The Performance of Sugar Beet Selections Made for Purity and Chloride at Three Levels of Nitrogen Fertility

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Received for publication June 15, 1964

Purity of beet juice is regarded to be the best criterion for the determination of the amount of extractable sugar which can be recovered from the beet. Low purity juice (or juice with high impurities) means the production of more molasses and less sugar obtained per ton of processed beets. The continued downward trend of sugar percent and low purity in recent years has caused concern to all beet processors, and attempts to rectify this situation have been made.

In 1960 J. B. Stark (9)[2] calculated that 1 pound of chloride carries 6.9 pounds of sugar into molasses. It was stated that chloride is much more deleterious than a pound of average impurities, which carries only 1.7 pounds of sugar into molasses. Since chloride is not removed in carbonation but goes into molasses, the problem of high chloride in beets in certain factory areas may become serious. In 1952 Doxtator and Bauserman (1) reported on 7 chemical constituents (along with percent sugar and percent purity) on 5 varieties grown in replicated plots in 6 midwestern factory areas of the American Crystal Sugar Company. Significant differences were found between varieties for various chemical constituents, one of which was chloride. Highly significant differences were found in each area for each of the chemicals studied. One factory area was found to be the lowest of all areas for sucrose percent and purity and highest in chloride. Sucrose and chloride were found to be negatively correlated (r −.97).

There is ample evidence that the beet responds to simple breeding methods for chemical constituents. Successful selections have been made for low sodium by Doxtator and Bauserman (2) and Wood (10), for low raffinose by Finkner and Bauserman (3) and Wood (10), for low aspartic acid and glutamine by Finkner *et al.* (4), for purity as reported by Powers *et al.* (8).

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[2] Numbers in parentheses refer to literature cited.

This investigation was undertaken to determine: the effect of selection for percent purity and chloride content on these and other beet characters; the effect of nitrogen fertilization on beet characters; and also to determine if the selections reacted similarly at different nitrogen fertility levels.

Materials and Methods

The varieties used in this experiment were the elite stocks of 59-401 and 59-417, both of which were good sucrose type monogerms. Field selection of roots was made for weight using a modification of the unit block method of Powers (7). Percent sucrose was obtained polarimetrically, while percent apparent purity was determined from the expressed juice of the beet brei.

Chlorides were determined by paper chromatography (5). Only the percent purity of juice of each beet was used in making the high and low selections in 59-401. Sucrose and weight data were not used. Similarly, in 59-417 only chloride data were used, with no consideration given to weight, sucrose or purity data. Random selections were made by taking every 20th beet of the 1046 field selected roots of 59-401, and every 13th beet of the 1023 field selected roots of 59-417. The selections, along with the mean data and standard errors for each selection are given in Table 1.

Selection for high and low purity in 59-401 resulted in a significantly large difference of 15.22% between the selections; and selections for high and low chlorides in 59-417 resulted in a five-fold spread (.91 to .16%). The effect of these selections on sucrose in 59-401 and on sucrose and purity in 59-417 was large, as shown in Table 1. High purity beets were found to be of high sucrose content while low chloride beets were high in both sucrose and purity. Differences in all 3 of these characters were significant. The random selections ranged between the high and low selections for the 3 characters. Roots of the 6 selections were planted in space-isolated groups in 1961 and produced adequate seed for plot tests.

In 1962 the 6 selections were planted in a split-plot replicated test at Rocky Ford, Colorado. Three rates of nitrogen fertilization were used: 0 units, 75 units, and 150 units per acre as main plots, on which the selections were planted as sub-plots. These sub-plots were single rows 35 feet long in 6 replications, with 2 rows of a commercial variety planted on each side of the main plots to give uniform competition for each selection and adequate spacing between nitrogen treatments. At harvest, each 35 foot plot was harvested for yield and the beets divided into 2 samples for sucrose, purity and other chemical determinations. Apparent purity was determined from the expressed juice of the beet brei.

Table 1.—Data on mother root selections of 59-401 and 59-417 for high and low chlorides and purity of juice.

1961 Selection number	Parent variety	Description of selection	No. of beets	Average beet data			
			Selected	Weight, Lbs.	% Sucrose	% Purity	% Chloride[a]
61-423	59-401	High Purity	50	2.85 ± .099	17.32 ± .226	93.17 ± .403	
61-415	59-401	Low Purity	54	2.66 ± .118	13.70 ± .338	77.95 ± .647	
61-409	59-401	Random Selection	52	2.93 ± .079	15.56 ± .195	89.31 ± .476	
		Total Population	1046	2.71 ± .032	15.29 ± .065	86.81 ± .162	
61-422	59-417	High Chloride	80	3.16 ± .107	12.99 ± .215	84.76 ± .528	.91 ± .036
61-421	59-417	Low Chloride	81	2.75 ± .072	16.47 ± .153	88.40 ± .342	.16 ± .009
61-417	59-417	Random Selection	79	2.86 ± .080	15.26 ± .231	87.82 ± .472	.40 ± .027
		Total Population	1023	2.96 ± .032	15.18 ± .064	86.85 ± .128	.44 ± .010

[a] Percent on Dry Substance

Chlorides, raffinose, and nine amino acids were determined by paper chromatography. Sodium, potassium, and calcium were determined with the flame spectrophotometer. The micro-Kjeldahl nesslerization method (6) was used to determine total nitrogen.

Experimental Results

The results of field and laboratory tests of the 6 selections as an average of the 3 nitrogen treatments are given in Table 2. Data are also given for the 3 nitrogen treatments as an average of the 6 selections. The only selection × nitrogen interaction that was significant was the one for sucrose, which is also presented in Table 2.

Selection Effects

Selection for purity of juice in 59-401 resulted in the high selection 61-423 giving a higher purity than the low selection 61-415, but the difference was not significant. However, since the random selection 61-409 was intermediate between the two, some selection effect is indicated. In beet and sugar per acre yield, and percent sucrose, the high purity selection 61-423 was significantly higher than the low purity selection. It was also significantly low in total nitrogen and in 6 amino acids—aspartic, asparagine, glutamine, glycine, gamma amino butyric acid (G.A.B.A.) and alanine, as well as in total amino acid content. Compared to 61-409 (random selection), 61-423 gave significant increases in beet and sugar per acre yield and significant reductions in aspartic acid, glutamic acid and asparagine. In other characters differences were not significant at the 5% point. However, the purity of 61-423 was higher, and lower percentages were obtained for chloride, total nitrogen and all 9 amino acids.

Selection for chloride content in 59-417 resulted in the low chloride selection 61-421 being reduced to approximately one-half the high selection, 61-422. Selection 61-421 was lower in beet yield and higher in sucrose percent than 61-422 by significant margins, resulting in a nearly equal sugar per acre yield. Purity of juice was 1.12% higher in 61-421, a non-significant but suggestively large increase. Since the random selection was intermediate between the purity values of the low and high chloride selections, it appears that selection for low chlorides did have the effect of increasing purity. The low chloride selection did not influence total nitrogen content but did reduce by significant percentages, sodium, potassium, aspartic acid, glutamic acid and valine. The G.A.B.A. content of the low chloride selection was significantly higher, and asparagine, glutamine, glycine, alanine, and leucines were all higher in rank than in the high chloride

Table 2.—Yield and chemical results obtained from three selections for purity and three selections for chloride, at three different fertility levels.

Selection no.	Parent variety	Character	Lbs. sugar per acre	Tons beets per acre	% Sucrose	% Purity	% on D.S. Chloride	% on D.S. Total nitrogen	% on Beet % Na.	% on Beet % K	% on Beet % Ca.	% on Dry Substance Raffinose	Asp. A.	Glut. A.	Aspara.	Gluta.	Glycine	G.A. B.A.	Alanine	Valine	Leucines	Total amino acids
61-423	59-401	Hi Purity	8390	26.55	15.80	88.10	.119	1.19	.088	.142	.025	.213	.108	.022	.101	.628	.084	.142	.045	.038	.064	1.23
61-415	59-401	Low Purity	7056	22.79	15.48	87.72	.109	1.27	.090	.140	.025	.199	.128	.019	.127	.685	.110	.158	.056	.041	.070	1.39
61-409	59-401	Ran. Sel.	7186	23.04	15.62	87.93	.123	1.21	.087	.141	.028	.216	.120	.027	.119	.632	.096	.150	.051	.040	.066	1.30
61-422	59-417	Hi Cl-	8124	26.96	15.06	87.64	.213	1.10	.104	.146	.025	.242	.126	.024	.089	.506	.095	.132	.045	.042	.062	1.12
61-421	59-417	Low Cl-	8184	25.34	16.16	88.78	.108	1.09	.065	.139	.027	.238	.116	.019	.098	.549	.096	.149	.050	.037	.066	1.18
61-417	59-417	Ran. Sel.	7224	23.18	15.61	88.19	.139	1.03	.091	.135	.028	.246	.112	.022	.074	.478	.074	.119	.037	.030	.046	.99
Sign. Diff. (19:1)			496	1.39	.36	NS	.023	.06	.009	.006	NS	.017	.009	.005	.016	.057	.016	.016	.008	.005	.008	.09
Sign. Diff. (99:1)			658	1.85	.48	NS	.031	.08	.011	NS	NS	.023	012	NS	.022	.076	.021	.022	.011	.007	.011	.13
Nitrogen rates[1]																						
0			7882	24.67	15.99	88.92	.125	1.04	.078	.140	.026	.217	.106	.018	.084	.503	.077	.131	.037	.033	.056	1.05
75			7851	25.16	15.63	87.85	.139	1.15	.090	.142	0.26	.228	.121	.022	.108	.582	.099	.140	.047	.038	.063	1.22
150			7346	24.09	15.24	87.37	.142	1.26	.096	.142	.027	.232	.128	.027	.111	.654	.100	.154	.057	.044	.068	1.34
Sign. Diff. (19:1)			280	NS	.33	.69	NS	.08	.008	NS	NS	NS	.013	NS	.011	.073	.020	.013	.009	.004	.005	.12
Sign. Diff. (99:1)			398	NS	.46	.99	NS	.12	.011	NS	NS	NS	.018	NS	.016	.104	NS	.018	.013	.005	.007	.17

Selection × nitrogen rates — percent sucrose

N. \ Sel.	61-423	61-415	61-409	61-422	61-421	61-417
0	16.17	15.29	16.35	15.62	16.47	16.10
75	15.87	15.90	15.60	14.62	15.97	15.85
150	15.37	15.27	14.90	14.97	16.07	14.88

Sign. Diff. (19:1) .64
Sign. Diff. (99:1) .85

Sign. Diff. (19.1) .63
Sign. Diff. (99:1) .84

[1] Average of six selections.

selection. Total amino acid, although higher for the low chloride selection was not significant. Compared to 61-417 (random selection), 61-421 was significantly higher in beet and sugar per acre yield and sucrose percent. Purity of juice was .45% higher and although non-significant, was greater than the high purity selection 61-423 for purity, which showed only .17% higher than the random selection 61-409. Selection 61-421 had significantly lower amounts of chlorides and sodium, but was higher in total nitrogen. It was higher in all 8 amino acids by significant margins with the exception of aspartic acid and glutamic acid and in total amino acids.

Nitrogen Effects

When increasing amounts of nitrogen were applied, remarkable differences were obtained as an average of the 6 selections. Comparing the zero and 150 pound rates, sugar per acre was reduced greatly, along with sucrose percent and purity. Total nitrogen, sodium and all amino acids were increased significantly with the exception of glutamic acid. All other characters showed minor increases, with the exception of beet yield, percent potassium and percent calcium. In all characters affected, the 75 pound nitrogen rate was intermediate in rank.

Selection × Nitrogen Interaction

The only selection × nitrogen interaction was for sucrose. As shown in Table 2, the low purity selection 61-415 had the highest sucrose content at the 75 pound nitrogen rate, and the 150 pound rate did not reduce the sucrose percent below the zero rate. Lesser variations in 61-421 and 61-422 also contributed to this interaction.

Discussion

In this experiment the selection for high and low purity, and high and low chloride resulted in progenies which were changed in the direction of the selection. The purity selections, although differing only slightly, appeared to be reliable. Selection for low and high chloride gave a highly significant difference. These differences resulted from a selection of approximately 5% of the beets available for each purity selection, and 7.8% of those available for each chloride selection (Table 1).

It is also of interest to observe the effect of these selections on sugar per acre yield, and on the other juice characters. The high purity selection improved beet and sugar per acre yield, and percent sucrose; and in general reduced the quantity of amino acids, and to a lesser degree nitrogen, chloride and sodium. The low chloride selection maintained sugar per acre yield, reduced beet yield per acre, increased sucrose percent and purity but had no effect on total nitrogen. Some amino acids were

increased; others slightly decreased. Sodium along with chloride was greatly decreased.

It appears therefore, that the purity selection had more effect on the nitrogen compounds of beet juice than the chloride selection; the chloride selection had more effect in reducing the mineral elements than the nitrogen compounds.

Although the percent purity data indicate no significant differences, the highest ranking purity was obtained in the low chloride selection. It must be pointed out however, that the low chloride selection 61-421 was significantly lower in total nitrogen and in total amino acids than the high selection 61-423. This, along with the low chloride and sodium content of 61-421, indicates that this selection should be high in purity. Since these two selections came from different parents it is interesting to note that their random selections are significantly different in nitrogen compounds — 61-409 (from 59-401) being high, and 61-417 (from 57-417) being low.

The selection $\times$ nitrogen interaction for sucrose is of interest because some of the selections showed a slightly different reaction to nitrogen applications than the random selections 61-409 and 61-417. The low chloride selection 61-421, although showing a reduction in sucrose percent with increasing rates of nitrogen, was not significantly different from the zero rate of nitrogen. There appears to be a possibility that varieties can be developed which will produce a satisfactory sucrose content in high nitrogen fertility levels.

The data presented indicate that the purity of beet juice can be increased by breeding beets with a low chloride content. Selecting beets with a low chloride content did not have an appreciable effect in changing the total nitrogen content of the beet. In previous investigations Finkner *et al.* (3) found that selection for low aspartic acid or low glutamine content significantly improved juice purity. It appears that the chemical pathways of chloride and amino acid physiology of the sugar beet plant are not highly associated, and that the plant breeder can select for both low chlorides and amino acids simultaneously. The results reported in this paper and the previous paper on amino acids (3) indicate that the breeder can increase sugar beet quality significantly and still maintain yield if selection pressures are applied for both low chloride and low aspartic acid (or glutamine) content.

Summary

(A) Selections for high and low purity were made in the elite stock 59-401, which resulted in progenies which differed

in yield, sucrose percent, and in the nitrogen components of beet juice. The high purity selection showed an improvement over the parent variety in these characters.

(B) Selection for high and low chloride was made in the elite stock 59-417, which resulted in progenies which differed in sucrose percent, in chlorides and in sodium and potassium content. The low chloride selection showed an improvement over the parent variety in these characters as well as in beet and sugar per acre yield.

(C) Nitrogen applications caused a decrease in percent sucrose and purity, and in sugar per acre yield, and an increase in the non-sugar compounds of the beet.

(D) A small but significant selection × nitrogen interaction for sucrose was obtained.

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