Response of Sugar Beets to Nitrogen Fertilizer in the Imperial Valley, California[1]

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To obtain information as to the optimum fertility practices for the growing of sugar beets in the Imperial Valley area of California three experiments were conducted during the 1951 season. Two of the experiments were designed to determine the nitrogen, phosphorus and potash requirements of sugar beets, to determine the effect of manure and to compare single vs. split application of nitrogen. The third experiment was designed to compare the nitrogen reqirements of U. S. 35/2, a high sugar strain, with that of the standard U. S. 22/3. The three expirements were conducted with farmer cooperators at three locations.

There were marked responses to nitrogen application, but no significant response to phosphorus, potash or manure application. The discussion in this paper will be limited to the effects of nitrogen application upon nitrate level in the plant and the yield and quality of the sugar beers.

Methods and Materials

The nitrogen fertility experiments were conducted on a Meloland fine sand at the Simons ranch near Brawley, and on a Holtville silty clay loam at the Glud ranch near Calexico. At the Simons ranch seven to nine inches of top soil had been removed from the experimental area by leveling during the previous season. This site was purposely chosen as it was assumed that the phosphorus and nitrogen level of the soil would be relatively low. At the Glud location the experimental area had been in beets in 1951 and had been in alfalfa for the previous three years.

Both experiments were laid out in a four x four balanced lattice design with five replications. The plots were four rows, 10 feet by 60 feet. Original plans were to conduct identical experiments at the two locations. However, it became apparent early in the season that the highest rate of nitrogen at the Simons location would not be sufficient to carry the plants through until the end of the season. Nitrogen rates were, therefore, increased for this location up to a maximum treatment of 400lbs./A. The step-ups were made on the 160-pound rates which still had adequate nitrogen as indicated by plant growth and petiole composition (5,000 p.p.m. NO_3-N).

The treatments involving rates and time of application of nitrogen for the two locations are given in Tables 1 and 2. All preplanting fertilizer was applied in a band 3 inches to one side and 3 inches below the seed. Phosphorus was applied preplant in all nitrogen comparisons at the rate of 200 lbs. P_2O_5/A. Ammonium nitrate was used for all nitrogen side-dressing applications. U.S. 56 seed was planted in dry single row sloping beds 30 inches apart and irrigated in every other furrow. The Glud experiment was planted October 20 and the Simons experiment November 3. After emergence the plants were thinned to 6 to 7 inches apart.

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The nitrogen variety experiment was conducted on a Holtville loam soil at the D'Arrigo ranch near Brawley. The field has been lettuse during 1950 and in Alfalfa previously. A split plot design was used with six replications. The variety whole plots were split into three rates od nitrogen. The whole plot size was 270 feet x 14 feet (8rows) and split plot size was 90 feet x 14 feet. The sugar beets were planted in double rows 12 inches apart on 42 inch beds January 26, 1951. The variety and nitrogen treatments are shown in Table 3.

Plant Sampling and Chemical Analysis Procedures.

At each sampling date twenty sugar beet petioles of recently matured leaves were selected at random from each plot. The petioles were cut up into sections one inch in length and dried in a convection oven at 75°C. The sample was ground in a Wiley mill to pass a 40-mesh screen, bottled and stored for chemical analysis.

The method of Johnson and Ulrich (2)[3] for the extraction and determination of nitrates in dried plant material was followed for the analysis of the petiole samples. Ulrich (3, 4) has found the nitrate content of the petiole to be closely related to nitrogen applications, sugar percentages and beet yields. Haddock (1) has recently shown that the soluble organic nitrogen fraction in sugar beet petioles is more closely related to the factors of quality of sugar beet roots than is nitrate-nitrogen. It was also shown, however, that the nitrate-nitrogen content of sugar beet petioles is highly correlated with sucrose and purity of beet roots. Because of the simplicity and rapidity of the nitrate-nitrogen determination and its adaptability for practical purposes it was considered as a satisfactory index of nitrogen nutrition.

Results and Discussion

Widely different responses to nitrogen were obtained in two fertility experiments. Data fro the yield and quality of sugar beets are shown in Tables 1 and 2.

At the Simons ranch the acre yield of sugar beets was increased by more than 14 tons. However, as pointed out above the nitrogen level on this field was lower than normal because top soil had been removed by leveling. The nitrogen level of the soil was so low that only 9 tons of beets were produced where no nitrogen was added. There was a significant increase in beet and sugar tonnage up through 160 pound per acre rate of nitrogen application. The upward trend in yield above the 160-pound level was not significant. A gradual decrease in sugar percentage with nitrogen application was obtained but the magnitude of the reduction was the greates at the higher rates of application. Since the high rates of application were made late in the season the depressing effect may have been greater than if they had been applied at normal sidedressing time.

[3] Numbers in parenthese refer to literature cited.

Table 1.—Yield and Quality of Sugar Beets and Seasonal Petiole Composition as Influenced by Nitrogen Fertilizer. James Simons Ranch, Brawley, 1951 Season.

Nitrogen Applied Lbs./A.	Yield Beets T/A.	Sucrose %	Purity %	Gross Sugar T/A.	Nitrate-Nitrogen in Beet Petioles 3/16 ppm	4/18 ppm	5/7 ppm	5/31 ppm	6/21 ppm
1. 0	9.01	19.1	86.9	1.72	118	70			
2. 0 + 40 sidedressed[1]	14.50	18.8	86.7	2.74	312	95	75		
3. 0 + 80 sidedressed[1]	15.83	18.2	85.8	2.87	629	127	103	52	
4. 0 + 160 sidedressed[1]	18.72	18.3	85.6	3.43	5,631	606	75	46	
5. 40	13.84	18.4	86.1	2.56	282	98	61		
6. 40 + 40 sidedressed[1]	14.40	18.6	85.4	2.68	399	72			
7. 40 + 120 sidedressed[2]	20.03	17.9	87.1	3.59	5,423	865	100	42	
8. 40 + 200 sidedressed[3]	21.60	17.1	85.0	3.71	4,178	2,757	196	69	
9. 40 + 280 sidedressed[4]	21.22	16.9	85.1	3.58	4,028	2,635	2,158	381	70
10. 40 + 360 sidedressed[5]	23.15	16.2	82.5	3.73	4,042	4,645	2,456	358	105
L.S.D. (05)	3.74	1.0	N.S.	0.22					
(01)	4.98	1.4		0.29					
C.V. %	16.2	4.5	2.5	5.4					

[1] Sidedressing at thinning, January 17.
[2] Split sidedressing, 80 lbs./A. at thinning and 40 lbs./A. on March 5.
[3] Split sidedressing, 120 lbs./A. at thinning and 80 lbs./A. on March 19.
[4] Split sidedressing, 120 lbs./A. at thinning, 80 lbs./A. on March 19 and 80 lbs./A. on April 23.
[5] Split sidedressing, 120 lbs./A. at thinning, 160 lbs./A. on March 19 and 80 lbs./A. on April 23.

Analysis of the petioles (Table 1) shows that the nitrate content of the petioles in the 40- and 80-pound treatments had dropped below the "critical level"[1] by March 16 (17 weeks before harvest). The nitrate level in the 160-pound treatments was still high but dropped rapidly and was below the 1.000 p.p.m. value by April 18 (12 weeks before harvest). At this date the nitrate level of the 240-pound plots was still high but had dropped sharply bv May 7 (9 weeks before harvest). These results indicate that optimum sugar yields are obtained when the nitrates in the petiole are maintained above the critical level until about mid-April. In treatments 9 and 10 where the nitrate remained high in May, the sugar percentage was reduced so much as to overshadow anv increase in beet yield.

Since the weather is hot prior to harvest, it is possible that growth had slowed up or stopped a considerable time before harvest. Thus the period between the depletion of the nitrates in the petiole and the end of growing season is not as long as indicated. Work is being continued along this line with earlier harvest dates included to establish optimum time for plant nitrate depletion in relation to harvest time.

In the Glud experiment (Table 2) there was no yield response to nitrogen. The fertility level in the soil was high enough that 22.4 tons of beets were produced in the no-nitrogen treatments. Even though the nitrogen level in the soil was high enough that there was no response to nitrogen application, the added nitrogen did not significantly depress the sugar per-

[4] Ulrich defines the critical level of a given nutrient as that concentration at which growth is first retarded in comparison to plants with a higher concentration of the same nutrient" (3). Through experience he has found the critical level for nitrate nitrogen in the petioles to be about 1,000 p.p.m. on a dry weight basis.

Table 2.—Yield and Quality of Sugar Beets and Seasonal Petiole Composition as Influenced by Nitrogen Fertilizer. Paul Glud Ranch, Calexico, 1951 Season.

Nitrogen Applied Lbs./A.	Yield Beets T/A.	Sucrose %	Purity %	Gross Sugar T/A.	Nitrate-Nitrogen in Beet Petioles 3/12 ppm	4/9 ppm	5/4 ppm	5/28 ppm
1. 0	22.4	19.1	89.0	4.28	2,525	535	195	215
2. 0 + 40 sidedressed[1]	20.4	19.4	88.8	3.96	1,993	604	309	273
3. 0 + 80 sidedressed[1]	22.0	19.0	88.0	4.18	2,004	807	245	504
4. 0 + 160 sidedressed[1]	23.9	18.2	84.8	4.35	2,328	1,021	401	371
5. 40	23.4	18.8	87.3	4.26				
6. 40 + 40 sidedressed[1]	21.8	19.2	87.2	4.19				
7. 40 + 120 sidedressed[1]	21.9	19.4	86.1	4.25				
8. 40 + 120 sidedressed[2]	22.5	18.7	86.6	4.21	2,030	1,855	.	. .

[1] Sidedressing at thinning, December 11.
[2] Split sidedressing, 80 lbs./A. at thinning and 40 lbs./A. on March 12.

centage. Purity was slightly depressed by nitrogen application. However, the amount of depression was small and the purity was relatively high throughout the experiment. There were no significant differences in yield of sugar—the zero nitrogen treatment yielding 4.28 tons/A.

March 12 the nitrate-nitrogen content of petioles was still high in all treatments, including the zero nitrogen plots. Likewise, there was no appreciable growth response to nitrogen application up through this date. By April 9 (11 weeks before harvest) all but the 160-pound plots had dropped below the critical value. However, this late difference did not appear to influence yield.

In the Variety x Nitrogen experiment the response due to nitrogen was far greater than that due to varieties (Table 3) .

Table 3.—Effect of Nitrogen Fertilizer Upon the Yield, Quality, and Seasonal Petiole Composition of Two Related Varieties of Sugar Beets. I>'Arrigo Bros., Brawley, 1951 Season.

Variety	Nitrogen Applied Lbs./A.	Yield Beets T/A.	Sucrose %	Purity %	Gross Sugar T/A.	Nitrate-Nitrogen in Beet Petioles 4/18 ppm	5/9 ppm	6/1 ppm	6/22 ppm
U. S. 22/3	40[1]	13.6	18.0	86.9	2.44	124	192	55	.
	160[2]	17.2	16.3	83.0	2.79	527	4,211	496	.. .
	320[3]	18.2	14.0	79.3	2.55	3,204	12,732	4,280	1,648
U. S. 35/2	40[1]	12.2	19.0	87.9	2.31	97	108	70	
	160[2]	15.6	18.0	86.4	2.81	223	3,173	172	.
	320[3]	17.8	15.9	82.6	2.83	1,811	11,463	2,510	970
Both Varieties	40	12.9	18.4	87.4	2.38				
	160	16.4	17.2	84.7	2.80				
	320	18.0	15.0	81.0	2.69				
L.S.D. (05) (Nitrogen Means)		1.5	0.5		0.24				
L.S.D. (01) (Nitrogen Means)		2.0	0.7		0.33				

[1] 40 lbs./A. sidedressed on March 6.
[2] 80 lbs./A. sidedressed on March 6 and 80 lbs./A. sidedressed on April 20.
[3] 160 lbs./A. sidedressed on March 6 and 160 lbs./A. sidedressed on April 20.

Nitrogen application increased the average yield of both varieties from 12.9 to 18.0 tons per acre. There was a slight, though significant, increase of the 320-pound nitrogen treatment over that of the 160-pound plots. However, this yield increase due to the last increment of nitrogen was overshadowed by the marked decrease in sugar percentage so that the sugar tonnage was slightly decreased. The sugar percentage in U. S. 35/2 was somewhat higher than that of U. S. 22/3 but there was no appreciable difference between varieties in beet or sugar yield.

Since a wide range in the nitrogen level was necessary to attain the objectives of this experiment, a second sidedressing was made on the medium and high treatments April 20.

These applications were reflected in the petiole nitrate content of the May 9 sampling (Table 3) . The nitrates in the 320-pound treatment were the highest observed in any experiment and were still high on June 1 and June 22. The sugar percentage was reduced 2.2 percent by the last increment of nitrogen.

The nitrate content of U. S. 35/2 was consistently low-er that that of U. S. 22/3. This was especially true in the highest nitrogen treatment late in the season. Likewise there was a tendency for the sugar percentage to be decreased less in U. S. 35/2, a high sugar selection, than in U. S. 22/3. However, this interaction was not significant.

Summary and. Conclusions

The effect of nitrogen application on petiole composition and yield and quality of sugar beets was studied under three widely varying fertility levels.

Where needed, nitrogen applications increased beet yields as much as 14 tons per acre and the sugar yields were increased from 1.72 tons to 3.73 tons by nitrogen application. There was a gradual decrease in sugar percentage with nitrogen application with the decrease becoming greater about the 160-pound nitrogen rate. At the Glud experiment where the zero nitrogen plots yielded 4.28 tons of sugar per acre, nitrogen had no significant effect on beet yield or sugar percentage.

Nitrogen application increased the beet yield and decreased the sugar percentage of both varieties of the Nitrogen x Variety experiment. The resultant sugar tonnage was increased by the first increment of nitrogen only. At the high rate of nitrogen application U. S. 35/2, a high sugar strain, showed a tendency toward higher sugar percentage and lower nitrate level than that of U. S. 22/3, but the interaction was not significant.

The nitrate-nitrogen content of sugar beet petioles was closely related to nitrogen application and degree of response. These preliminary results indicate that for optimum yields the nitrate in the petiole should be maintained above the critical level until about 11 to 12 weeks before harvest.

When high nitrates were found as late as 3 to 9 weeks before harvest the sugar percentages were decreased enough to overshadow any increase in beet yield. However, further study is necessary to establish critical levels in relation to harvest time for a wider range of conditions in Imperial Valley. This type of information could be a valuable aid to growers in determining their nitrogen fertilization program for optimum sugar yields.

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