

A Study and Economic Appraisal of the Effect of Nitrogen Fertilization and Selected Varieties on the Production and Processing of Sugar Beets

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Introduction

During recent years, the problem of declining net extraction in the beet sugar industry has focused attention on factors which influence the type and amount of nonsugars entering the process (15, 16, 9).² Increased availability and use of commercial fertilizers are known to be one of these factors (11, 13, 17). In addition, new varieties have been introduced periodically with little or no thought given to their possible effect on the process.

Since the upward trend in the use of nitrogen fertilizers continues and the possibility now exists for developing new varieties with reduced amounts of certain nonsugars, there is need for experimental data concerning the influence of nitrogen fertilization and varieties on the production and processing of beet sugar. Moreover, since production and processing of sugar beets are commercial ventures, the above mentioned problems should also be evaluated on a monetary profit and loss basis. With these problems in mind the experiment reported herein was designed to study the effect of three levels of nitrogen fertility and seven sugar beet varieties on production and extraction of sugar. A concerted effort was made throughout to obtain data which would permit realistic dollar values to be assigned for an economic appraisal of the results obtained.

Materials and Methods

The field selected for the test was a sandy loam soil located in the Nyssa, Oregon district and had a cropping history of beets, grain, and corn with no nitrogen fertilizer applied to the corn crop. During the previous season the corn showed extreme nitrogen deficiency symptoms indicating a low level of nitrogen fertility.

The experimental design was a randomized split plot with eight replications. Seven varieties were planted as the main plots, 18 rows wide and 40 feet long. Each main plot was divided into

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² Numbers in parentheses refer to literature cited.

three six-row subplots for the three separate levels of nitrogen fertility. Each replication was separated by a three foot alleyway.

The plots were planted on April 7, 1955, using 22-inch row spacing. The varieties included in the test were:

1. SLC 824 (US 35/2)—An open pollinated, high sugar, curly-top resistant variety.
2. C-51-1—A new potential commercial variety derived from rigid selection for high sugar and low sodium content within an open pollinated variety.
3. A2-90H0 (CT9)—The male sterile equivalent of a curly-top resistant inbred line which is relatively low in sucrose content.
4. US 22/3—A standard open pollinated tonnage variety with excellent curly-top resistance but low sucrose content.
5. US22S—Currently used commercial variety resulting from a blend of SLC 824 and N47.
6. F54-2H—A monogerm hybrid.
7. 4323SB—A "hybrid" between A2-90H0 and SLC 824 produced by blending the seed of the parental lines prior to planting the commercial seed field.

During spring seedbed preparation of the fall plowed land, 126 units of P_2O_5 and 65 units of nitrogen in the form of granular fertilizers were disced into the soil. This was done to provide an adequate level of P_2O_5 for the season and sufficient nitrogen to support early growth on all plots.

Additional applications of nitrogen were applied in the form of anhydrous ammonia by side dressing in alternate furrows midway between the rows and at a depth of six inches. A metering pump was used to regulate the amount of fertilizer applied. On June 9, 75 pounds of nitrogen per acre were applied to the medium and high fertility plots thus raising the level on these plots to 140 units per acre. Again on July 5, in two separate applications of 70 lbs. each, 140 lbs. of nitrogen per acre were applied to the high nitrogen plots. Thus, the three rates of nitrogen fertilization were established at 65, 140, and 280 pounds per acre.

Locally accepted practices of cultivation and irrigation were followed. The alternate rows in which the fertilizer was injected were used for irrigation until the last two irrigations when the water was changed to the alternate set of rows.

Petiole samples were taken just prior to harvest according to the method outlined by Ulrich (18). Each sample consisted

of 30 to 40 petioles taken at random from the two center rows of each subplot.

The plots were harvested on October 13. To reduce possible border effects, 18 inches of row were discarded from each end of all plots and only the two center rows of each subplot were harvested for yield measurements and to supply roots for processing. Two ten-beet samples were taken from each subplot to determine sucrose content at harvest. An additional 150 pounds of beets from each subplot were placed in cold storage for the processing studies conducted at Central Laboratory, Twin Falls, Idaho.

Beets from each subplot were removed from storage for processing at such a time as to provide an equal storage period for each variety-nitrogen level condition. Thus storage time did not become a variable.

Upon removal from storage the beets were washed and sliced into cossettes which were thoroughly mixed. Samples of the cossettes were analyzed for sugar, sodium, and potassium (8). Samples were also furnished to International Minerals and Chemical Corporation, Research Laboratory, Woodland, California, for glutamic acid assays by the microbiological method (10). Juice prepared from the cossettes was analyzed for apparent purity (12), total nitrogen including that in the form of nitrate (1), phosphate (7), total ash (2), invert sugar (3), and raffinose (4). The amino nitrogen compounds were estimated by boiling 10 ml. of the juice with three pellets of pure sodium hydroxide almost to dryness, determining the nitrogen content of the residue (1), and multiplying this result by a factor of 7.5.

The cossettes were processed in a continuous, countercurrent flow, pilot diffuser under the following conditions:

Temperatures: First 15% of cossette travel—82° C.
Remainder of cossette travel 70° C.

Retention time: 36 minutes

Pulp, % Sugar: 0.18

Draft: Varied as necessary to maintain desired sugar level in pulp.

Diffusion juice samples were analyzed for apparent purity, total ash, invert sugar, and amino nitrogen compounds by the same methods as used for the beet press juice.

Carbonation was simulated by preparing thin juice from diffusion juice in the manner described by Brown and Serro for beets (5). Thin juice samples were analyzed for apparent purity, amino nitrogen compounds, and monosodium glutamate (MSG). The latter was determined by the decarboxylase method (14).

Where samples of cosettes and juices were not analyzed immediately after preparation, they were quick frozen for storage.

The economic evaluation was based on factual values. To facilitate the calculation of realistic figures for growing and processing each variety at each nitrogen fertility level, the sugar content and yield averages were applied to 20,000 acres and an assumed slicing rate of approximately 3500 tons per day. The processor's various agricultural and processing costs used in this study include beet freight, beet receiving expenses, beet labor expense, general agricultural expense, operating supplies and other raw materials, operating labor, maintenance and repairs, local general expense, insurance, taxes, depreciation, and sugar loss in storage. These costs were balanced against returns for salable sugar (corrected for sales expense), molasses, pulp and C.S.F. to establish a processor's earnings for each condition tested.

The grower costs included only the harvesting and delivery and the cost of fertilizer actually removed in the beets, using current fertilizer prices. Other grower costs were deemed too dependent on the type of operation and individual efficiency to be included as fixed costs. It was assumed that the fertilizer content of the beet tops would be returned to the soil.

To estimate sugar losses in storage a special method was developed. It was first assumed that there would be 10 days of direct delivery, which allowed 35,000 tons of beets at no storage loss. The remainder of the beets from 20,000 acres was considered in storage.

The tonnage entering storage was then converted to sugar by applying the sugar content figure. An amount of sugar was calculated to be removed daily from storage which was equivalent to 3500 tons of beets plus a sugar loss in the pile. This procedure continued until the amount of sugar in storage was eliminated.

The daily sugar loss value was taken from Figure 1 which describes the rising losses (as percentage of sugar entering storage) against storage time. These data were plotted from the results of storage tests conducted under conditions considered ideal.

Storage losses calculated in these tests were found to compare favorably with losses under actual conditions calculated by the method of Cottrell (6) for the same acreage.

The final molasses apparent purity was assumed to be 62.0 at a brix of 79.5. This, together with a nominal sugar loss in the process and thin juice apparent purity, provided the data necessary for calculating extraction.

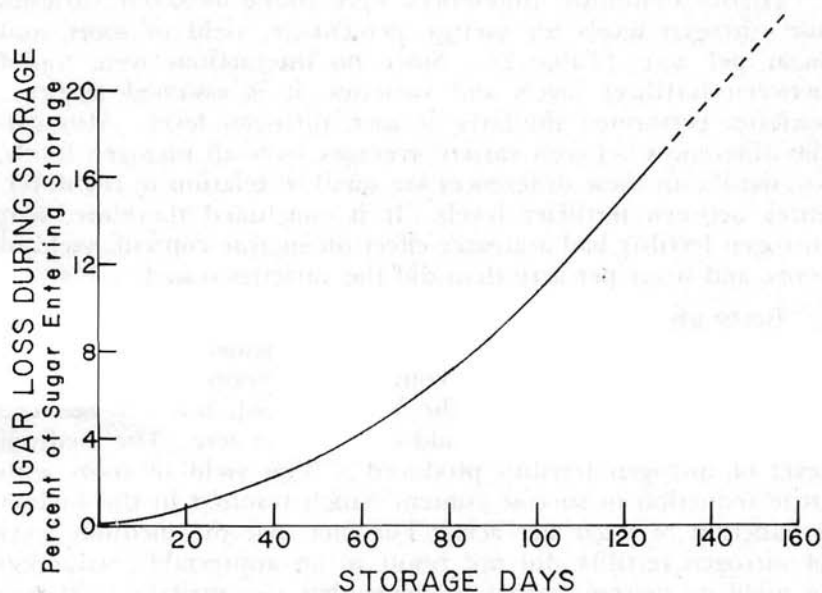


Figure 1.—Daily sugar loss during storage.

Results and Conclusions

Petiole Analysis:

Petiole samples taken at harvest showed highly significant differences for both NO_3 and P_2O_5 concentration (Table 1). For NO_3 the differences were highly significant for both varieties and nitrogen fertility levels whereas differences in P_2O_5 were significant for fertility levels only. Although the variation in P_2O_5 in the petioles was relatively small in comparison to NO_3 concentration, there appeared to be a slight decrease in P_2O_5 as the nitrogen applications were increased.

The generally accepted critical level for NO_3 in the petioles is 1000 P.P.M. and 750 P.P.M. for P_2O_5 (19). On this basis it can be assumed that P_2O_5 was well above the deficiency level for all plots whereas NO_3 was below the deficiency level for the low and medium fertility plots at harvest. The high concentration of NO_3 in the petiole of beets grown on the high level of nitrogen fertility shows that an excess of nitrogen was available to these plots at harvest time.

Percent Sucrose, Yield and Gross Sugar per Acre:

Highly significant differences were found between varieties and nitrogen levels for sucrose percentage, yield of roots, and sugar per acre (Table 2). Since no interactions were found between fertilizer levels and varieties, it is assumed that the varieties performed similarly at each nitrogen level. Although the differences between variety averages, over all nitrogen levels, are significant these differences are small in relation to the differences between fertilizer levels. It is concluded therefore, that nitrogen fertility had a greater effect on sucrose content, yield of roots, and sugar per acre than did the varieties tested.

Beets grown on low nitrogen fertility plots were of high sugar content, but the low root yield resulted in the lowest yield of sugar per acre. In contrast, the roots from the high nitrogen fertility plots had the highest yield, but the reduced sugar content depressed the yield of sugar per acre. The medium level of nitrogen fertility produced a high yield of roots with little reduction in sucrose content which resulted in the highest production of sugar per acre. The fact that the medium level of nitrogen fertility did not result in an appreciable reduction in yield or sucrose content suggests that the available nitrogen was near depletion at or just prior to the time the beets were harvested. Additional evidence from the analysis of NO_3 nitrogen in the petioles at harvest likewise supports this conclusion and which is in agreement with work done by Ulrich (17). In any event, since the yield of roots was near that of the high level plots, it must be assumed that for the major part of the growing season the medium fertility plots had sufficient nitrogen available to support normal growth.

Nonsugars in the Beet:

It is apparent from Table 3 that the amino nitrogen constituents and ash make up a large portion of the total nonsugars present in the beets. The remaining impurities are present in relatively smaller amounts but certain of these are of special importance in the process. For the purposes of sucrose production, invert sugar and raffinose are classed with nonsugars.

The effects of nitrogen fertilization and varieties on the quantities of total nonsugars, amino nitrogen constituents, and ash in the beet are given in Table 3. The concentration of these impurities increased in the beet as the rate of nitrogen application increased. The same marked effects of nitrogen fertilization were noted for concentrations of MSG, total nitrogen, potassium, and sodium. No significant difference was found in invert or

raffinose content due to nitrogen fertility levels, although in the case of the latter there was some difference due to varieties. The effect on P_2O_5 concentration was small although statistically significant.

Table 1.—Variety and Fertilizer Averages for Concentration of NO_3 and P_2O_5 in Petioles at Harvest as Parts Per Million.

Variety	NO_3	P_2O_5
SLC 824	1090	1270
C-51-1	1270	1180
A2-90H0	2050	1270
US22/3	1580	1300
US22S	1410	1170
F54-2H	1860	1390
4323SB	1630	1230
LSD .05	578	N.S.
Nitrogen Levels		
65 lbs./acre	720	1370
140 lbs./acre	700	1210
280 lbs./acre	3240	1200
LSD .05	304	72
.01	403	95
Test Ave.	1560	1260

Table 2.—Variety and Nitrogen Level Averages for Percent Sucrose at Harvest, Yield and Gross Sugar Per Acre.

Variety	Sucrose Percent	Yield Tons/Acre	Gross Sugar Lbs./Acre
SLC 824	16.8	23.1	7780
C-51-1	16.5	26.0	8540
A2-90H0	15.9	24.5	7760
US22/3	15.9	25.5	8080
US22S	16.6	23.6	7820
F54-2H	16.6	25.7	8560
4323SB	16.3	25.0	8140
LSD .05	0.3	1.4	480
.01	0.4	1.9	660
Nitrogen Levels			
65 Lbs./Acre	16.8	20.7	6960
140 Lbs./Acre	16.7	26.4	8820
280 Lbs./Acre	15.6	27.3	8520
LSD .05	0.19	0.7	240
.01	0.25	0.9	320
Test Ave.	16.4	24.8	8100

Table 3.—Variety and Nitrogen Level Averages for Concentrations of Nonsugars in the Beet as Pounds Per Ton of Beets.

Varieties	Total Nonsugars	Amino Nitrogen Constituents	Ash Constituents	Invert Sugar	Total Nitrogen (incl. NO ₃)	P ₂ O ₅	Sodium	Potassium	MSG	Raffinose
SLC 824	42.4	17.2	12.0	2.4	2.6	1.1	.294	1.84	3.9	2.0
C-51-1	43.5	16.7	12.9	2.5	2.5	1.5	.324	1.98	3.4	2.1
A2-90H0	42.2	16.4	12.2	2.4	2.5	1.1	.379	1.85	3.0	1.8
US22/3	42.1	16.5	13.6	2.4	2.4	1.1	.441	2.08	3.3	1.9
US22S	43.7	17.0	12.7	2.9	2.6	1.5	.331	1.86	3.6	1.8
F54-2H	40.8	15.4	12.2	2.4	2.4	1.3	.333	1.77	2.8	2.0
4323SB	42.6	16.8	12.9	2.4	2.6	1.3	.379	1.95	3.5	1.7
LSD .05	N.S.	1.0	0.9	N.S.	N.S.	0.14	.043	0.11	0.53	0.23
.01	N.S.	N.S.	1.2	N.S.	N.S.	0.19	.058	0.15	0.71	0.30
Nitrogen Levels										
65 Lbs./Acre	37.5	13.0	11.0	2.5	1.9	1.1	.257	1.74	1.6	2.0
140 Lbs./Acre	40.8	16.0	12.7	2.4	2.4	1.4	.309	1.84	2.8	1.8
280 Lbs./Acre	49.2	20.7	14.3	2.6	3.2	1.3	.497	2.13	5.7	1.9
LSD .05	1.1	0.6	0.6	N.S.	0.09	0.08	.025	0.08	0.25	N.S.
.01	1.4	0.7	0.8	N.S.	0.12	0.10	.033	0.10	0.33	N.S.
Test Ave.	42.5	16.6	12.6	2.5	2.5	1.4	.354	1.90	3.4	1.9

In general, the nitrogen levels caused greater variations in the amounts of nonsugars present in the beets than did the varieties tested. This was particularly evident for total nitrogen and amino nitrogen compounds. For example, in comparing the range in variety averages to the range in fertility level averages (Table 3) for amino nitrogen constituents, it is evident that the effects of nitrogen fertility were greater than varietal effects. The same is true for ash but the differences in ranges are not nearly so striking. Two exceptions to this generalization were raffinose and P_2O_5 content for which varietal effects were greater than fertilizer effects.

Significant interactions of varieties \times nitrogen fertility levels were found for sodium content. The interaction was primarily due to the behavior of variety US 22/3 which had proportionately higher sodium content than the other varieties under high nitrogen fertility. The indicated interaction for MSG as well as for amino nitrogen was primarily the result of variety F54-2H being proportionately lower than the other varieties under high nitrogen fertility, but the interaction F value only approached significance at the .05 level of probability.

The data presented indicate that both varieties and nitrogen fertility levels can appreciably influence the amount of nonsugars present in beets. Excessive nitrogen fertilization is particularly harmful because of the direct effect of nitrogen on the nonsugar constituents as well as sucrose content.

Elimination of Nonsugars in the Process:

For the purpose of evaluating the processing tests, the results were calculated on the basis of sugar rather than tons of beets. Table 4 shows that on this basis the nonsugar load entering the process increased 10.5 percent from the low to medium nitrogen fertility condition and another 31.0 percent from the medium to high nitrogen level. The maximum difference attributable to varieties was 11.2 percent.

In general, as the nonsugar load increased with the nitrogen fertility, the elimination by diffusion also increased, but not proportionately. Elimination by simulated carbonation was generally the same regardless of the amount of nonsugars entering; therefore, the total beet end elimination did not proportionately adjust to increases in the amounts of nonsugars introduced. The amounts and types of nonsugars remaining in the process will determine the sugar and molasses production, upon which the economics of processing sugar beets rests.

There were significant differences in total nonsugars remaining due to varieties.

Table 4.—Total Nonsugars Removed by Diffusion and Carbonation as Pounds Per 100 Sucrose.

	Entering	Removed			Remaining
		Diffusion	Carbonation	Total	
Averages for Varieties, All Nitrogen Levels					
SLC 824	12.0	2.1	4.3	6.4	5.6
C-51-1	12.6	2.6	4.4	7.0	5.6
A2-90H0	12.9	2.5	3.9	6.4	6.5
US22/3	12.8	2.2	4.6	6.8	6.0
US22S	12.5	2.3	4.5	6.8	5.7
F54-2H	11.6	2.2	4.3	6.5	5.1
4323SB	12.5	2.1	4.3	6.4	6.1
LSD .05	1.38	0.43	0.56	0.95	1.06
Averages for Nitrogen Levels, All Varieties					
Low	10.5	2.1	4.3	6.4	4.1
Medium	11.6	2.2	4.3	6.5	5.1
High	15.2	2.6	4.4	7.0	8.2
LSD .05	0.68	0.40	0.27	0.47	1.22

Purity values also reflect the elimination of nonsugars. As shown in Table 5, highly significant differences resulted between varieties and nitrogen fertility levels. These differences appear to be relatively constant for purities shown. As was the case with the nonsugars studied, the effect of nitrogen fertility levels was more pronounced than were varietal effects.

Due primarily to variety F54-2H, a significant variety \times nitrogen level interaction for purity was found (Table 5, thin juice values for varieties at all nitrogen levels). This can be traced to the indicated interaction found in MSG and amino nitrogen constituents already discussed in the section concerning nonsugars in the beet. Variety F54-2H did not show an increased concentration of these nonsugars in proportion to that of other varieties under the high level of nitrogen fertility. The interaction also appeared in total nonsugars entering and remaining in the process (Table 4) but approached significance at the .05 level of probability. Since purity is the ratio of sugar to total dissolved solids (sugar plus nonsugars) expressed as percent, the significant variety \times fertilizer interaction found for purity might be expected.

The amino nitrogen constituents were followed through the process in the same manner as the total nonsugars. Table 6 is a tabulation of the results. The increases in removal of amino nitrogen compounds with the rise in nitrogen fertility levels are

Table 5.—Variety and Nitrogen Level Averages for Purities in Beet Juices with Individual Variety Nitrogen-Level Averages for Thin Juice.

Variety	Variety Averages		
	Beet	Diffusion	Thin
SLC 824	89.5	90.9	94.6
C-51-1	88.9	90.9	94.6
A2-90H10	88.6	90.7	94.0
US22/3	88.7	90.5	94.4
US22S	88.8	90.7	94.5
F54-2H	89.6	91.4	95.1
4323SB	88.9	90.7	94.3
LSD .05	0.52	0.51	0.50
.01	0.69	0.68	0.68
Nitrogen Levels			
65 lbs./acre	90.5	92.2	96.0
140 lbs./acre	89.6	91.4	95.1
280 lbs./acre	86.6	88.8	92.4
LSD .05	0.28	0.24	0.23
.01	0.37	0.32	0.30
Test Ave.	89.0	90.8	94.5
Nitrogen Levels, Thin Juice			
Variety	65 lbs.	140 lbs.	280 lbs.
SLC 824	96.2	95.1	92.6
C-51-1	96.2	95.2	92.5
A2-90H10	95.8	94.7	91.5
US22/3	95.9	95.3	92.0
US22S	95.9	95.1	92.6
F54-2H	96.3	95.4	93.7
4323SB	95.9	94.8	92.0
LSD .05 between varieties within nitrogen levels = 0.70			

significant, but again not proportional to amounts entering. Varieties caused no significant differences in the elimination of these compounds. The variety F54-2H was significantly lower in amounts of amino nitrogen compounds entering the process, which is in accordance with previous comments made on this variety.

Because of its commercial importance, the amino nitrogen compound mono-sodium glutamate was measured in the beets and thin juice. No elimination of this compound was found. This is possibly due to the fact that different methods were used for the determination. Table 7 shows the amounts found in the beet and in thin juice. Nitrogen fertility levels caused significant

differences in MSG while differences due to varieties were not significant. Variety F54-2H showed the least amount of MSG.

The following figures based on averages for nitrogen levels, over all varieties, show the relationship of MSG to the total amino nitrogen compounds as measured in thin juice.

Nitrogen Fertility Levels		
Low	Medium	High
24.3%	31.9%	42.1%

In these tests the ash constituents were measured in press juice and diffusion juice. Little or no elimination was accomplished by diffusion. The ash content in both the beet and diffusion juice showed significant differences due to nitrogen fertility and varieties (Table 7). The ranges of the averages show that the effects of nitrogen fertility are greater than the effects of varieties.

The invert sugar content of beet and diffusion juice showed a significant rise with the nitrogen fertility level which is also shown in Table 7. There were no significant differences in invert content caused by varieties. The over-all elimination of invert sugar was 0.25 pound per 100 sucrose or 34.2 percent of the average amount entering in the beet.

Table 6.—Amino Nitrogen Compounds Removed by Diffusion and Carbonation as Pounds Per 100 Sucrose.

	Entering	Removed			Remaining
		Diffusion	Carbonation	Total	
Averages for Varieties, All Nitrogen Levels					
SLC 824	4.9	1.2	0.8	2.0	2.9
C-51-1	4.9	1.2	0.9	2.1	2.8
A2-90H0	5.0	1.2	0.8	2.0	3.0
US22/3	5.0	1.2	0.9	2.0	3.0
US22S	4.9	1.2	0.8	1.9	3.0
F54-2H	4.4	1.1	0.8	1.9	2.5
4323SB	4.9	1.2	0.8	1.9	3.0
LSD .05	0.34	N.S.	N.S.	N.S.	N.S.
Averages for Nitrogen Levels, All Varieties					
Low	3.7	1.1	0.7	1.8	1.9
Medium	4.5	1.1	0.8	1.9	2.6
High	6.4	1.3	0.9	2.2	4.2
LSD .05	0.25	0.17	0.11	0.17	0.66

Raffinose content was measured only on beets. It is shown in Table 7 for comparison with other nonsugars when calculated on a sugar basis. As such there were significant differences due to nitrogen fertility levels and varieties. The ranges of differences show that varieties had a greater influence on raffinose content than did nitrogen levels. This was the only constituent measured in which varieties showed a greater influence than nitrogen fertility levels.

Table 7.—Variety and Nitrogen Level Averages for Concentrations of Nonsugars as Pounds Per 100 Sucrose.

Varieties	M. S. G.		Ash		Invert		Raffinose
	Beet	Thin Juice	Beet	Diff. Juice	Beet	Diff. Juice	Beet
SLC 824	1.10	1.05	3.41	3.35	.67	.47	.55
C 51-1	.97	1.05	3.74	3.65	.72	.50	.60
A2 90110	.90	.98	3.73	3.63	.73	.45	.55
US22/3	.99	1.04	4.10	4.15	.72	.49	.58
US22S	1.04	1.04	3.67	3.53	.84	.53	.51
F54-2H	.79	.86	3.50	3.36	.69	.45	.57
4323SB	1.02	1.10	3.77	3.68	.72	.45	.49
LSD .05		N.S.	0.30	0.29	N.S.	N.S.	.07
.01		N.S.	0.40	0.29	N.S.	N.S.	N.S.
Nitrogen Levels							
65 lbs./acre	.43	.46	3.09	3.10	.69	.45	.55
140 lbs./acre	.81	.84	3.59	3.45	.70	.46	.52
280 lbs./acre	1.74	1.76	4.43	4.32	.79	.53	.57
LSD .05		N.S.	0.30	0.22	N.S.	N.S.	.07
.01		0.15	0.23	0.17	.09	.06	N.S.
Test Ave.	0.98	1.02	3.70	3.62	.73	.48	.55

Extraction:

Those nonsugars which remain in the juice after carbonation will enter the crystallization phase of the process, and as a group will depress the crystallization rate of the associated sucrose to the point where it becomes impossible to further extract sucrose economically by crystallization. At this stage the product is molasses, not sugar. Net extraction is the ratio of salable white sugar produced to the total amount of sugar entering the process, expressed as percentage. It is actually an efficiency figure for the processing of sugar beets and as such is of prime importance to the economics of sugar processing.

Table 8 lists the net extraction figures calculated from the results of these tests (see Methods and Materials). Varieties caused no significant differences but every rising step in the nitrogen fertility level caused a significant drop in net extraction.

Table 8.—Percent Extraction.

Variety	Low	Medium	High	Variety Average
SLC 824	91.9	90.0	85.3	89.1
C-51-1	91.9	90.0	85.1	89.0
A2-90H0	91.2	89.1	84.7	88.3
US22/3	91.3	90.2	84.0	88.5
US22S	91.4	90.0	85.3	88.9
F54-2H	92.1	90.4	87.3	89.9
4323SB	91.4	89.4	84.1	88.3
N level Ave.	91.6	89.9	85.1	88.9

LSD .05 between variety averages = 1.7
LSD .05 between nitrogen level averages = 0.9

It is of interest to note that although it is not significant at the 5 percent level, the variety F54-2H led all other varieties tested in net extraction at each nitrogen fertility level. The ranges of averages show that the influence on extraction by nitrogen fertility levels was far greater than by varieties in these tests.

Production of Sugar, Molasses and MSG.

Also of prime importance to the economics of the industry is the over-all production of sugar, molasses, and concentrated Steffens filtrate resulting from the growing and processing operations. Table 9 is a compilation of this information as calculated from the results of these tests. This tabulation again shows the tremendous effect of nitrogen fertility levels on both sugar and byproducts, while varieties show significant differences on the gross sugar and salable sugar. It is of interest to note in this case that each variety occupies the same position in production of gross sugar and salable sugar.

Correlations:

The correlation coefficients (Table 10) show a definite inter-relationship among all the variables correlated with the exception of raffinose which was significantly correlated only with sodium. Amino nitrogen constituents, MSG, and total nitrogen appeared to show a higher degree of association with purity than sucrose percentage, although percent sucrose was highly correlated with purity. Also they gave correlation coefficients equal to or higher than percent sucrose with extraction but of opposite sign. In addition, the correlations of ash with percent sucrose, purity and extraction were lower than for nitrogen constituents.

Table 9.—Sugar and Byproduct Production Averages for Variety and Nitrogen Level Before and After Processing as Pounds Per Acre.

Variety	Entering		Leaving			MSG
	Gross Sugar	Non-Sugars	Salable Sugar	Molasses	CSF Solids	
SLC 824	7780	994	6596	1395	422	89
C-51-1	8540	1144	7174	1517	459	97
A2-90H0	7760	1046	6503	1483	475	82
US22/3	8080	1099	6740	1494	452	92
US22S	7820	1035	6619	1427	432	88
F54-2H	8560	1053	7256	1359	411	79
4323SB	8140	1075	6809	1557	469	97
LSD .05	480	N.S.	666	N.S.	N.S.	N.S.
Nitrogen Levels						
65 lbs./acre	6960	771	6144	900	271	34
140 lbs./acre	8820	1074	7182	1391	422	78
280 lbs./acre	8520	1347	6815	2091	614	156
LSD .05	240	176	764	272	86	42
Test Ave.	8100	1064	6814	1462	446	89

In brief, the nitrogen and nitrogen compounds in the beets appear to be the most closely associated with quality factors of any of the beet constituents measured in this study.

Of interest also were the significant correlations found between NO_3 in the petioles and nonsugars constituents in the roots. NO_3 in the petioles showed as strong a negative association with percent sucrose as did the nitrogen compounds in the roots.

Economic Appraisal:

This section is an attempt to evaluate the effects of nitrogen fertility and varietal differences by the most critical indicator of all—that of profit.

The influence of nitrogen fertility level and the individual varieties chosen on the economics of growing and processing sugar beets in this test is shown by the dollar return index values in Table 11. This table shows that the medium nitrogen fertility level was the most beneficial for both grower and processor for all varieties tested. The high nitrogen condition was more profitable than the low. Of the varieties tested, F54-2H and C-51-1 showed the greatest profit possibilities for both grower and processor considering all nitrogen levels tested, while, as would be expected, the inbred A2-90H0 offered the least return.

These figures show that the influence of the individual varieties on the economics of the combined operations was less than

Table 10.—Correlation Coefficients Among 12 Variables Determined from Individual Plot Values. Where Applicable, Values Obtained for Concentrations in the Beet Were Used to Compute r Values.

Variables	Sucrose	Purity	Nonsugar	Ash	Amino N	MSG	Total N	Raffinose	Sodium	Potassium	NO ₂ in Pet.
% Sucrose	—										
Purity	.68	—									
Total non-sugars	-.57	-.96	—								
Ash	-.46	-.65	.63	—							
Amino N	-.52	-.89	.91	.62	—						
MSG (Thin Juice)	-.58	-.89	.88	.59	.89	—					
Total N	-.56	-.87	.88	.64	.92	.89	—				
Raffinose	.09	.11	-.14	-.11	-.18	-.15	-.19	—			
Sodium	-.66	-.78	.74	.59	.73	.70	.70	-.29	—		
Potassium	-.47	-.58	.54	.55	.53	.53	.52	-.03	.49	—	
NO ₂ in Petioles	-.64	-.67	.61	.42	.60	.64	.64	.06	.51	.44	—
Extraction	.75	.88	-.73	-.56	-.72	-.76	-.73	.04	-.69	-.55	-.66

$r = .16$ for significance at .05

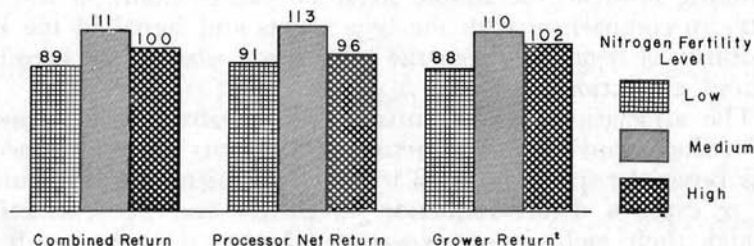
$r = .20$ for significance at .01

that of the nitrogen fertility levels. This is exemplified in Table 11 for combined returns where nitrogen fertility levels was responsible for a 22 percent range from the over-all test average while varietal differences caused only 13 percent range in these returns. This provides a total of 35 percent variation from the lowest to highest fertility-variety combination. Figure 2 is a graphic representation of the data of Table 11.

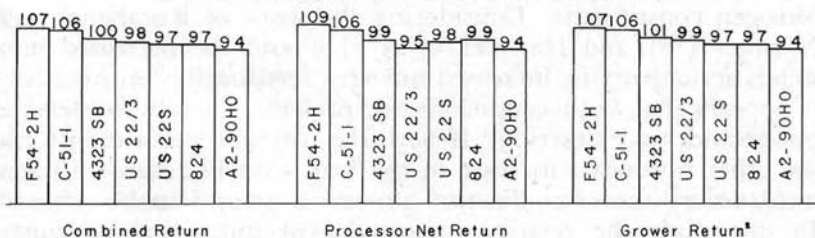
Table 11.—Index Figures for Variety and Nitrogen Level Averages.

Variety	Combined Return	Grower Return	Processor Net Return
SLC 824	97	97	99
C-51-1	106	106	106
A2-90H0	94	94	94
US22/3	98	99	95
US22S	97	97	98
F54-2H	107	107	109
4323SB	100	101	99
Nitrogen Levels			
65 lbs./acre	89	88	91
140 lbs./acre	111	110	113
280 lbs./acre	100	102	96
Test Average	100	100	100

Index^a of Returns, Dollars Per Acre
Averages For All Varieties



Averages For All Nitrogen Levels



^a Overall test average set at 100.
^b Less costs of fertilizer and harvesting.

Figure 2.—Variety and nitrogen level averages.

The most profitable combination of variety and fertilizer level for both processor and grower was the variety F54-2H grown on the medium level of nitrogen fertility. This combination resulted in an increase in combined returns of 18 percent over the entire test average.

Discussion

The effects of nitrogen fertilization on the economics of sugar production and extraction were more pronounced than the effects of the varieties tested. This was the result of the greater effect of nitrogen fertilization on yield, percent sucrose, and nonsugar content.

The most profitable level of nitrogen fertilization for grower and processor was the medium level which produced the maximum gross sugar and salable sugar per acre. The low nitrogen fertility level effected a low root yield which resulted in the lowest gross sugar in spite of the high sugar content and thus depressed the production of salable sugar and byproducts. The high nitrogen application resulted in the highest root yield, but the gross sugar was depressed by the low sugar content. The accompanying nonsugars in this case caused a reduced net extraction and thus lowered the salable sugar but produced the highest yield of byproducts.

The results of the economic appraisal pointed out the overwhelming influence of salable sugar on the economy of the industry in comparison with the byproducts and signalled the impossibility of regaining from the byproducts what is lost through reduced extraction.

The association of total nitrogen and nitrogen compounds with reduced purity and extraction in the roots was pronounced. This raises the question as to whether the nitrogen compounds *per se* cause a direct reduction in purity and net extraction through their melassigenic power or whether it is the result of the melassigenic power of other nonsugars associated with the nitrogen constituents. Considering the work of Rorabaugh and Norman (13) and Haddock et al (11) and the increased nonsugars accompanying increased nitrogen fertilization in this study, it appears that both conditions are probably factors influencing purity and net extraction. If both the nitrogen constituents and the other nonsugars increase in the beet with increased nitrogen fertilization, the crystallization process is bound to be affected. In this study the relative importance of individual nonsugars to the rate of crystallization has not been considered, but consideration of this factor could only make the case for high nitrogen fertilization worse than has been shown by these results.

Having a wide range of nitrogen fertilization as well as different varieties in the test produced a wide variation in the concentration of nitrogen compounds in the beets. This made it possible to obtain correlation coefficients of variables affected by a wide range of conditions. As a result, the r values obtained in this study may vary from those obtained by other workers studying primarily varietal variations.

There was evidence in this study of interactions of varieties and fertilizer levels in regard to correlations. For instance, ash increased with nitrogen fertilization as did the amino N constituents resulting in a highly significant r value between ash and amino N. On the other hand, the varieties high in amino N were not necessarily high in ash (Table 3).

In the case of raffinose, variation was due primarily to varieties rather than to the effects of nitrogen fertilization as was the case with other nonsugars. This may partially explain the low correlation coefficients obtained with raffinose vs. other nonsugars.

Although other factors of climate and soil undoubtedly affect quality and production of sugar beets, nitrogen fertility is so critical that every effort should be made to apply near "optimum" amounts of nitrogen to the commercial beet crop. The "optimum" level may be defined as that level of nitrogen fertilization beyond which increases in yield are not sufficient to justify the cost of additional nitrogen applied, and the losses due to reduced sucrose percentages and net extractions are not significant. To be able to determine such a level for a particular field prior to planting is a near impossible task because of the factors that influence the nitrogen requirements such as irrigation practices and seasonal differences. However, through the aid of cropping histories, fertilizer histories, and soil tests, control of high or low nitrogen fertilization applications is practicable and should be achieved.

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