Sugarbeet Production Response to Water and Nitrogen Fertilizer

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Summary

The response of sugarbeets to varying irrigation and nitrogen fertility levels was studied. The major response of sugarbeets was to nitrogen fertilizer. Root yields tended to increase and sucrose percentages decrease as the nitrogen fertilizer rate was increased. The effect of irrigation treatments on sugarbeet production was generally small. Water use efficiency and sugar yield data indicate that within the range of irrigation levels compared, considerable quantities of water can be conserved without greatly influencing sugar production.

Introduction

In sugarbeet production in central Arizona the most important factors that are controlled by the farmer are water and N fertilizer. Proper water management is particularly important in the Southwest where beets receive nearly all of their water through irrigation and where water may be in short supply. Nitrogen fertilizer is generally required to produce high root yields since the desert soils are characteristically low in organic matter and therefore low in reserve N.

The influence of irrigation levels on sugarbeet production has been reported for various other growing areas (1, 3, 5, 10). In central Arizona, Erie and French (2) found that there generally were no differences in yield among treatments that were irrigated when 40, 60 or 80% of the available soil moisture had been depleted in the top three feet of soil. Consumptive use of water by sugarbeets planted in late September and harvested at the end of July was found to be about 42 in.

Nitrogen requirements of this crop have received considerable research attention. Beets grown in central Arizona have responded to N fertilization (6). But, in recent years there has been a decline in beet quality in most growing areas. This problem has reportedly been related to improper N fertilization practices (8). Purity and concentration of sucrose in the root are generally reduced when excessive N is present in the soil, particularly late in the season. Therefore, N must be managed with regard to sucrose content as well as root yield. Although information is available concerning both optimum soil moisture conditions and N fertilization for growing beets, the relationship between these two variables has not been established under Arizona conditions.

The study reported here is part of a project contracted by Iowa State University and the University of Arizona with the Bureau of Reclamation to provide the basis for agronomic and economic evaluation of irrigation development on individual farms (4). The efficient allocation of such resources as water and N fertilizer is of major importance, in view of the increasing cost and short supply of energy. The objective of this study was to determine the relationship of the percent water depleted and N fertility levels to root yield, sucrose percentage, gross sugar yield and top yields of sugarbeets. The results of this study have been published in Arizona Agricultural Experiment Station Technical Bulletin No. 230 (7).

Materials and Methods

Experiments were conducted during the 1970-71 and 1971-72 seasons on soil classified as Laveen clay loam at the University of Arizona, Mesa Branch Experiment Station at Mesa, Arizona. The soil had a paste pH value of 7.8 and an organic matter content of 0.78% in the surface layer. Water holding capacity of the soil was about 1.75 inches of available water per foot. In 1970, beets were planted after alfalfa and in 1971 after alfalfa and forage sorghum. Each year, phosphorus fertilizer was broadcast at 40 lbs P per acre over the experimental area prior to seedbed preparation. Seed of S301-H 8, a monogerm, non-bolting diploid hybrid was planted in late September each year on 40-inch, double-row beds. The plant rows were 14 inches apart on top of the beds and 26 inches between rows on adjacent beds. Plantings received two emergence irrigations totaling eight acre inches of water. Seedlings were thinned to an in-row spacing of 10 inches.

After thinning, the plantings were divided into plots nine rows wide and 22 feet long. Water applied was pumped through a meter and transported by gated pipe to each plot. Beets were irrigated when 25, 35, 55, 65, and 90% of the available soil moisture had been depleted at the 18 inch soil depth. These treatments correspond to the maximum soil moisture suctions shown in Table 2. Soil moisture content at the 18 inch depth was considered to be representative of average moisture conditions in the top three feet of soil. Nearly 90% of the water used by beets is extracted from the top three feet of soil (2). Moisture suction in plots of treatments 1, 2 and 3 was measured with tensiometers. For treatments 4 and 5, suction was measured indirectly through gravimetric analysis of soil samples. Normally, only the amount of water needed to replenish the moisture deficiency in the effective root zone was measured onto each plot. Exceptions to this were irrigations to germinate seed and to activate N fertilizer. In the 1970-71 season total water use was estimated for each irrigation and nitrogen treatment combination (Table 1). Total water use was determined from the water applied by irrigation, rainfall and the moisture content of the soil at planting and at the late harvest.

Nitrogen application rates of 0, 90, 180, 270, and 360 lbs per acre were established as shown in Table 2. When the application rate was greater than 180 lbs of N per acre, two applications were made to avoid injury to plants. Ammonium nitrate was used to side-dress the plots on each application date. After N was applied, all plots including check plots were irrigated with three acre inches of water, regardless of soil moisture conditions.

Prior to planting, soil samples were collected from each foot to a depth of four feet and were analyzed for NO_3 content. There were approximately 101 and 186 lbs of residual N per acre in 1970-71 and 1971-72, respectively.

Plots were sampled on July 7 each year. Plants in 28 feet of row were harvested. Leaves and crown tissue removed in the topping operation were weighed and recorded as fresh tops. One sample of 10 to 12 roots per plot was collected for determination of sucrose percentage. Petiole samples were collected periodically during the season and at harvest from each plot.

Results and Discussion

Average root yields, sucrose percentages, gross sugar yields and top yields for all irrigation and N treatment combinations are shown in Tables 3 and 4. Statistical comparisons among treatment means could not be made because the experimental design involved factorial treatments with unequal replications of treatments within a block. This design was utilized to facilitate the estimation of coefficients for production functions (functions not presented here). However, it is apparent that the major response of sugarbeets was to N. Irrigation treatments appear to have had very little effect on root or sugar yields.

Maximum sugar yields were produced when 180 to 270 lbs of N was supplied. Sucrose percentages tended to decrease as the N fertilizer rate was increased. Sucrose accumulation by the sugarbeet is generally favored by N deficiency. The ideal situation is one in which there is sufficient N in the soil early in the season to promote rapid growth followed by a period of N deficiency prior to harvest. It has been demonstrated that sugarbeets become deficient in N when the NO_3-N content of newly matured petioles drops below approximately 1000 ppm (9). Petiole analysis for NO_3-N in these experiments (Table 5) indicated that all plots except those receiving 270 and 360 lbs of N per acre were deficient in N at harvest. In general, plants with petiole NO_3-N levels above 5000 ppm in March did not become deficient in N before harvest.

Top yields obtained in July, as in this study, normally do not represent maximum yields. In most years, top yields peak in April or May and then decrease due to slower growth and defoliation of older leaves. Nevertheless, the July harvest data indicate that top yields increased as the N fertilizer rate was increased. Irrigation treatments also appear to have had an influence on top yields. As the percentage of available soil moisture depleted between irrigations was increased, top yields were decreased, primarily in the higher N fertility levels.

Water use efficiency for each treatment combination, expressed in terms of pounds of sucrose per acre inch of water, is given in Table 6. In general, water use efficiency increased as the percentage of soil moisture used between irrigations was increased. Water use efficiency and sugar yield data indicate that within the range of irrigation levels used in these experiments, considerable quantities of water can be conserved without greatly influencing sugar production.

References

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Table 1. Summary of irrigation treatments.

Irr. Treat.	N Treat.	Available Moisture Depleted %	Maximum Suction[1/] Bars	No. of Irrigations[2/] 1970-71	No. of Irrigations[2/] 1971-72	Inches Water Applied[3/] 1970-71	Inches Water Applied[3/] 1971-72	Total Water Use(Inches) 1970-71
1	1	25	0.4	14	14	44	45	41
1	3	25	0.4	18	17	56	54	53
1	5	25	0.4	20	18	62	57	58
2	2	35	0.6	13	14	41	45	40
2	4	35	0.6	16	15	50	48	48
3	1	55	1.0	9	9	33	35	31
3	3	55	1.0	11	11	41	43	38
3	5	55	1.0	11	11	41	43	42
4	2	65	3.0	9	10	37	43	35
4	4	65	3.0	10	10	42	43	37
5	1	90	10.0	6	7	26	31	23
5	3	90	10.0	6	8	26	37	26
5	5	90	10.0	7	8	32	37	31

[1/]Soil moisture suction at the 18 inch soil depth when irrigation applied.
[2/]Includes two emergence irrigations and two irrigations to activate N fertilizer.
[3/]Includes water applied in emergence irrigations and irrigations to activate N fertilizer. Does not include 1.71 inches of rainfall in 1970-71 and 2.53 inches in 1971-72.

Table 2. Summary of N treatments.

N Treatment	Date Applied: Oct. 30-Nov. 28	Date Applied: Jan. 14-15	Total
	lbs N/acre		
1	0	0	0[1/]
2	90	0	90
3	180	0	180
4	180	90	270
5	180	180	360

[1/]Residual N in the top four feet of soil was 101 and 186 lbs per acre in 1970 and 1971, respectively.

Table 3. Average root yield, sucrose percentage, gross sugar yield and fresh top yield, 1970-71.

Avail. Water Depleted %	N Level[1/] Lbs/Acre	Root Yield Tons/Acre	Sucrose %	Gross Sugar Yield Tons/Acre	Fresh Top Yield Tons/Acre
25	0	21.2	16.9	3.6	9.0
25	180	32.2	15.7	5.4	21.5
25	360	37.6	13.4	5.0	37.6
35	90	25.3	17.0	4.3	10.6
35	270	38.7	15.1	5.8	32.3
55	0	20.5	17.3	3.6	6.1
55	180	34.3	15.5	5.3	18.9
55	360	36.6	14.2	5.2	28.7
65	90	29.9	16.4	4.9	11.9
65	270	35.4	14.4	5.1	25.6
90	0	22.2	16.7	3.7	7.2
90	180	27.9	16.4	4.6	11.7
90	360	33.6	13.5	4.5	20.8

[1/]The amounts of N are the amounts added as fertilizer. Residual N amounting to 101 lbs per acre could be added to these amounts.

Table 4. Average root yield, sucrose percentage, gross sugar yield and fresh top yield, 1971-72.

Avail. Water Depleted %	N Level[1/] Lbs/Acre	Root Yield Tons/Acre	Sucrose %	Gross Sugar Yield Tons/Acre	Fresh Top Yield Tons/Acre
25	0	22.0	16.7	3.7	7.8
25	180	34.6	14.9	5.1	21.8
25	360	34.3	13.6	4.7	28.1
35	90	28.8	16.8	4.8	8.9
35	270	33.2	14.6	4.8	22.4
55	0	24.6	16.7	4.1	8.6
55	180	30.0	16.4	4.9	12.2
55	360	34.0	13.1	4.4	22.2
65	90	29.2	16.1	4.7	16.0
65	270	31.8	15.1	4.8	19.4
90	0	20.0	16.2	3.2	7.9
90	180	30.2	15.5	4.7	14.0
90	360	31.0	13.1	4.1	18.6

[1/]The amounts of N are the amounts added as fertilizer. Residual N amounting to 186 lbs per acre could be added to these amounts.

Table 5. Summary of NO_3-N content of petioles, 1970-71 and 1971-72.

Avail. Water Depleted	N Level[1/]	1970-71 May 4	1970-71 Jul. 7	1971-72 Feb. 15	1971-72 Mar. 16	1971-72 Apr. 13	1971-72 May 3	1971-72 Jul. 7
(%)	(Lbs N/A)				(ppm NO_3-N)			
25	0	750	720	1070	1580	1030	790	900
25	180	1060	870	3840	4090	1590	1520	940
25	360	2870	1350	3900	7570	5710	3680	1230
35	90	1690	780	1670	2180	1070	820	630
35	270	2140	1090	4430	7730	4850	3320	1020
55	0	890	760	1090	1750	1840	1320	840
55	180	1690	890	3580	4550	1590	880	700
55	360	3390	1310	4030	9730	7210	4970	2050
65	90	930	760	2350	3190	940	710	690
65	270	1900	1080	3660	8930	4190	2640	1420
90	0	880	830	890	930	1100	710	780
90	180	1510	740	3020	3240	1880	1670	710
90	360	3200	1040	4250	5160	6810	5420	1930

[1/]The amounts of N are the amounts added as fertilizer. Residual N amounting to 101 and 186 lbs per acre could be added to these amounts in 1970-71 and 1971-72, respectively.

Table 6. Water use efficiency, based on both water used and irrigation water applied.

Avail. Water Depleted %	N Level[1/] Lbs/Acre	Pounds Sucrose Per Acre Inch 1970-71 Water Used	1970-71 Water Applied	1971-72 Water Applied
25	0	176	164	164
25	180	204	193	189
25	360	172	161	165
35	90	215	210	213
35	270	242	232	200
55	0	232	218	234
55	180	279	259	228
55	360	248	254	205
65	90	280	265	219
65	270	276	243	223
90	0	322	285	206
90	180	354	354	254
90	360	290	281	222

[1/]The amounts of N are the amounts added as fertilizer. Residual N amounting to 101 and 186 lbs per acre in 1970-71 and 1971-72, respectively, could be added to these amounts.