Response of Yield-Type Versus Sugar-Type Sugar Beet Varieties to Soil Nitrogen Levels and Time of Harvest

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Improvements in disease control and cultural practices have resulted in striking increases in the per acre production of beet sugar in California in the past two decades. This increase, however, has been due entirely to increased root yields as the trend in sucrose concentration has been steadily downward. An improvement in the sucrose concentration even though slight would mean a substantial gain for processor and farmer alike.

A promising, and highly worthwhile, approach to this problem is through the development of varieties with the ability to store greater concentrations of sugar. Such a variety, to be commercially acceptable, should also maintain disease resistance and other desirable characteristics, and be able to produce at least as much, and preferably more, sugar per acre than existing varieties. Attempts have been, and are being made, to develop "high sugar" varieties. At least one such variety, U. S. 35/2, has been released for commercial use in California.

The depressing effect of nitrogen on sugar storage has been demonstrated many times. In California, nitrogen is one of the principle variables among sugar beet fields (5)[2] (6). In at least one important beet growing area of California (Davis-Woodland area) the nitrogen nutrition of sugar beets has been demonstrated to be one of the main reasons for fluctuations in sugar concentration among beet fields (2) (3).

It would seem logical, therefore, to evaluate "sugar" varieties under varying nitrogen environments. Because varietal differences are likely to be small and difficult to measure such evaluations can best be made in factorial experiments where varieties can be grown close together at different nitrogen levels. This paper presents the results of two such experiments both conducted under essentially curly top-free conditions.

Procedure

General

In both experiments ammonium nitrate was used as the nitrogen source and was side-dressed on one side of each beet row shortly after thinning with a tractor-mounted precision applicator. The fertilizer rates used in both years supplied 0, 80, 160, and 240 pounds of N per acre. Plots were 8 rows wide and 70 feet long and the middle 60 feet of the 4 center rows were harvested. The beets in each plot were counted at harvest and four root samples, 15 to 25 beets each, were taken from each plot for sucrose concentration and tare determinations.

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[2] Numbers in parentheses refer to literature cited.

Petiole samples were collected at 3-week intervals throughout the growing season in both experiments to determine the nutritional status of the plants with respect to nitrogen, phosphorus and potassium.

Results were evaluated statistically by the method of analysis of variance (1).

Woodland, 1950

Two "sugar" varieties, SL 824 and SL 828, were compared with two standard varieties, U. S. 33 and U. S. 22/3, at the four levels of nitrogen. Subsequently SL 824 was released as U. S. 35/2 and for clarity will be designated as such in the Woodland experiment.

The 16 possible combinations of variety and nitrogen levels were arranged in a simple lattice with the basic design duplicated (4 replications) (1). Due to a nitrogen fertility gradient in the area selected for the experiment, this was an unfortunate choice of design. In the two replications where nitrogen levels were contiguous on variety blocks a good deal of precision as to variety comparisons was lost due to variations in initial fertility between the variety blocks. Where varieties were placed contiguously on nitrogen-level blocks highly precise variety and variety x nitrogen comparisons were possible. Only the data from these two replications, analyzed statistically as split plots, will be presented here.

Davis, 1951

U. S. 22/3 and U. S. 35/2 were the only varieties included in the second experiment. A third factor, time of harvest, was introduced as it was felt that this factor might have some influence on comparative varietal performance. A split plot design was used with nitrogen levels as the main plots laid out in a 4 x 4 Latin square. These plots were split for varieties and the variety plots split again for dates of harvest in strips across all 4 replications (1).

Results

There was a marked growth response to nitrogen in the Woodland experiment. The optimum rate of nitrogen fertilization for this soil was about 160 pounds of N per acre. At harvest time a visible difference in top growth could be detected between beets which received 240 pounds of N as compared to plants which received the 160-pound rate. At harvest, petiole analyses indicated a low level of nitrate-nitrogen even in plants fertilized with 240 pounds of nitrogen per acre.

The field chosen for the Davis experiment turned out to be one of high fertility. There was very little or no growth response to nitrogen. Petiole analyses indicated that none of the non-fertilized plots became deficient in nitrogen until September. In this experiment the principal effect of nitrogen fertilization was to lower sucrose concentrations and thereby decrease total sugar production.

As a result of the difference in the initial nitrogen fertility of the two fields chosen for these experiments and the rates of nitrogen fertilization used it can be concluded that the two varieties U. S. 35/2 and U. S. 22/3 were compared over a wide range of nitrogen fertility.

In both experiments root counts at harvest indicated excellent stands and no important differences among treatments.

Sucrose Concentration

Woodland. All varieties reacted similarly to increasing levels of nitrogen with the possible exception of SL 828. This variety did not decrease in sucrose concentration at the 160-pound N rate as did the others. This probably accounts for the F value for the interaction of variety x nitrogen being close to the 5 percent level (Table 1). More data would be necessary before concluding that this was more than chance variation.

On the average U. S. 35/2 was the highest in sucrose concentration and U. S. 22/3 the lowest. U. S. 35/2 had higher sucrose concentration than U. S. 22/3 at all nitrogen levels. SL 828, on the average, was better than U. S. 22/3 but poorer than IT. S. 35/2. U. S. 33 responded similarly to U. S. 22/3 but tended toward slightly greater sugar concentrations.

Table 1.—Effect of Variety and Nitrogen on Sucrose Percentage of Sugar Beets at Woodland, California, 1950.

Lbs. N per acre	Varieties: U. S. 35/2[1]	SL 828	U. S. 33	U. S. 22/3	Nitrogen Means[3]
	Variety x Nitrogen Means[2]				
0	16.1	15.7	15.6	15.1	15.6
80	16.4	15.3	16.1	15.5	15.8
160	15.2	15.6	15.0	14.5	15.1
240	14.8	14.4	13.7	13.7	14.1
Variety Means[3]	15.6	15.2	15.1	14.7	

Significant differences at the 5% level: Between varieties at same nitrogen level—0.6; Variety means—0.3; Nitrogen means—1.5.

[1] SL 824

[2] Calculated F value for interaction = 2.55. F value required for significance at 5 percent level = 2.80.

[3] Significant at the 5 percent and 1 percent levels respectively.

Table 2.—Effect of Variety, Nitrogen and Date of Harvest on Sucrose Percentage of Sugar Beets at Davis, California, 1951.

Lbs. N per acre	U. S. 22/3 Sept. 28	U. S. 22/3 Nov. 1	U. S. 22/3 Dec. 13	U. S. 35/2 Sept. 28	U. S. 35/2 Nov. 1	U. S. 35/2 Dec. 13	U. S. 22/3	U. S. 35/2	Nitrogen Means[2]
	Variety x Nitrogen x Date of Harvest Means[1]						Variety x Nitrogen Means[1]		
0	13.5	14.6	14.7	14.5	15.1	15.3	14.3	14.9	14.6
80	12.7	13.0	13.5	13.9	14.4	14.2	13.1	14.2	13.6
160	12.1	12.9	13.4	12.8	13.4	14.3	12.8	13.5	13.2
240	11.7	13.1	12.7	12.4	12.9	13.5	12.5	12.9	12.7
	Variety x Date of Harvest Means[1]						Variety Means[3]		
	12.5	13.4	13.6	13.3	13.9	14.3	13.2	13.9	

Date of Harvest Means[3]: Sept. 28	Nov. 1	Dec. 13
12.9	13.7	14.0

Significant differences at the 5% level: Nitrogen means—1.2; Variety means—0.4; Date of harvest means—0.5.

[1] Interactions not significant at the 5 percent level.

[2] [3] Significant at the 5 percent and 1 percent levels respectively.

Davis. Both varieties reacted to nitrogen and date of harvest *in* the same way. There were no interactions. U. S. 35/2 had a slightly higher sugar concentration at all nitrogen levels and dates of harvest. The sucrose concentrations of both varieties, at all nitrogen levels, increased with time. The greatest increase occurred during the month of October. The increase from November 1 to December 13 was small and probably not significant.

Root Yields

Woodland. U. S. 22/3, U. S. 33 and SL 828 all produced greater root yields than U. S. 35/2 at all nitrogen levels. U. S. 22/3 was the best root producer.

The significant variety x nitrogen interaction is principally due to the relatively greater response made by the sugar types to the first increment of nitrogen. Also, it appears that the tonnage types continued to respond relatively more to the 160-pound rate than did the sugar types.

Table 3.—Effect of Variety and Nitrogen on Yield of Beet Roots (Tons per Acre) at Woodland, California, 1950.

Lbs. N per acre	Varieties U. S. 35/2[1]	SL 828	U. S. 33	U. S. 22/3	Nitrogen Means[2]
	Variety x Nitrogen Means[2]				
0	13.2	15.1	16.7	18.0	15.7
80	18.3	20.9	20.0	20.1	19.9
160	19.3	21.1	21.6	23.4	21.3
240	18.7	21.5	19.8	22.6	20.7
Variety Means[3]	17.4	19.6	19.5	21.0	

Significant differences at the 5% level: Between varieties at the same nitrogen level—1.3; Between nitrogen levels for any variety—4.7; Nitrogen means—1.6; Variety means—0.7.

[1] SL 824

[2,3] Significant at the 5 percent and 1 percent levels respectively.

Table 4.—Effect of Variety, Nitrogen and Date of Harvest on Yield of Beet Roots (Tons per Acre) at Davis, California, 1951.

Lbs. N per acre	Varieties: U. S. 22/3 Sept. 28	U. S. 22/3 Nov. 1	U. S. 22/3 Dec. 13	U. S. 35/2 Sept. 28	U. S. 35/2 Nov. 1	U. S. 35/2 Dec. 13	Varieties: U. S. 22/3	U. S. 35/2	Nitrogen Means[2]
	Variety x Nitrogen x Date of Harvest Means[1]						Variety x Nitrogen Means[1]		
0	28.2	33.1	35.9	26.0	29.5	29.9	32.4	28.4	30.4
80	29.6	35.6	37.1	24.6	29.8	30.9	34.1	28.4	31.2
160	29.5	35.9	37.6	26.4	28.9	30.9	34.3	28.7	31.5
240	28.3	33.3	34.5	26.0	30.1	31.9	32.0	29.3	30.7
	Variety x Date of Harvest Means[3]						Variety Means[4]		
	28.9	34.4	36.3	25.7	29.6	30.9	33.2	28.7	

Date of Harvest Means[4]		
Sept. 28	Nov. 1	Dec. 13
27.3	32.0	33.6

Significant differences at the 5% level: Between harvest dates for the same variety—1.0; Between varieties for the same harvest date—1.4; Variety means—1.1; Date of harvest means—1.1.

[1] Interactions not significant at the 5 percent level.

[2] No significant response to nitrogen.

[3,4] Significant at the 5 percent and 1 percent levels respectively.

Davis. U. S. 22/3 produced a greater root yield than U. S. 35/2 at all nitrogen levels and all harvest dates. There was a significant variety x date of harvest interaction with U. S. 22/3 making a relatively greater gain with time than U. S. 35/2. Considerably more growth occurred during the month of October than during the subsequent six-week period from November 1 to December 13.

Gross Sugar Production

Woodland. There was a significant variety x nitrogen interaction due principally to the relatively greater response in root yield made by U. S. 35/2 to the first 80-pound nitrogen rate as compared to U. S. 22/3 and the failure of U. S. 35/2 to do as well at the higher nitrogen levels as did U. S. 22/3. The highly significant variety effect indicates the overall superiority of U. S. 22/3 to the other varieties.

Table 5.—Effect of Variety and Nitrogen on Yield of Gross Sugar (Tons Per Acre) at Woodland, California, 1950.

Lbs. N per acre	Varieties: U. S. 35/2[1]	SL 828	U. S. 33	U. S. 22/3	Nitrogen Means[2]
	Variety x Nitrogen Means[2]				
0	2.12	2.36	2.58	2.69	2.43
80	2.99	3.20	3.21	3.10	3.12
160	2.92	3.28	3.23	3.40	3.20
240	2.78	3.08	2.71	3.09	2.91
Variety Means[3]	2.70	2.98	2.93	3.07	

Significant differences at the 5% level: Between varieties at the same nitrogen level—0.25; Between nitrogn levels for any variety—0.62; Variety means—0.12; Nitrogen means—0.58.

[1] SL 824.
[2][3] Significant at the 5 percent and 1 percent levels respectively.

Table 6.—Effect of Variety, Nitrogen and Date of Harvest on Yield of Gross Sugar (Tons per Acre) at Davis, California, 1951.

Lbs. N per acre	U. S. 22/3 Sept. 28	U. S. 22/3 Nov. 1	U. S. 22/3 Dec. 13	U. S. 35/2 Sept. 28	U. S. 35/2 Nov. 1	U. S. 35/2 Dec. 13	Varieties: U. S. 22/3	U. S. 35/2	Nitrogen Means[2]
	Variety x Nitrogen x Date of Harvest Means[1]						Variety x Nitrogen Means[1]		
0	3.80	4.80	5.26	3.72	4.45	4.57	4.62	4.25	4.43
80	3.75	4.65	5.01	3.39	4.26	4.39	4.47	4.01	4.24
160	3.53	4.59	5.04	3.37	3.82	4.42	4.59	3.87	4.13
240	3.50	4.34	4.57	3.21	3.87	4.26	4.00	3.78	3.89
	Variety x Date of Harvest Means[2]						Variety Means[3]		
	3.60	4.59	4.92	3.42	4.10	4.41	4.37	3.98	
	Date of Harvest Means[2]								
	Sept. 28	Nov. 1	Dec. 13						
	3.51	4.35	4.66						

Significant differences at the 5% level: Nitrogen means—0.19; Between harvest dates for the same variety—0.17; Between varieties for the same date of harvest—0.18; Variety means—0.11; Date of harvest means—0.09.

[1] Interactions not significant at the 5 percent level.
[2][3] Significant at the 5 percent and 1 percent levels respectively.

Davis. U. S. 22/3 produced more sugar per acre at all harvest dates and all nitrogen levels than U. S. 35/2. A variety x date of harvest interaction occurred indicating that the sugar production advantage observed for U. S. 22/3 over U. S. 35/2 increased with time, particularly during the month of October, a period of rapid growth.

Discussion

These experiments were designed primarily to learn more about possible variety x nitrogen interactions. While U. S. 22/3 was compared to the sugar type, U. S. 35/2, over a wide range of fertility levels in the two experiments more precise comparisons could have been made had the fertility levels all occurred in the same experiment. The use of an inefficient design in the Woodland experiment further reduced the precision with which these varieties might have been compared. Nevertheless, these data do point out that these varieties probably do respond somewhat differently to different levels of nitrogen fertility. When nitrogen is an important factor limiting growth the sugar-type appears to respond more rapidly to nitrogen fertilization. Skuderna and Doxtator (4) found the same sort of interaction in a study where a sugar type was compared to a tonnage-type variety at different levels of plant food (principally phosphorus). This indicates that varieties like U. S. 22/3 may be better nutrient foragers than sugar types such as U. S. 35/2. When a variety such as U. S. 35/2 is grown it appears to be even more important to provide sufficient fertility for maximum growth than it would be with a variety such as U. S. 22/3. More important, however, is the fact that under the conditions of these experiments U. S. 22/3 consistently produced more sugar regardless of nitrogen level or time of harvest than did U. S. 35/2 despite the fact that the latter variety consistently had a higher sucrose concentration.

On the basis of its performance in regard to total sugar production, a variety such as U. S. 35/2 appears to be less efficient photosynthetically than U. S. 22/3. The consistently higher sucrose concentration and lower root yield of U. S. 35/2 also indicates that sugar storage takes place at the expense of root and top growth.

Summary

Field experiments were conducted near Davis, California, to determine how soil nitrogen levels and time of harvest might affect the performance of newly developed sugar-type varieties as compared to the more widely used tonnage types. The initial experiment compared the varieties SL 824 (U. S. 35/2), SL 828, U. S. 33 and U. S. 22/3 at 0, 80, 160 and 240 pounds of nitrogen per acre. Only U. S. 35/2 and U. S. 22/3 were compared in the second experiment. These two varieties were compared at the same four nitrogen levels and in addition at three dates of harvest (September 28, November 6, December 13).

Highly significant variety differences were observed in both experiments. The sugar-type varieties consistently contained higher sucrose concentrations but produced lower root yields and less gross sugar, regardless of nitrogen level or date of harvest, than did the tonnage types.

There was a significant variety x date of harvest interaction. U. S. 22/3 gained relatively more in root yield with increasing length of the fall growing period than did U. S. 35/2.

A significant variety x nitrogen interaction occurred with respect to root yield and sugar production when the varieties responded to nitrogen fertilization. This interaction indicates that U. S. 35/2 makes a relatively greater initial response to nitrogen than does U. S. 22/3 probably because U. S. 35/2 is a less efficient nutrient forager.

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