Effect of Nitrogen Fertilization on Yield and Quality of Sugar Beets[1]

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The need for greater efficiency in production of sugar beets has caused an increase in the use of nitrogen fertilizer on this crop. In some areas there has been excessive use of nitrogen which has resulted in lower quality beets. The influence that nitrogen fertilizer has on quality will depend not only upon the rate of fertilization but also upon other management practices as well as variety and season. The objective of this study was to determine the interactions of rate of nitrogen fertilization, date of planting, and plant spacing in the row on yield and quality of the beet.

Materials and Methods

The experiment was conducted on a Rocky Ford loam located on the Arkansas Valley Branch Station near Rocky Ford, Colorado. Analysis of a representative soil sample from the experimental area showed 1.7% $CaCO_3$, 1.2% organic matter (6)[3], and 40 lb available P_2O_5 per acre by the sodium bicarbonate procedure (4). Previous crops were sorghum in 1959, corn in 1958 and alfalfa in 1957. Thirty-eight pounds of nitrogen was applied in 1959 for sorghum but no fertilizer was used for corn.

The experiment was designed as a factorial with 4 fertility treatments, 2 dates of planting, and 2 stands. There were 4 replications. The fertilizer treatments, expressed on an acre basis, were: 1) no-nitrogen check, 2) 40 lb nitrogen preplant, 3) 120 lb nitrogen preplant, and 4) 120 lb nitrogen side-dressed June 17, at the time of thinning. Preplant nitrogen fertilizer was broadcast in the spring before plowing. The side-dressed fertilizer was applied about five inches from the row in alternate middles not used for irrigation. Ammonium nitrate was the nitrogen source. Concentrated super phosphate, applied at the rate of 100 lb P_2O_5 per acre, was broadcast uniformly over the experimental area before plowing.

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[3] Numbers in parentheses refer to literature cited.

Planting dates were April 7 and May 3, 1960, with a commercial monogerm seed. The sugar beet stands established for the experiment were 1) 12 to 14 inch spacing and 2) 6 to 7 inch spacing of plants in 22-inch rows. The heavy population was not attained in harvested beets, however, and the average stand counts based on beets recovered at harvest were 9 inches for the heavy stand and 13 inches for the normal stand. Some of the smaller beets from the heavy population were lost during harvest which reduced recovery of beets and the apparent stand.

The beets were harvested November 3, and root samples were taken for sugar, purity and analysis of the pressed juice. Crop yields may have been reduced somewhat by a severe hail in June; otherwise, growing conditions were good. At harvest, foliage on the check treatments exhibited marked nitrogen deficiency symptoms and the treatments receiving 40 lb nitrogen showed slight nitrogen deficiency.

Leaf petioles were sampled July 12, August 5 and September 15. The petioles were analyzed for total nitrogen, nitrate-nitrogen, and acetic-acid soluble phosphorus (3). The pressed juice in the beets at harvest was analyzed for nine amino acids by paper chromotography methods as outlined by Hanzas[4]. Galactinol and raffinose were determined by paper chromatography procedures similar to those reported by Brown (2). Potassium and sodium were determined with the flame photometer (1) and total nitrogen by a microkjeldahl procedure (5).

Results and Discussion

Yield and Quality of Roots

Root yields, sucrose content, sucrose production and purity are summarized in Table 1 for the main effects of fertilizer treatment, date of planting and spacing in the row. The analysis of variance (Table 1) shows that the main effects of fertilizer treatment were significant for root yield, sucrose content and purity, but not for sucrose production. The first increment of nitrogen (40 lb) increased the yield of roots, but there was no additional response to the next increment of nitrogen. Both sucrose content and purity decreased with each nitrogen rate. The application of nitrogen did not significantly increase sucrose production at the five percent level of significance. The trend was for a small increase for the 40-lb rate followed by a decrease in sucrose for the 120-lb rate of nitrogen.

[4] "A paper chromatographic method for semiquantitative analysis of amino acids found in sugar beet juices" (1957); unpublished report by P. C. Hanzas, Research Station, American Crystal Sugar Company.

Table 1.—Effect of fertilizer treatment, date of planting and plant spacing in the row, on yield and quality of sugar beets.

Treatment	Root yield T/A	Sucrose %	Sucrose production T/A	Purity %
lb N/A				
0 (check)	20.7	16.4	3.39	90.3
40	22.6	15.4	3.48	89.2
120	22.2	14.5	3.22	86.9
120[1]	22.0	15.0	3.30	89.1
Early plant	22.9	15.4	3.53	88.6
Late plant	21.6	14.9	3.22	88.6
9 in spacing	22.3	15.2	3.39	88.4
13 in spacing	22.3	15.2	3.39	88.7
Significance for:				
Fertilizer treatment	**	**	N.S.	**
Planting date	*	+	**	N.S.
Plant spacing	N.S.	N.S.	N.S.	N.S.

+ Significant at 10% level of significance
* " " 5% " " "
** " " 1% " " "
[1] Side-dressed at thinning

The early planted beets yielded 1.3 tons more than the late planted beets, and were 0.5% higher in sucrose content (Table 1). Sucrose production was significantly lower for the second date of planting. Purity was not affected by date of planting.

There were no significant effects of plant stand on yield or quality of root (Table 1). The lack of significance may have been caused, at least in part, by too small a difference between the two stands.

The application of 120 lb nitrogen at thinning resulted in about the same yield and quality of beet as the same rate of fertilizer applied preplant. There was no apparent adverse effect on quality.

Of greater interest than the main effects are the interactions between rate of nitrogen and date of planting (Table 2). Planting date had little effect on yield of the check treatment (no nitrogen); on the other hand there was a significant yield response to 40 lb nitrogen for the early planting but not for the late planting. There was no further response to the 120-lb rate of nitrogen for either planting date. When 120 pounds nitrogen was side dressed at thinning for the early or late-planted beets, yield and quality of roots did not differ significantly from results obtained with the same amount of nitrogen applied preplant.

There was a marked decrease in sucrose content when nitrogen fertilizer was applied and the decrease tended to be greater for

Table 2.—Influence of nitrogen fertilizer and date of planting on yield and quality of sugar beets.

Fertilizer lb N/A	Planting date	Root yield T/A	Sucrose %	Sucrose T/A	Purity %
0 (Check)	4-7-60	20.5	16.5	3.38	90.6
40	"	23.6**	15.6	3.68*	90.5
120	"	22.9**	14.9*	3.41	86.7*
120[1]	"	22.2**	15.1*	3.35*	88.4*
0 (Check)	5-3-60	20.9	16.3	3.41	90.0
40	"	21.5	15.2	3.27	87.9
120	"	21.6	14.2**	3.08*	87.1
120[1]	"	21.9	14.7*	3.22	89.9

* Differs from check for the same date of planting at 5% level of significance.

** Differs from check for same date of planting at 1% level of significance.

[1] Nitrogen fertilizer side-dressel at thinning.

the late planted beets. The application of nitrogen fertilization caused a decrease in purity of the beet, but the effect was not as pronounced as for sucrose content.

For the early planting, the application of 40 lb nitrogen increased sucrose production whereas there was the trend for the same amount of nitrogen to cause a small decrease in sugar for late-planted beets. The high rate of nitrogen significantly decreased sucrose production for the late planting. If the value of the sugar is calculated as 4¢ per pound, and the cost of nitrogen is 13¢ per pound, 0.065 tons sugar per acre is required to equal the cost of 40 lb of nitrogen, and 0.195 tons sucrose is needed to pay for 120 lb nitrogen. On this basis 40 lb nitrogen for the early planting was the only fertilizer treatment (Table 2) that gave an increase in sucrose production large enough to balance or exceed the cost of the fertilizer. The results emphasize the need to consider date of planting when making nitrogen fertilizer recommendations for beets. The recommended rate of fertilization with nitrogen should be flexible, and if planting is delayed it may be necessary to reduce the amount of fertilizer applied.

Petiole Analyses

The results of petiole analyses for nitrate-nitrogen and acid soluble phosphorus are given in Table 3 for three sampling dates. There were no significant differences between stands for petiole nitrogen or phosphorus at any sampling date.

The application of nitrogen fertilizer increased the nitrate-nitrogen in the petioles. The effect persisted throughout the season and was associated, at harvest, with lower sucrose in the root (Table 1). The petiole nitrate was slightly lower for the delayed application of nitrogen than for the same amount of

Table 3.—Effect of fertilizer treatment and date of planting on nitrate-nitrogen and acid-soluble phosphorus in petioles.

Treatment	Nitrate-nitrogen sampling date			Acid-soluble phosphorus sampling date		
	7-11-60	8-5-60	9-9-60	7-11-60	8-5-60	9-9-60
lb N/A	ppm NO_3-N			ppm P		
0 (Check)	7810	4600	1140	2400	1600	970
40	9580	4980	1820	2270	1580	1040
120	14610	9490	3150	2180	1560	1050
120[1]	11830	6160	1930	2330	1620	980
Early plant	9370	5200	1330	2070	1510	1050
Late plant	13920	8330	3420	2500	1690	980
Significance for Fertilizer treatment	**	**	**	N.S.	N.S.	N.S.
Date of planting	**	**	**	**	**	N.S.

** Significant F-test at 1% level of significance.
[1] Nitrogen fertilizer side-dressed at thinning.

nitrogen applied at planting; and sucrose content and quality were slightly higher for the delayed treatment (Table 1). The nitrogen for this treatment was side dressed at thinning between alternate unirrigated rows. Placement of the fertilizer in this position may have been less favorable for efficient absorption of nitrogen by the plant than plowing under the fertilizer for the preplant application.

Nitrate nitrogen was higher in the petiole for the late-planted beets at all sampling dates. This was associated with a lower sucrose content of the root for the late planted beets (Table 1). The results show that the late-planted beets did not "ripen" to the same degree as did the early-planted beets.

The acid soluble phosphorus content of the petioles was not affected by the application of nitrogen fertilizer. Phosphorus was higher in petioles from the late-planted beets for the July and August samplings but not for the September sampling. The trends were probably caused, as with nitrate nitrogen, by reduced plant growth and lower crop demands on soil nutrients by the late-planted beets.

Chemical Composition of Pressed Juice

Total nitrogen, total amino acids, sodium, potassium and raffinose were determined in the pressed juice. The results are summarized in Table 4. The nine individual amino acids were summed for total amino acids in Table 4 since individual statistical analyses showed that they all reacted in a similar way to the imposed treatments.

Table 4.—Effect of fertilizer treatment and date of planting on partial chemical analysis of pressed juice (percent on dry basis).

Treatment	Total N[2] %	Total amino[2] acids+ %	Sodium[3] %Na	Potassium[3] %K	Raffinose[2] %	Galactinol[2] %
lb N/A						
0 (Check)	0.56	0.71	0.067	0.153	0.40	0.25
40	0.65	0.84	0.086	0.165	0.41	0.25
120	0.74	1.23	0.111	0.164	0.42	0.30
120[1]	0.68	0.96	0.084	0.157	0.43	0.25
Early plant	0.61	0.81	0.083	0.155	0.43	0.26
Late plant	0.73	1.06	0.097	0.163	0.42	0.27
Significance for:						
Fertilizer treatment	**	**	**	N.S.	N.S.	N.S.
Planting date	**	**	*	N.S.	N.S.	N.S.

+ Sum of nine amino acids: alanine, asparagine, aspartic acid, glutamine, valine, isoleucine, glycine, glutamic acid, gamma amino butyric acid.
* Significant F-test at five percent level.
** Significant F test at one percent level.
[1] Side-dressed at thinning.
[2] Dissolved substance basis.
[3] On beet root weight.

The total nitrogen and amino acid contents of the pressed juice increased when nitrogen fertilizer was added, and were higher for the late-planted beets. Trends for nitrogen components in the pressed juice were similar to the nitrate-nitrogen in the petiole and were negatively associated with sucrose content of the root.

Sodium in the pressed juice increased with an increase in rate of nitrogen fertilizer and was also higher for the late planting. The sodium content of the pressed juice was positively associated with changes in total nitrogen and amino acids in the pressed juice and with nitrate-nitrogen in the petioles. In experiments conducted in northeastern Colorado, it has also been observed that where application of nitrogen fertilizer increased nitrate-nitrogen in the petiole, the sodium content also increased (7).

The potassium, raffinose, and galactinol contents of the pressed juice were not influenced, at the five percent level of significance, by either nitrogen fertilization or date of planting.

Summary

An experiment was conducted to study the influence of nitrogen fertilization, date of planting, and plant spacing in 22-inch rows on yield and quality of sugar beets.

Early planted beets produced higher yields and more sucrose than late-planted beets.

Forty-pounds nitrogen increased sugar production when the beets were planted April 7, but the same amount of nitrogen applied to beets planted May 3, failed to increase sugar production. Application of 120 lb nitrogen decreased sucrose production for the late planting.

The application of nitrogen fertilizer increased the total nitrogen and amino acids in the pressed juice and nitrate-nitrogen in the petioles and decreased the sucrose content and purity of the root. Sodium content of the pressed juice was associated in a positive relationship with nitrogen content of the pressed juice and nitrate-nitrogen in the petiole.

Plant spacings of 9 and 13 inches in the row had little effect on yield and quality of root.

The experiment demonstrates the need to adjust the rate of nitrogen fertilization with date of planting in climatic areas where the harvest date cannot be extended.

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