

# Chemical Constituents of Five Varieties Grown in Six Midwestern Factory Areas

C. W. DOXTATOR AND H. M. BAUSERMAN<sup>1</sup>

Improvement of the sugar beet in the past has been confined largely to selection of types high in yield, sucrose percent and disease resistance. The importance of juice purity has long been known, and it is the main factor controlling the amount of sucrose which can be extracted from the beet. However, it is only within the last decade in this country that much attention has been given to varietal differences in purity of juice. It is only recently that the non-sugar elements in beet juices have been studied for the purpose of making varietal improvements.

Dahlberg (1)<sup>2</sup> reported on selection for high purity in 1942 in which some reference was made to non-sugar elements. In 1950 Doxtator and Calton (3) reported on variety differences with respect to sodium and potassium. That same year Dahlberg (2) reported on many non-sugar elements in cossette samples obtained from sugar factories scattered over a wide geographic area. A study of that article by the authors of this paper resulted in plans being made to study varietal differences, not only of many of the non-sugar elements but beet yields as well, in several factory areas of the American Crystal Sugar Company.

This paper presents results obtained in 1951 on five varieties tested in six replications of plots at six factory locations for the following characteristics: yield of beets and sugar per acre, and percentage of sucrose, sodium, potassium, magnesium, calcium, chlorine, ash, sulphate, total nitrogen and purity of juice.

## Materials and Methods

Five varieties were used in this experiment as follows: 6-419-X, a natural hybrid of American No. 1 and curly-top-resistant types; 8-601-0, a leaf-spot-resistant elite stock; 9-604-0, an *Aphanomyces* root-rot-resistant elite; 0-803, an American No. 3 Northern elite, and Commercial American No. 1.

These five were planted along with 11 other varieties in 16-variety six-replicate plot tests at Rocky Ford, Colorado; Grand Island, Nebraska; Mason City, Iowa, and Moorhead and East Grand Forks, Minnesota. In the sixth test, located at Missoula, Montana, the five varieties were part of a 12-variety test of six replications of plots. All plots were four rows wide and from 50 to 75 feet long, except at Missoula and Rocky Ford where three-row plots were used. In the latter two tests the center row of each plot was used for yield determination. In the other four tests, at least 80 feet of the two center rows were harvested for yield.

Two samples of not less than 10 beets each were taken from all plots for sucrose percentage determination. Part of the samples of leached filtrate used in the sucrose test in the six factory areas were sent to Rocky Ford for the other analyses. Purity of a hot digestion juice was determined at

<sup>1</sup> Plant Breeder and Experimental Chemist, respectively, American Crystal Sugar Company, Rocky Ford, Colorado.  
<sup>2</sup> Numbers in parentheses refer to literature cited.

each factory by refractometer. At Rocky Ford the percentages of sodium, potassium, magnesium, calcium, chlorine and sulphate were obtained by use of the Beckman flame spectrophotometer. Ash by incineration analysis was made at Rocky Ford, from samples of pulp (dried) taken at the time sucrose analysis was made at the six factories. The data obtained from the five varieties was complete for six replications of plots at each of the six factory areas.

### Experimental Results

#### Differences Between Varieties

In order to present the results of this experiment in concise form, extensive summarizations of the data have been made. In Table 1 is given the performance of the varieties for yield, sucrose, purity, total nitrogen, ash and the six ions: Na, K, Mg, Ca, Cl, and  $SO_4$ , as an average of the six factory areas.

Table 1. Variety Performance for Yield and Sucrose Percent, Along with Analysis Data on Nine Characters of Juice. (Average of Six Factory Areas).

Characteristic	Variety						F <sup>1</sup>	Sign. Diff. (10:1)
	6-419-X	Amer. 1	8-601-0	9-604-0	0-803	Ave.		
Tons per A.	13.57	13.38	13.86	13.30	13.95	13.63	.56	
% Sucrose	15.77	15.29	14.80	15.17	15.65	15.54	3.70	.57
Lbs. S. per A	4305	4088	4115	4067	4379	4190	1.87	
% Na	.041	.051	.057	.055	.044	.050	2.06	.014
% K	.238	.250	.244	.233	.239	.241	2.20	.013
% Mg	.066	.066	.064	.065	.066	.065	4.00	.001
% Ca	.024	.024	.022	.023	.025	.024	1.80	
% Cl	.016	.018	.025	.019	.015	.019	4.31	.004
% Ash	.801	.797	.828	.836	.796	.812	.53	
% $SO_4$	.032	.033	.032	.032	.032	.032	1.86	
% Total N	.102	.092	.093	.099	.099	.097	4.10	.006
% Purity	87.13	86.86	86.58	86.37	87.03	86.79	.87	

<sup>1</sup> 5% point 2.87

1% point 4.43

The yield of beets and of sugar per acre given in the above table are averages of 36 plots—six plots at each of six locations. Since two samples were taken from each plot for sucrose test, this data along with other chemical analyses are averages of 72 determinations. The analysis of variance was obtained by using averages of six plots at each location as individual performance figures, with locations being considered as replications. For the average of the six areas, F values indicate significant differences between varieties for percent sucrose, magnesium, chlorine and total nitrogen, and near significance for percent sodium and potassium.

Comparisons between varieties is of interest in this table. The variety 6-419-X was highest in sucrose, magnesium and total nitrogen, and lowest in percent sodium and potassium. American No. 1 was highest of all varieties in percent potassium and lowest in total nitrogen. 8-601-0 was lowest in percent sucrose, highest in percent sodium and chlorine and lowest in percent magnesium. 0-803 was high in percent magnesium and low in percent chlorine.

Table 2a.—Five Variety Average Results on Tonnage and Sugar per Acre Yield, by Factory Locations.

Location	Tons per A.	Percent Sucrose	Lbs. Sugar per Acre
Missoula	10.86	15.31	3,362
Rocky Ford	12.64	15.04	3,329
Grand Island	13.59	11.02	3,008
Mason City	15.27	17.83	5,458
Moorhead	11.91	17.47	4,154
East Grand Forks	17.51	15.32	5,356
Significant Difference (19:1)	1.07	.57	370

### Differences Between Areas

The six factory areas where the tests were conducted represent a very wide range of soil and climatic conditions for beet growing, and, therefore, differences between the chemical constituents of beets grown in these areas might be expected. The average results for all 12 characteristics of the five varieties are given by location of test in Table 2.

Table 2b.—Five Variety Average Results of the Analyses for Nine Characteristics of Juice, by Factory Locations.

Location	Characteristics of Beets								
	Na	K	% Mg	% Ca	% Cl	% Ash	% SO <sub>4</sub>	% TN	% Purity
Missoula	.028	.300	.048	.018	.016	.847	.031	.091	86.11
Rocky Ford	.108	.208	.060	.033	.031	.752	.031	.062	91.15
Grand Island	.094	.296	.078	.021	.038	1.143	.037	.147	79.34
Mason City	.012	.232	.069	.027	.008	.590	.030	.061	90.04
Moorhead	.013	.170	.070	.023	.007	.712	.030	.085	88.99
E.G.F.	.042	.239	.068	.016	.008	.822	.033	.135	85.11
Sign. Diff.	.014	.013	.001	.003	.004	.073	.001	.006	.96

Note: F values are highly significant for all characteristics.

The data obtained indicates very great variation in all characteristics, all of which are attributable to geographic location. At Missoula, percentages of magnesium and calcium were lower than other locations. At Rocky Ford, the highest sodium and calcium percentages were obtained. The Grand Island results show higher percentages of potassium, magnesium, chlorine, ash, sulphate and total nitrogen than at other locations. At Mason City, the percentages of sodium and total nitrogen were low. Percentages of potassium, chlorine, ash and sulphate were lowest at Moorhead. East Grand Forks was low in calcium.

Differences were also significant between areas for yield of beets, percent sucrose, pounds sugar per acre and also in percent purity of juice. Due to the difficulties in procedure for obtaining purity of juice by the refractometer method it is likely that some of the variation observed is the result of slight differences in laboratory procedure at the different factories.

### Varietal Differences in Different Areas

Since the five varieties selected for this experiment were all different in origin and had been selected for use in different factory areas, it would

be expected that some differential performance at the six locations would be observed. Sucrose types such as American No. 1 commonly are slightly lower in tonnage yield than northern types such as 0-803, when tested in northern areas. American No. 1 was selected for high sucrose percent and leaf spot resistance, mainly for the Arkansas Valley of Colorado.

In order to determine comparative differences between varieties at different locations, the data obtained from each of the six plots of each of the five varieties at all six factory locations were set up and statistically analyzed for the twelve characteristics. Significant F values obtained from this analysis for the variety-location interaction are given in Table 3.

Table 3.—Variety-Location Interaction F Values Obtained for Percentages of Sucrose, Na, Ca, Cl, and Ash.

Characteristic	F Value	Significance <sup>a</sup>
Percent Sucrose	1.83	*
Percent Na	2.34	**
Percent Ca	2.19	**
Percent Cl	10.61	**
Percent Ash	1.82	*

15% point—1.63. 1% point—2.00.

From this analysis it is evident that certain of these varieties did not perform in similar relationship to others at all locations of test. A study of the variations in the varieties is therefore of interest.

Of the five varieties, the hybrid variety 6-419-X was the most variable of all. This variety was lower in sucrose percent than 9-604-0 at Missoula, and significantly higher than 9-604-0 at Rocky Ford. It was higher in sucrose than 0-803 at Moorhead, and lower at East Grand Forks. Sodium content of 6-419-X at Moorhead was one-half that of American No. 1, but at East Grand Forks it was nearly double that of American No. 1. For ash, this variety was significantly higher than American No. 1 at Missoula and similarly lower at Moorhead. In calcium content at Missoula, 6-419-X ranked lowest and American No. 1 highest, and at Grand Island the reverse was true.

The percentage of chlorine was also different in two varieties at two locations. At Mason City American No. 1 was significantly higher than 9-604-0, but at Moorhead the reverse was true by a significant amount.

Table 4.—F Values for Varietal Differences Obtained for 12 Characters in Six Factory Areas.

Location	Tons per acre	% Suc.	SPA	Na	K	Mg	Ca	Cl	SO <sub>2</sub>	Ash	TN	Purity
Missoula				0	*		**					
Rocky Ford		**	**	**			*	**	0			
Grand Island		**		**			*	0			0	0
Mason City				0			0		**			
Moorhead		*		**	0							
E.G.F.	0									*		

\* 5% point—2.87

\*\* 1% point—4.43

0 near 5% point

### Differences Between Varieties at Each Location

In order to determine the characteristics of each variety at each location, a statistical analysis was made using the data from the six blocks for the 12 characteristics at the six locations. In all, 72 variance analyses were made to determine these varietal differences. In order to reduce the volume of data to be presented, individual location results have not been included. Instead, a listing is given in Table 4 of the significant and near significant F values for the twelve characters at each location.

In spite of the fact that the varieties used were different in origin and selected for different agronomic characters there was no difference between them for tonnage yield, with the possible exception of the East Grand Forks test where 0-803 (American No. 3 Northern) was highest in yield rank. Variety differences for percent sucrose were significant at Rocky Ford, Grand Island and Moorhead. Reliable sugar per acre differences between varieties were obtained at Rocky Ford.

Significant differences for percent sodium were obtained at Rocky Ford, Grand Island and Mooi'head, and large differences at Missoula and Mason City. Differences for potassium were obtained at Missoula and near significant differences at Moorhead. In percent calcium, varieties were significantly different at Missoula, Rocky Ford and Grand Island, and nearly so at Mason City. Varieties differed greatly with respect to chlorine content at Rocky Ford, and at Grand Island differences were quite large. In sulphate content large varietal differences were observed at Mason City; and there were indications of similar results at Rocky Ford. Of the six test locations, East Grand Forks was the only one where varieties were different in ash content. Near significant differences in total nitrogen and purity were obtained at Grand Island.

It will be observed in the above table that greatest variability in variety performance occurred in percent sucrose, sodium and calcium. In the characteristics of potassium, chlorine, sulphate and ash, reliable differences occurred only at one location.

Table 5.—Correlation Coefficients of Eight Juice Characteristics of the Five Varieties Tested at Six Locations.

Percent of	Suc.	Na	K	Ca	Cl	Ash	SO <sub>4</sub>	Ca & Mg
Suc.								
Na	-.98**							
K	-.26	+.22						
Ca	+.95*	-.87*	-.15					
Cl	-.97**	+.92*	+.24	-.99**				
Ash	-.73	+.74	-.44	-.80	+.75			
SO <sub>4</sub>	-.56	+.66	+.55	-.47	+.49	+.20		
Ca & Mg	+.54*	-.87*	-.09		-.99**	-.83	-.56	

5% point—.87. 1% point—.95.

### The Relationship of the Characteristics of the Five Varieties Tested

The characteristics of yield and sucrose percent are of first importance in the growing of sugar beets. It is well known that the correlation of yield and sucrose percent is negative. Despite this fact, however, varieties have been developed which are not only high in yield but also high in sucrose.

In this study of varieties, it was considered important to determine the relationship of one character with another. This was done by obtaining correlations using the co-variance analysis method. It was expected that tonnage yield between varieties would show significant differences but this did not occur, hence the yield of beets and of sugar per acre were not used for the relationship studies. Of the twelve characteristics studied, seven were used, along with a combination of two of them. These eight characteristics were all that were considered as giving reliable variation within the five varieties tested. The correlation coefficients for all pair combinations of the eight characters except one are given in Table 5.

Due to the fact that there were only five varieties in test, the significant level for correlation was extremely high. Nevertheless, there were nine of the 27 correlations which were significant; and the remainder were generally in line with the data presented by Dahlberg (2).

Positive correlations were obtained for percent sucrose with calcium, and with calcium-magnesium; and negative correlations with percent sodium and chlorine. Percent sodium was negatively correlated with calcium, and with calcium-magnesium, and positively with chlorine. Calcium and calcium-magnesium were negatively correlated with chlorine. There was no significant relationship of potassium, nor of sulphate, to other elements. Percent of ash showed a fairly high positive correlation with sodium and a similar negative relationship with sucrose. The correlation of ash and calcium-magnesium was negative, approaching the significant level.

#### Summary and Conclusions

The data presented indicate differences between varieties for sucrose, sodium, potassium, magnesium, chlorine and total nitrogen, as an average of the six areas. However, due to the extremely small amounts of magnesium and chlorine found it is probable that these minerals are not of as great importance in variety improvement work as other elements.

Considering test areas, the five-variety average data for the 12 characters show very great difference for all six areas. These differences were so large that it can be concluded that the area of production is the most important factor in yield and quality in sugar beet production.

Varietal characteristics were found to be different in different test areas, for percent sucrose, sodium, calcium, chlorine and ash. None of the five varieties was suitable in all six areas for these elements. These effects were, however, secondary to the main variety differences obtained.

Within each test area the major variety differences occurred in percent sucrose, sodium and calcium; with potassium, chlorine, sulphate and ash differences occurring only in one of the six test areas. These results are important for the beet breeder, since they indicate the effect of environment on sugar beet varieties.

There were eight juice characters, recorded in percentage figures, which were used for the correlation study. The results show that sucrose and calcium were positively correlated. Sucrose was negatively correlated with sodium,

and with chlorine. Sodium was negatively correlated with calcium and positively with chlorine. Chlorine with calcium gave a negative correlation. The combination of calcium-magnesium was positively correlated with sucrose, and negatively with sodium and chlorine.

#### Literature Cited

- (1) DAHLBERG, H. W.  
1942. Non-sugar relationships in breeding high purity beets. Proc. Am. Soc. Sug. Beet Tech. pp. 322-25.
- (2) DAHLBERG, H. W.  
1950. Composition of beets grown in widely separated areas. Proc. Am. Soc. Sug. Beet Tech. pp. 565-69.
- (3) DOXTATOR, C. W. and CALTON, F. R.  
1950. Sodium and potassium content of sugar beet varieties in some western beet growing areas. Proc. Am. Soc. Sug. Beet Tech. pp. 144-151.