	High	15	1350	16.2	4200	340	2680	218	18.3	88.5	1070	14300
SLC 117 mm	Normal	15	1820	17.6	2500	230	2380	313	19.3	90.8	490	11500
	High	15	1520	16.6	3700	340	2570	251	18.8	88.6	1240	13700
CT8	Normal	15	1440	18.4	2600	160	2370	263	20.3	90.5	390	13300
	High	15	1540	17.6	3300	280	2690	268	19.7	89.1	1750	16100
CT7	Normal	15	1200	17.2	5200	100	2270	206	19.5	88.4	350	14800
	High	15	1110	16.5	7100	120	2630	183	19.2	86.1	690	17100
			Mean for all varieties at each fertility level									
	Normal	75	1520	17.7	3100	210	2500	266	19.6	90.0	460	12700
	High	75	1440	16.6	4300	320	2760	237	18.8	88.2	1270	14900
	Difference		—80	—0.9[2]	1200[2]	90[2]	260[2]	—29[2]	—0.8[2]	—1.8[2]	810[2]	2200[2]

[2] Significant at 1% level

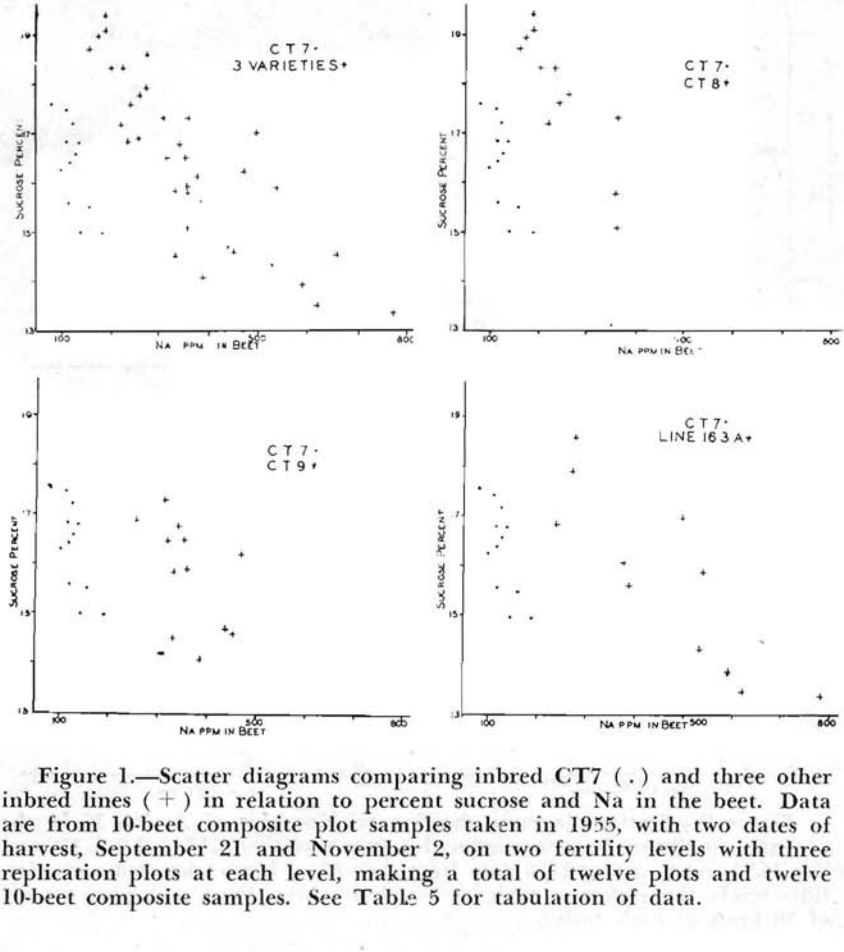

Figure 1.—Scatter diagrams comparing inbred CT7 (.) and three other inbred lines (+) in relation to percent sucrose and Na in the beet. Data are from 10-beet composite plot samples taken in 1955, with two dates of harvest, September 21 and November 2, on two fertility levels with three replication plots at each level, making a total of twelve plots and twelve 10-beet composite samples. See Table 5 for tabulation of data.

The same 1955 data for sucrose percentage and Na content shown in Table 5 are illustrated by scatter diagrams in Figure 1. In these scatter diagrams the positions for CT7 are so different from those of the other varieties that there is no overlapping. CT7 occupies a unique position in all comparisons.

Table 4 shows means for fertility levels and varieties for 1955. The mean nitrate-nitrogen in the petioles was 460 p.p.m. at the normal fertility level, and 1270 p.p.m. at the high fertility level. The difference between fertility levels was not so great in 1956 (Table 6); the normal fertility averaged 3622 p.p.m. and the high fertility 4545 p.p.m. The higher nitrate-nitrogen in petioles in 1956 was due to the earlier date of harvest, September 24, as compared with the late date of harvest, November 4, in 1955.

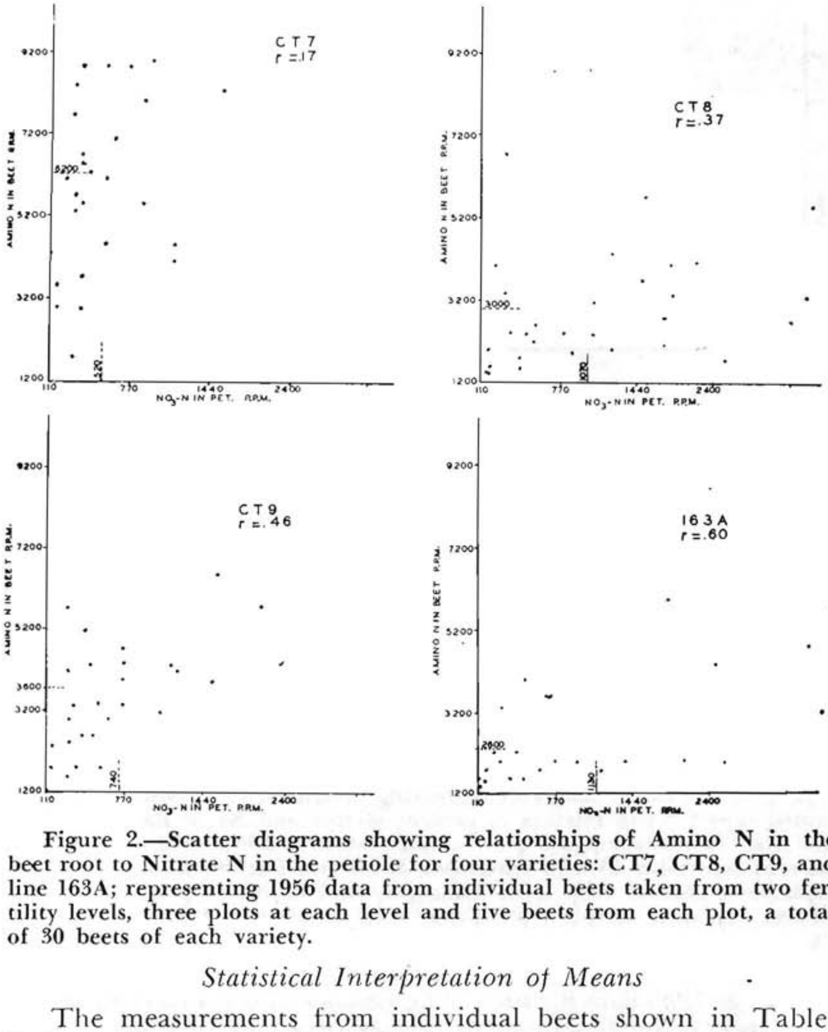

Figure 2.—Scatter diagrams showing relationships of Amino N in the beet root to Nitrate N in the petiole for four varieties: CT7, CT8, CT9, and line 163A; representing 1956 data from individual beets taken from two fertility levels, three plots at each level and five beets from each plot, a total of 30 beets of each variety.

Statistical Interpretation of Means

The measurements from individual beets shown in Tables 3, 4, and 6, were subjected to variance analysis and the statistical interpretation is presented in Table 7 for 1955 and 1956 data. The variance ratios, or calculated F values in terms of errors variance, show highly significant differences due to varieties. In interpreting these results one should bear in mind that the varieties were selected principally for differences in sucrose content. Sodium content was also considered to some extent. The varieties were not selected for the other chemical constituents; yet, for the most part, highly significant differences were obtained between varieties for all chemical constituents.

In 1956 (Table 7), there were highly significant differences due to varieties for all measurements, including petiole nitrate analyses. In 1955 the results were much the same but with a less pronounced effect of variety on petiole nitrate-nitrogen. The decided decreases in sucrose at the high-fertility levels (Tables 4 and 6) are shown to be highly significant by the variance ratios (Table 7). The influence of fertility level on most other chemical analyses was also highly significant.

Table 5.—Means from 10-beet Composite Samples in 1955 with Three Replicated Plots at Each Fertility Level.

Variety	Weight	Sucrose	Purity	Amino N	Na	K
	Lbs.	Percent	Percent	PPM	PPM	PPM
			Oct. 3 harvest—High N			
Line 163A	29.2	13.6	87.5	3400	660	3850
CT9	28.9	14.6	87.6	4600	410	3400
CT8	20.1	16.0	88.9	4100	310	3240
CT7	21.5	15.2	84.9	7400	150	2970
Avg.		14.8	87.2	4875	384	3365
			Oct. 3 harvest—Normal fertility			
Line 163A	29.2	15.3	90.3	2100	430	3500
CT9	23.3	15.1	88.6	2500	380	3120
CT8	18.0	18.1	92.8	1600	230	2610
CT7	19.3	16.4	90.0	5000	130	2850
Avg.		16.2	90.4	2800	292	3020
			Nov. 4 harvest—High N			
Line 163A	21.8	15.7	82.8	5300	480	3710
CT9	22.8	16.2	85.9	4400	380	2790
CT8	20.5	18.1	87.0	3500	250	2540
CT7	18.8	16.6	83.9	7800	120	2560
Avg.		16.6	84.9	5250	307	2900
			Nov. 4 harvest—Normal fertility			
Line 163A	25.7	17.8	87.3	2500	350	2860
CT9	24.5	17.0	87.5	3100	300	2850
CT8	20.7	18.9	87.4	1900	190	2300
CT7	21.3	17.3	84.8	5800	100	2300
Avg.		17.8	86.8	3325	235	2578

In general the differences due to fertility level were larger in 1955 than in 1956. This is accounted for by the fact that the fertility gradients were more distinct in 1955. Unfortunately in 1956 there were differences in degree of fertility among the different plots on the normal fertility level. Fertility level had a distinct effect on the content of nitrate-nitrogen in the petioles in 1956, but the F value of 8.52, due to fertility level, was lower than the F value of 13.50, due to variety. Significant differences in beet weight due to fertility level were not obtained in either year. This was due to the fact that the nitrate-nitrogen was above the critical level (1000 p.p.m.) and so would not affect growth differentially (10). However, significant reductions in sucrose percentage do occur at nitrate concentrations higher than the critical level affecting beet weight.

Table 6.—Effect of Fertility Level, 1956.

Variety	Fertility	No. Beets	Root Analyses: Beet Weight	Sucrose	Amino N	Na	K	Sugar Content	Solids	Purity	Petiole Analyses: NO_3-N
			Grams	Percent	PPM	PPM	PPM	Grams	Percent	Percent	PPM
					Mean for variety at each fertility level						
US 41	Normal	60	1380	13.1	6800	360	3620	181	15.9	82.5	5887
	High	60	1400	13.0	8600	410	3980	182	15.5	83.7	6277
Line 163	Normal	60	1590	12.4	11600	210	3590	196	15.5	80.1	5022
	High	60	1570	11.6	9800	180	3810	182	14.0	82.8	4863
CT5	Normal	60	1200	14.9	5500	260	2680	177	17.3	85.9	3463
	High	60	1350	14.4	7200	240	3040	194	16.7	86.5	4921
CT5 subline	Normal	60	1130	14.8	5100	140	2780	166	17.0	86.8	3463
	High	60	1380	14.0	7000	170	3160	193	16.2	86.6	4877
CT8	Normal	60	1240	16.3	5100	210	2640	200	18.8	86.6	2323
	High	60	1290	15.3	6200	190	2990	194	17.4	87.8	4113
CT7	Normal	60	1090	15.4	8900	110	2440	167	18.2	84.3	1616
	High	60	1060	14.7	9300	100	2600	155	17.0	87.0	2251
					Mean for all varieties at each fertility level						
Average	Normal	360	1270	14.5	7200	250	2960	181	17.1	84.4	3622
	High	360	1340	13.8	8000	220	3260	183	16.1	85.7	4545
	Difference		70	—0.7[2]	800	-30	300[2]	2	—1.0[2]	-0.7[1]	923[2]

[1] Significant at 5% level
[2] Significant at 1% level

Table 7.—F Values from Variance Analyses.

Variable	Degrees of Freedom	Root Analyses: Beet Weight	Root Analyses: Sucrose	Root Analyses: Amino N	Root Analyses: Na	Root Analyses: K	Root Analyses: Sugar content	Root Analyses: Solids	Root Analyses: Purity	Petiole Analyses: NO_3-N	Petiole Analyses: Total N
Calculated F values, 1955											
Fertility	1	1.06	25.96[2]	10.41[2]	21.66[1]	11.85[2]	6.60[1]	15.14[2]	19.19[2]	26.63[2]	28.69[2]
Varieties	4	6.09[2]	4.12[2]	12.08[2]	16.73[2]	8.15[2]	8.32[2]	4.23[1]	5.37[2]	2.01	12.02[2]
Varieties × Fertility	4	.91	1.05	.33	2.72	1.15	0.99	1.53	0.21	1.14	0.27
Calculated F values, 1956											
Fertility	1	1.37	8.04[2]	3.10	2.94	18.31[2]	0.11	21.03[2]	6.51[1]	8.52[2]	
Varieties	5	5.48[2]	25.96[2]	12.70[2]	32.78[2]	35.48[2]	2.42	22.03[2]	12.15[2]	13.50[2]	
Varieties × Fertility	5	5.54[2]	0.27	1.52	1.63	0.28	1.12	0.71	0.72	0.94	

[1] Significant at 5% level
[2] Significant at 1% level

The F value (Table 7) measuring the interaction between variety and fertility level, with the exception of beet weight in 1956, shows no evidence of significance. No significant interaction with sucrose percentage is indicated. However, Table 4 indicates that the sucrose percentage of the higher sugar lines CT8 and CT7 may have been less affected by fertility level than the other varieties in 1955. Here (Table 4) the reductions in sucrose percentages at the high versus the normal fertility levels were: For CT8, 0.8; for CT7, 0.7; for CT9, 1.1; for SLC 117, 1.0; for 163A, 1.9. These figures indicate a tendency for an interaction between fertility level and variety, but the differences were not great enough for statistical significance.

Coefficients of Variability

Table 8 shows that the greatest variability was in measurements of weight, amino N, Na, sugar content and nitrate-nitrogen in the petiole. Variability was decidedly lower for percent sucrose, percent solids, and purity. The coefficients of variability at each fertility level were roughly the same for most measurements except for nitrate-nitrogen in the petioles. The variability of petiole nitrate was greater on normal fertility because the nitrogen was near the deficiency level. Some individual plants were deficient while others were not.

Correlations with Petiole Nitrate

Table 9 shows r values obtained in 1955 by variety and in 1956 by variety and fertility level correlating nitrate-nitrogen in the petioles with eight different root measurements. In 1955 petiole nitrate correlations with root analyses for amino N, Na, and K varied considerably according to variety. Line CT7 with high amino N and low Na and K, which in previous tables was shown to be different from other lines in actual values, also appears to have given somewhat different correlation values. The three correlations with petiole nitrate, 0.17 for amino N (Figure 2), 0.28 for Na, and 0.06 for K, are low positive values but not statistically significant. The corresponding correlations with some of the other varieties are highly significant in the positive direction. In 1956 (Table 9) the results with CT7, correlating nitrate-nitrogen in the petiole with amino N in the root, show a statistically significant negative r value, whereas a positive r value was expected based on results with other varieties.

Correlations with Sodium

Correlations between Na content and other quantitative measurements are shown in Table 10 for 1955 and 1956. Na is correlated negatively with percent sucrose (Figure 1), solids,

Table 8.—Coefficients of Variability[1].

Variety	No. Beets	Root Analyses: Beet Weight	Sucrose	Amino N	Na	K	Sugar Content	Solids	Purity	Petiole Analyses: NO_3-N	Total N
1955											
Line 163A	30	26.6	8.4	56.1	59.0	15.8	26.0	8.0	2.0	40.5	19.2
CT9	30	21.0	6.0	39.2	23.5	11.0	20.9	5.0	1.8	94.6	12.8
SLC 117 mm	30	31.7	7.0	31.9	36.6	17.6	30.0	6.5	2.1	94.8	19.3
CT8	30	25.5	5.0	44.3	39.1	15.4	22.9	4.4	1.7	79.9	14.0
CT7	30	18.7	5.6	36.3	26.4	16.4	18.5	4.4	2.5	66.9	15.3
Normal	75	29.8	5.5	21.1	46.5	16.2	27.9	4.9	1.8	105.6	17.0
High	75	27.7	6.7	32.4	60.6	16.7	26.6	8.2	1.8	70.3	17.6
All plots combined	150	22.0	6.8	33.8	61.0	17.1	27.8	6.1	2.25	94.7	18.9
1956											
US 41	120	37.2	13.5	41.4	63.5	14.7	38.6	10.5	4.8	19.5	
Line 163	120	33.6	13.5	40.9	45.5	13.9	35.3	11.6	5.7	9.0	
CT5	120	30.4	7.5	31.1	38.4	18.2	29.8	6.6	3.4	21.3	
CT5 subline	120	31.9	9.1	30.6	40.0	16.3	31.2	7.8	4.3	28.7	
CT8	120	35.6	8.6	43.3	39.0	22.7	33.1	7.5	3.8	28.5	
CT7	120	29.6	5.6	26.5	33.0	13.7	28.4	6.1	2.8	73.5	
Normal	360	36.9	13.1	54.7	88.4	22.7	33.9	10.2	4.8	64.5	
High	360	34.3	12.8	32.7	64.6	21.3	33.3	10.5	4.8	47.1	
All plots combined	720	35.5	13.1	44.3	81.2	22.5	33.5	10.8	4.9	56.1	

[1] Based on the standard deviation for numbers of beets shown.

Table 9.—Correlations, By Variety, Obtained Between Nitrate-Nitrogen In Petiole and Other Quantitative Characters.

Variety	Fertility Level	No. Beets	Nitrate-Nitrogen in Petiole Correlated with: Beet Weight	Percent Sucrose	Amino N	Na	K	Sugar Content	Percent Solids	Purity	Total N in Petiole
			1955 *r* values								
Line 163A	Combined	30	-.26	-.32	.69[2]	.37[1]	.16	.35[1]	-.21	-.50[1]	.72[2]
CT9	Combined	30	-.02	-.23	.46[2]	.01	-.21	-.09	-.16	-.31	.44[1]
SLC 117 mm	Combined	30	-.06	-.32	.09	.44[1]	.10	-.13	-.26	-.27	.73[2]
CT8	Combined	50	.02	-.39[1]	.37	.63[2]	.37[1]	.11	-.20	-.65[2]	.76[2]
CT7	Combined	30	.19	-.40[1]	.17	.28	.06	.30	-.35[1]	.30	.45[1]
			1956 *r* values								
US 41	Normal	60	.22	-.78[2]	.28[1]	.54[2]	.29[1]	.47[2]	.75[2]	.67[2]	
	High	60	-.06	-.18	.11	.11	-.05	-.11	-.23	.04	
Line 163	Normal	60	.23	-.23	.07	.29	.35[1]	.18	-.08	-.29	
	High	60	.07	.10	.04	.09	.27[1]	.10	.14	0	
CT5	Normal	60	-.01	-.33[1]	.16	.28	.36[1]	.07	-.34	-.17	
	High	60	.18	.09	.17	-.16	.05	-.15	.21	-.17	
CT5 subline	Normal	60	.36[2]	-.70[2]	.54[2]	.32[1]	.69[2]	.20	-.71[2]	-.32[1]	
	High	60	-.02	-.20	.09	.54	.15	.06	-.21	.03	
CT8	Normal	60	.09	-.35[1]	.34[1]	.03	.36[1]	.22	-.30[1]	-.29[1]	
	High	60	.20	-.45[2]	.25[1]	.17	.25[1]	.10	-.42[2]	-.21	
CT7	Normal	60	-.06	-.48[2]	-.25[1]	.42[2]	.26[1]	-.16	-.53[2]	.02	
	High	60	-.10	-.44[2]	-.01	.47	.26[1]	-.16	-.52[2]	.04	

[1] Significant at 5% level

[2] Significant at 1% level

and purity. Most of these strong negative correlations are very highly significant. Na is correlated positively with K content and in general with amino N, also with nitrate-nitrogen in the petioles and with total nitrogen in the petioles.

Discussion

The most striking evidence from the three years' work reported is that each inbred line of sugar beets may have its own peculiar chemical and physiological characteristics. These peculiar characteristics are shown by the correlation relationships. Two measurements correlated in one way for one inbred line may be correlated in quite another way with another inbred (8) (Figures 1 and 2).

The strong negative correlation between Na content and sucrose percentage reported by Doxtator (1) was well confirmed. In connection with this correlation it was interesting to note that Na content was strongly affected by both variety and nitrogen fertility level. In 1954 a late heavy application of nitrogen (Table 2) more than doubled the Na content in the beet roots. The effect of variety was equally striking. Variety CT7 (Tables 3, 4, 5, and 6) was extremely low in Na in the root. Nearly four times as much Na was taken up by certain other varieties. Early in the work, before the relationship between Na and sugar percentage was as well understood as it is now, some consideration was given to Na as a direct means of selection. It is likely that selection of low Na individuals in a heterogeneous beet population would result at the same time in higher sucrose percentage types. At first one gained the impression that all the higher sugar lines were low Na lines. However, after three years of experience it became clear that no fast rules could be followed. CT8 consistently produced a higher sugar percentage than CT7 but the Na content for CT8 was nearly twice as great as that for CT7 (Tables 3, 4, 5, and 6). It would; therefore, be very unwise to depend upon low Na as a true index of high-sucrose genotypes.

To a certain extent the picture is the same for some of the other chemical analyses. Nitrate-nitrogen in the petioles, although very strongly associated with the nitrogen level of the soil, was also influenced by variety. Under similar environments less than half as much nitrate-nitrogen was found in the petioles of CT7 as in some of the other varieties. The nitrate content in the petioles of the high-sugar line CT8 was nearly twice as high as that for CT7 (Tables 3, 4, and 6).

The exceptional characteristics of CT7 may lead to interesting assumptions regarding underlying physiological relationships. The low nitrate-nitrogen but high total nitrogen in the

Table 10.—Correlations by Variety Obtained Between Na in Beet and Other Quantitative Characters.

Variety	Fertility Level	No. Beets	Na in the Beet Correlated With: Beet Weight	Percent Sucrose	Amino N	K	Sugar Content	Percent Solids	Percent Purity	NO_3-N Petiole	Total N in Petiole
			1955 *r* values								
Line 163A	Combined	30	.10	—.78[2]	—.05	.54[2]	—.15	—.80[2]	—.10	.37[1]	.10
CT9	Combined	30	.24	—.64[2]	.08	.29	.06	—.66[2]	—.27	.04	.18
SLC 117 mm	Combined	30	.33	—.69[2]	.41[1]	.62[2]	.21	—.58[2]	—.51[2]	.44[1]	.48[2]
CT8	Combined	30	.02	—.46[2]	—.18	.54[2]	—.08	—.40[1]	—.31	.63[2]	.54[2]
CT7	Combined	30	.04	—.25	—.12	.06	—.03	—.31	—.02	.28	.24
			1956 *r* values								
US 41	Normal	60	.10	—.76[2]	—.09	.25[1]	—.21	—.18[2]	—.59[2]	.54[2]	
	High	60	.04	—.55[2]	.19	.21	—.11	—.54[2]	—.39[2]	.11	
Line 163	Normal	60	.00	—.57[2]	.10	.27[1]	—.16	—.33[1]	—.58[2]	.29	
	High	60	—.01	—.74[2]	.20	.36[2]	—.32[1]	—.72[2]	—.57[2]	.09	
CT5	Normal	60	.14	—.66[2]	.26[1]	.45[2]	—.01	—.63[2]	—.49[2]	.28	
	High	60	.08	—.68[2]	.12	.39[2]	—.11	—.62[2]	—.17	—.16	
CT5 subline	Normal	60	.17	—.62[2]	.32[1]	.54[2]	.01	—.55[2]	—.49[2]	.32[1]	
	High	60	.13	—.60[2]	.13	.60[2]	—.04	—.40[2]	—.38[2]	.54	
CT8	Normal	60	—.06	—.42[2]	.18	.32[1]	—.15	—.40[2]	—.32[1]	.03	
	High	60	—.04	—.17	.00	.06	—.06	—.20	.00	.17	
CT7	Normal	60	.18	—.44[2]	—.12	.17	.10	—.41[2]	—.17	.42[2]	
	High	60	.16	—.47[2]	—.08	.26[1]	.10	—.41[2]	—.12	.47[2]	

[1] Significant at 5% level
[2] Significant at 1% level

petioles of CT7, and high amino nitrogen in the roots indicate that this line may be able to metabolize nitrate more rapidly than the other varieties. These special characteristics of CT7 may be interpreted as a precaution also against too much generalization concerning correlation values, without considering each variety separately. When one line behaves differently from other lines in the association of chemical and physiological characteristics correction values may be a distinguishing feature of the line.

The variance ratios expressed as F values in Table 7 give strong evidence that the varieties investigated reacted more or less the same at both normal and high fertility. Coefficients of variability (Table 8) were also relatively independent of fertility level except for petiole nitrate.

The r values were not large for petiole nitrate-nitrogen correlated with amino N, Na, K, and purity; however, some of these relatively low r values were statistically significant. Some of the low values could be due to curvilinear relationships instead of straight-line relationships (10). A curvilinear relationship may be more applicable for petiole nitrate correlations with beet weight, K in beet and sugar content, etc., where few significant r values were obtained. Stronger r values might be obtained if multiple or partial correlations were calculated.

The expense and time required for progeny tests make the breeder very conscious of doing everything he can to make the greatest gains possible in his initial selection work. Powers (4) has illustrated this point and has developed statistical methods which help separate genetic from environmental variability. With more information on the association between chemical and physiological characteristics, it may be possible that correlation values could be arrived at which may help the breeder.

Petiole nitrate measurements would undoubtedly be more valuable if one could make analyses at different specific times during the growing season. The final date when the beet is harvested and selected is perhaps the least desirable date for taking the petiole samples. Petiole nitrate taken some time before harvest may give a much better index of available nitrogen to each individual beet (10).

A comparison of harvest dates in 1955 illustrates a physiological problem quite independent of variety. Table 5 shows that the sugars from the late harvest were higher than from the early harvest while the purities were lower. This is contrary to what one may expect. This unexpected decrease in purity is not accounted for by an increase in Na and K but may be partly accounted for by an increase in Amino N.

The present information shows that there are distinct differences between different lines in sodium, potassium, and amino nitrogen, as well as the other usually measured constitutents. Percentage raffinose (11) has been shown to be a heritable character. High respiration rate of beet root tissues is another undesirable character because of the greater storage loss from such beets (6). Unpublished studies have shown that respiration rate is also a heritable character. Little information is available at present on the individual effects of some of the other constituents on processing quality, although impurities in processing liquors have increased in recent years. More information is needed regarding the relative importance of these impurities. It seems quite certain that plant breeding can result in considerable alteration in these factors. However, an overall economic evaluation must be made because breeding for a reduction in some impurities may reduce the acre yield of roots.

Summary

Inbred lines of sugar beets were shown to have their own peculiar chemical and physiological characteristics. In general there was a high negative correlation between sucrose percentage and Na content of the root but there were striking genotypic differences. Inbred CT7 from root analyses was relatively high in sucrose, extremely low in Na, and high in amino N. In petiole analyses CT7 was low in nitrate-nitrogen but high in total N. Inbred CT8 was higher in sucrose than CT7 but contained nearly twice as much Na in the root and nearly twice as much nitrate-nitrogen in the petiole. On the basis of the nitrogen relationships some physiological explanations are attempted to account for the genotypic differences.

Measurements of nitrate-nitrogen in the petioles, amino N in the roots, and Na content in the roots were greatly influenced by high nitrogen fertilization, but for these same measurements varietal differences were just as striking. In Na content, a four- or five-fold difference between low Na types and high Na types was not uncommon. In general sucrose percentage was less variable than some of the other measurements and was influenced more by nitrogen fertilization than by variety, although there were also very significant varietal differences.

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