Levels of Total Nitrogen, Potassium and Sodium in Petioles and in Thin Juice of Sugar Beets[1,4]

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In 1961 studies were conducted to determine levels of total nitrogen, potassium and sodium in the petioles as compared with levels of those chemicals in the thin juice of sugar beets (*Beta vulgaris L.*). The petioles are a structure of the tops of the sugar beet and the thin juice is prepared from the roots of the same plant. The primary purpose of the study was to determine whether genotypes differ as to levels of these chemical constituents in the petioles and in the thin juice and, if so, whether some genotypes tend to have higher levels in the petioles and lower levels in the thin juice, whereas for other genotypes the reverse is true. In other words is there an interaction of genotypes and material analysed (petioles or thin juice) as regards levels of total nitrogen, potassium and sodium? Such information is of great fundamental and practical importance to the beet sugar industry as these chemicals have been found to be associated with yield and quality.

Literature Review

Emmert (3, 4, 5,)[5] working with tomatoes, lettuce and cucumbers developed rapid methods for estimating nitrate nitrogen, phosphate, and potassium in plants. He believed that inasmuch as the nutrients derived by a growing plant from the soil must enter in solution through the stem that the concentration of a given nutrient in this mature conductive tissue should be directly proportional to the available supply of the nutrient in the soil. Hence, a measure of the concentration of nutrients in this conductive tissue may be a better measure of the ability of the soil to supply nutrients to growing plants than chemical tests of the soil itself. Also, he felt that an optimum content of nutrients

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[5] Numbers in parentheses refer to literature cited.

in this kind of tissue exists for the various stages of growth of each kind of crop, regardless of the kind of soil in which the crop is growing. His researches supported these deductions and hence seemed to justify the practice of analysing the mature conducting tissues of the plant to determine the ability of the soil to provide the nutrient requirements. Gardner and Robertson (6) anaylsed petioles of sugar beets and found it useful in determining fertilizer needs as regards nitrate, phosphate and potassium.

Ulrich (16, 17, 18) and Tolman and Johnson (15) conducted extensive experiments with sugar beets, studying yield and quality as regards fertilizer practices. He found a negative relation between levels of nitrate nitrogen in the petioles and percentage sucrose of the roots. He also established the optimum level of nitrate nitrogen in the petioles as regards percentage sucrose to be approximately 1000 ppm. He found that once the critical nutrient level for an element has been established for a crop through many field experiments, plant analysis has the following applications: (A) determination of the kind of nutrient that might be deficient in the field; (B) estimation of the time of application and the amount of fertilizer to apply; (C) aid in selecting the location of fertilizer experiments; and (D) aid in maintenance of the proper level of soil fertility. Also, some beet sugar companies have used the techniques he developed to determine fertilizer practices and established dates of harvest. Probably one of the more important contributions of the researches by Ulrich is the stimulation of rather extensive researches on the effects of fertilizer practices on the yield, quality and processing of sugar beets.

Rorabaugh and Norman (12) found the order in which some of the common beet-sirup impurities adversely affect crystallization of sugar, during factory processing, to be as follows: (A) carbonate and chloride salts, (B) amino acids, (C) betaine and non-nitrogenous organic acids, and (D) sulfate salts. They found the carbonates and chlorides to be strongly melassigenic and to be present in relatively large concentrations in the beet syrups. Hence, the carbonates and chlorides accounted for a large fraction of the total sugar lost in molasses. They conclude that the most fertile ground for improvement of the crystallization characteristic lies in the elimination of carbonate and chloride salts with lowering of pyrolidonecarboxylic acid and that glutamic acid is the second most likely point of attack. They further point out that the case against pyrolidonecarboxylic acid and glutamic acid is a two-edged one, since not only are they major contributors to sugar loss in molasses, but also decomposition of glutamine, the amide from which they originate, causes processing difficulties through lowering of buffering capacity of juice and lowering alkalinity. The rather extensive studies of Carruthers and Oldfield (2) in general agree with those of Rorabaugh and Norman (12). In addition Carruthers and Oldfield present methods of assessing quality that appear to have considerable merit and hence extensive application.

Haddock, Linton and Hurst (7) found that nitrogen fertilization and nitrogen plant composition are closely associated with sucrose storage in beet roots and sugar recoveries from extract juice. Also, they found that the soluble nitrogen constituents of the sugar beet roots are highly associated with, if not responsible for, variations in purity and sucrose percentage as well as in dry matter percentage. From their studies the particular components which appear to be most highly associated with changes in quality are the glutamine and ammonia fractions. They believe the glutamine nitrogen to be of greatest significance in quality variation, because of its high association with quality factors, and because the concentration of this form of nitrogen is ten times that of amomnia nitogen.

Rounds et al. (13) found that the nitrogen levels caused greater variations in the amounts of nonsugars present in the beet roots than did the varieties tested. Significant interactions of varieties × nitrogen fertility levels were found for sodium content. The data presented indicate that both varieties and nitrogen fertility levels can appreciably influence the amount of nonsugars in beets. The association of total nitrogen and nitrogen compounds with reduced purity and extraction in the roots was pronounced. Ryser et al. (14) in a comparison of harvest dates found that the sugars from the late harvest were higher than from the early harvest while the purities were lower. The unexpected decrease in purity was not accounted for by an increase in the level of amino nitrogen. Levels 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 varietal differences were just as striking. In Na content, a four or fivefold difference between low Na types and high Na types was not uncommon.

Owen et al. (8) found that highest purity was not always associated with highest percentage sucrose. They attributed their results to be due to an interaction between genotypes (as represented by hybrids) and locations. Power et al. (9) found that some genotypes might have a high nitrate nitrogen content in the petioles and low total nitrogen in the thin juice as compared with other genotypes. The same was found to hold true for potassium. Some populations were found to be high in level of potassium in the petioles and low in levels of potassium in the thin juice as compared with other populations.

Materials and Design of the Experiment

The materials used in the study are as follows. There is a total of 20 populations in the experiment. One is a commercial variety, 4 are three-way hybrids, each composed of 3 inbreds, and 15 are F_1 hybrids each composed of 2 inbreds. The dates of harvest are September 14, October 3, and October 16. The experiment was conducted in 1961. The characters studied are levels of total nitrogen, potassium and sodium in the petioles and in the thin juice. In the petioles the characters are expressed as milligrams per 100 grams and in the thin juice as milligrams per 100 milliliters of thin juice equated to a refractive dry substance of 10. The thin juice was prepared by The Great Western Sugar Company by an oxalate method standard with them [see (1)]. In the process the nitrate nitrogens are removed. Hence the total nitrogen for the thin juice does not include all the nitrogenous compounds found in the total nitrogen analysis of the petioles.

The design of the experiment is a split plot with populations randomized within replications and dates of harvest randomized within blocks. Each block is composed of 3 dates of harvest and each date of harvest has 2 replications with 20 populations randomized within each replication. There are 5 such blocks. Hence the design of the experiment is a modified randomized complete block.

Results

The F values calculated from an analysis of variance are listed in Table 1. A study of this table reveals that there are significant differences between populations as regards all chemical characters for both the levels in the petioles and in the thin juice. This is

Table 1.—The F values calculated from the analyses of variance for levels of total nitrogen, potassium, and sodium in the petioles and in the thin juice.[1]

Variation due to	Total nitrogen		Potassium		Sodium		Value of F at:	
	Petioles	Thin juice	Petioles	Thin juice	Petioles	Thin juice	5%	1%
Populations	6.85	41.84	48.87	19.43	9.62	9.36	1.60	1.92
Dates	———	———	———	1.59	1.99	7.80	4.46	8.65
P × D	1.22	1.20	1.33	———	1.45	1.08	1.42	1.64

[1] ——— signifies that the error mean square is the larger.

Table 2.—Means and the least significant differences for levels of total nitrogen, potassium, and sodium in the petioles and in the thin juice.

Population, LSD and average	Entry number	Total nitrogen		Potassium		Sodium	
		Petioles	Thin juice	Petioles	Thin juice	Petioles	Thin juice
		Mg/100gm	Mg/100ml	Mg/100gm	Mg/100ml	Mg/100gm	Mg/100ml
52-430 × 52-407 F_1	1	1365.0	49.2	16.2	66.3	40.6	50.3
52-305 CMS × (52-430 × 52-407) F_1	2	1376.7	56.1	24.2	69.9	32.3	43.9
52-305 CMS × 52-430 F_1	3	1374.0	49.6	26.5	65.7	28.5	37.2
52-305 CMS × 52-407 F_1	4	1345.0	62.1	17.0	73.4	34.5	39.3
52-430 × 52-307 F_1	5	1470.8	40.9	18.0	53.9	35.9	45.2
52-305 CMS × 52-307 F_1	6	1489.8	52.3	27.8	62.2	32.2	41.8
52-430 × 52-408 F_1	7	1431.8	44.8	21.1	60.4	36.9	36.8
52-430 × 54-520 F_1	8	1488.7	57.6	13.8	60.0	35.3	36.5
52-305 CMS × 54-520 F_1	9	1383.5	65.6	17.9	65.2	31.3	37.8
52-430 × 54-565 F_1	10	1330.8	41.6	18.4	44.7	32.9	30.9
52-305 CMS × 54-565 F_1	11	1431.7	45.6	24.1	48.2	30.9	30.6
52-305 CMS × 54-458 F_1	12	1321.0	64.9	16.4	71.9	32.0	39.4
52-430 × 54-346 F_1	13	1278.2	37.4	14.2	41.9	32.3	38.0
52-305 CMS × 54-346 F_1	14	1315.3	42.0	20.7	53.1	32.7	35.9
52-305 CMS × (52-430 × 54-346) F_1	15	1316.2	44.5	20.5	53.6	30.4	37.3
52-305 CMS × (52-430 × 54-520) F_1	16	1442.6	65.2	22.4	67.2	30.8	36.3
52-305 CMS × 34 F_1	17	1485.7	61.3	24.7	57.9	35.4	42.1
52-305 CMS × (54-458 × 34) F_1	18	1404.5	60.1	21.0	62.1	33.7	36.8
54-565 × 52-407 F_1	19	1488.2	57.4	17.9	73.2	39.0	46.0
A56-3	20	1531.2	54.4	16.4	60.7	35.9	55.7
LSD at 5%		77.8	3.9	1.6	5.7	2.7	5.5
LSD at 1%		102.6	5.1	2.1	7.6	3.5	7.2
Average		1403.5	52.6	20.0	60.6	33.7	39.9

not true for dates of harvest (with the possible exception of sodium in the thin juice) as the differences noted between dates of harvest can readily be explained by chance. This is also true of the first order interaction of populations $\times$ dates of harvest. It may be concluded that the changes in levels of total nitrogen, potassium and sodium when harvested September 14, October 3, and October 16 have little if any practical significance. Further research is necessary to determine whether the change in levels of sodium for the different dates of harvest are other than chance deviations, as for the thin juice they were significant at the 5% level, but just barely so. For that reason the different dates of harvest will not be considered individually in this article.

The means and least significant differences for levels of total nitrogen, potassium, and sodium in the petioles and in the thin juice are listed in Table 2. As has been shown by Powers et al. (11) very little environmental variability is included in the differences between means of populations, the differences noted are predominantly genetic. In this article the data in Table 2 have their greatest interest in the degrees of association between levels of a chemical in the petioles and the level of the same chemical in the thin juice; and the interactions involving levels of the chemicals in the petioles as compared with levels of the chemicals in the thin juice. The correlation coefficients will be considered first.

Associations

From Table 3 it can be seen that the genetic correlation between total nitrogen in the petioles and in the thin juice is 0.29, between potassium in the petioles and in the thin juice is 0.06, and finally between sodium in the petioles and in the thin juice is 0.60. Hence the greatest percent of the variability accounted

Table 3.—Correlation coefficients for levels of total nitrogen, potassium and sodium in the petioles and in the thin juice.[1]

	Total nitrogen	Potassium		Sodium	
Character and material analysed	Thin juice	Petioles	Thin juice	Petioles	Thin juice
Total nitrogen					
Petioles	0.29	0.20	0.22	0.38	0.43
Thin juice		0.03	0.77	−0.01	0.15
Potassium					
Petioles			0.06	−0.44	−0.21
Thin juice				0.21	0.40
Sodium					
Petioles					0.60
Thin juice					

[1] The approximate value of r at the 5% level is 0.273.

for by the correlation of a chemical in the petioles and in the thin juice is 36 percent and is for sodium.

The strongest association (−0.44) between chemicals in the petioles involves potassium and sodium and here only 19 percent of the genetic variation of one is accounted for by the genetic variation of the other. The greatest association between chemicals in the thin juice is 0.77 and involves total nitrogen and potissium. Here 59 percent of the total variation is covariation. The next strongest association for the thin juice is 0.40 and is between potassium and sodium.

Further, from the correlation coefficients listed in Table 3 it can be determined that in no case is a chemical character in the petioles closely associated with another chemical character in the thin juice. These results show that by proper breeding procedures it should be possible to recombine desirable levels of these chemical characters in the petioles with desirable levels of the same characters in the thin juice.

Interactions

The means showing the interactions are taken from Table 2.

Means for levels of total nitrogen showing interactions of populations × materials analyzed are listed in Table 4. The F_1 hybrid 52−430 × 54−346 has a low level of total nitrogen in both the petioles and in the thin juice. The F_1 hybrid 52−305 CMS × 54−458 has a low level of total nitrogen in the petioles and a high level of total nitrogen in the thin juice. The F_1 hybrid (52−430 × 52−307) shows the reverse in that it has a high level of nitrogen in the petioles and a low level of nitrogen in the thin juice. The commercial variety A56-3 has the highest level of total nitrogen in the petioles and has an intermediate level of total nitrogen in the thin juice.

Table 4.—Means for levels of total nitrogen showing interactions of populations × materials analyzed.

Population	Total nitrogen	
	Petioles	Thin juice
	Mg/100gm	Mg/100ml
52-430 × 54-346 F_1	1278.2	37.4
52-305 CMS × 54-458 F_1	1321.0	64.9
52-430 × 52-307 F_1	1470.8	40.9
A56-3	1531.2	54.4
LSD at 5%	77.8	3.9
LSD at 1%	102.6	5.1

The comparisons for the F_1 hybrids 52-430 × 54-346 and 52-305 CMS × 54-458 are not significant for total nitrogen in the petioles but are significant for total nitrogen in the thin juice. The comparisons for the F_1 hybrids 52-430 × 54-346 and 52-430 × 52-307 are statistically significant for the petioles but not for the thin juice. The comparisons for the F_1 hybrids 52-305 CMS × 54-458 and 52-430 × 52-307 are significant for both the petioles and the thin juice. The same is true for the comparison involving 52-305 CMS × 54-458 and A56-3. The comparison between the F_1 hybrid 52-430 × 52-307 and A56-3 are not significant for the petioles but are statistically significant for the thin juice.

These results definitely show that some populations at time of harvest have higher levels of total nitrogen in the petioles as compared to other varieties and lower levels of total nitrogen in the thin juice. The reverse is also true some populations have high levels of total nitrogen in the thin juice and low levels of total nitrogen in the petioles as compared with other populations. These results definitely show that for total nitrogen there is an interaction between genotypes and material analysed (petioles and thin juice). Hence by proper breeding procedures different combinations of levels of total nitrogen in the petioles and in the thin juice are attainable.

Means for levels of potassium showing interactions of populations × material analysed are listed in Table 5. The F_1 hybrid 52-430 × 54-346 has low potassium in both the petioles and in the thin juice, whereas 52-305 CMS × 54-458 is low in potassium in the petioles and high in the thin juice. The F_1 hybrid 52-305 CMS × 54-565 is high in potassium in the petioles and low in the thin juice. The variety A56-3 is low in potassium in the petioles and moderately high in the thin juice.

Table 5.—Means for levels of potassium showing interactions of populations × material analysed.

Population	Potassium	
	Petioles	Thin juice
	Mg/100gm	Mg/100ml
52-430 × 54-346 F_1	14.2	41.9
52-305 CMS × 54-458 F_1	16.4	71.9
52-305 CMS × 54-565 F_1	24.1	48.2
A56-3	16.4	60.7
LSD at 5%	1.6	5.7
LSD at 1%	2.1	7.6

Again there is an interaction between genotypes and levels of potassium in the petioles as compared with levels of potassium in the thin juice. It is apparent that genotypes can be obtained having different levels of potassium in the petioles and in the thin juice. That is, populations can be bred that have desirable levels of potassium in the petioles and desirable levels of potassium in the thin juice.

Means for levels of sodium showing interactions of populations × material analysed are listed in Table 6. The F_1 hybrid 52-305 CMS × 54-565 is low in levels of sodium in both the petioles and thin juice. The F_1 hybrid 52-305 CMS × 52-307 possesses a low level of sodium in the petioles and a high level in the thin juice. The F_1 hybrid 52-430 × 52-408 has the highest level of sodium in the petioles and a moderately low leve! in the thin juice. A56-3 has a high level of sodium in both the petioles and in the thin juice. In fact it is significantly higher in level of sodium in the thin juice than any other population listed in Table 6. Also for sodum, as was the case for total nitrogen and potassium, there is an interaction between genotypes and levels of sodium in the petioles as compared with levels of sodium in the thin juice. It follows that different combinations of levels of sodium in the petioles and in the thin juice can be obtained by proper breeding procedures.

Table 6.—Means for levels of sodium showing interactions of populations × material analyzed.

Population	Sodium	
	Petioles	Thin juice
	Mg/100gm	Mg/100ml
52-305 CMS × 54-565 F_1	30.9	30.6
52-305 CMS × 52-307 F_1	32.2	41.8
52-430 × 52-408 F_1	36.9	36.8
A56-3	35.9	55.7
LSD at 5%	2.7	5.5
LSD at 1%	3.5	7.2

Discussion

The interactions involving genotypes × material analysed (petioles and thin juice) have shown that at time of harvest levels of the three chemicals vary in the petioles and thin juice according to populations. When interpreting these findings it is well to have in mind that the petioles are a part of the tops of the sugar beet and the thin juice is prepared from the roots. Hence, it appears that at time of harvest some genotypes have the higher levels of these chemicals in the tops of the plant, whereas for other genotypes the higher levels are found in the roots as represented by analysis of the thin juice. These findings are of extreme importance to the beet sugar industry in that this shows populations can be bred that will have the higher levels of these three chemical characters in the tops of the plant rather than in the roots. These three chemicals at higher levels have a decided adverse effect on percentage sucrose and percentage apparent purity (see Powers and Payne, 10).

Hence it is of importance to know whether the genotypes tending to have the higher levels of the three chemical characters in the petioles rather than in the thin juice, at time of harvest, have yielding ability. The results from the studies involving these three chemical characters and weight per root, percentage sucrose and percentage apparent purity are presented in another article (see Powers and Payne, 10).

Summary

1. Populations of sugar beets were found to differ in the relative levels of total nitrogen, potassium, and sodium in the petioles as compared with levels of these same chemicals in the thin juice. It is well to keep in mind that the petioles are part of the tops of the sugar beet plant, whereas the thin juice is prepared from the roots.

2. The interactions involving genotypes × materials analysed (petioles or thin juice) have shown that, at time of harvest, higher levels of the three chemicals occur in either the petioles or the thin juice, or in both. Conversely, at time of harvest, some genotypes have higher levels of these three chemical characters in the petioles associated with lower levels in the thin juice.

3. This latter finding is of extreme importance to the beet sugar industry, because it shows that populations can be bred that will have the higher levels of these chemicals in the tops (petioles) of the sugar beet rather than in the roots (thin juice). The higher levels of these three chemicals in the thin juice have a decidedly adverse effect with percentage sucrose and on percentage apparent purity (see Powers and Payne, 10).

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