EFFECT OF IRRIGATION METHOD AND LEACHING OF NITRATE-NITROGEN ON SUCROSE PRODUCTION BY SUGARBEETS[1]

J. N. Carter, C. H. Pair, and S. M. Bosma[2]

Factors that influence sugarbeet root yield and sucrose concentration affect sucrose production. Inadequate nitrogen (N) limits root yield; excess N stimulates top growth and reduces sucrose percentage (2, 4). Inadequate irrigation limits root and sucrose yields (3); overirrigation leaches nutrients and affects the sugarbeet response to N application (6).

For maximum sucrose production in southcentral Idaho, the available N level in the soil should be highest during July, when the plant N uptake rate is highest, and should be nearly depleted by about August 20. The desired available N supply in silt loam soil depends on proper N application and removal of excess N from the root zone late in the season. If the available N level in the soil can be controlled to meet these requirements, beet quality and sucrose production may be increased.

In furrow-irrigated sugarbeets, nitrate-nitrogen (NO_3-N) accumulates in the surface, near the center of the ridges. The NO_3-N below the furrow decreases at each irrigation, but that in the ridges becomes more concentrated as the season progresses because water moves toward the drying surface and carries NO_3-N with it. Fall rains can move this accumulated N into the root zone, causing regrowth of the beet tops at the expense of the stored sucrose. Sprinkler irrigation presumably gives a more even distribution of NO_3-N in the soil throughout the season compared to furrow irrigation. As a result, sucrose percentage and sucrose yield should be greater under sprinkler than under furrow irrigation.

This paper reports the effects of irrigation method, intentional leaching of NO_3-N in late August, and N fertilizer rate on sucrose production by sugarbeets.

MATERIALS AND METHODS

A field experiment involving two methods of irrigation, two methods of leaching, and four N levels was conducted in 1969 on Portneuf silt loam soil near Twin Falls, Idaho. The soil has a weakly cemented hardpan at the 16- to 20-inch depth that has little effect on water movement when saturated, but restricts root penetration. The experimental area had been cropped to barley without fertilizer during 1968 and was considered to be low in N and phosphorus. Phosphorus fertilizer was broadcast at a rate of 44 lbs P/A before seedbed preparation.

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[2] Research Soil Scientist, Research Engineer (Irrigation), and Physical Science Technician, respectively, Snake River Conservation Research Center, Soil and Water Conservation Research Division, Agricultural Research Service, USDA, Route 1, Box 186, Kimberly, Idaho 83341.

Portneuf silt loam has a high mineralization and nitrification capacity. Samples taken from the 0- to 16-inch depth and incubated for 3 weeks at 30° C produced 190 lbs N/A. A total supply of 300 lbs N/A, which includes NO_3-N, mineralizable N, and applied N, is generally considered optimum for maximum sucrose yields in this area.

Two irrigation methods (sprinkler, furrow), and two irrigation treatments (nonleached, leached), as main plots; and four N fertilizer rates, all replicated four times, were used. The sugarbeets were planted April 15 in 24-inch rows, and then replanted May 12 because of a poor stand. They were thinned to a spacing of approximately 12 inches within rows early in June.

All plots were irrigated when the soil moisture reached prescribed levels based on estimated evapotranspiration (5) except the late August and early September irrigations on the intentionally leached plots. Irrigation water was applied to alternate furrows on all plots for the first two irrigations (5/13, 6/5). Ammonium nitrate at the rates of 50, 100, 150, and 200 lbs N/A was applied as a side-dressing just below and to the side of the irrigation furrows (6/19/69). These rates were not intended to bracket an optimum level and were not expected to produce large sucrose yield increases. The high rates were needed to evaluate the effects of intentional leaching. The fertilizer application was followed by a third furrow-irrigation (6/22) in which all furrows received water. Beginning with the fourth irrigation (7/11), and for the remainder of the season, one-half of each replication was furrow-irrigated using alternate furrows, and the other half was sprinkler-irrigated. One-half the sprinkled and furrow-irrigated areas was leached with about 18 inches of water in late August and early September (Table 1).

Table 1. Summary of irrigation

Date	Water applied			
	Furrow		Sprinkler	
1969	Nonleached	leached	Nonleached	leached
	Inches			
5/13	4.0	4.0	4.0*	4.0*
6/5	2.8	2.8	2.8*	2.8*
6/22	2.9†	2.9†	2.9†	2.9†
7/11	3.6	3.6	4.0	4.0
7/23	3.8	3.8	3.5	3.5
8/1	3.5	3.5	3.4	3.4
8/12	3.5	3.5	3.5	3.5
8/20	---	18.0†	---	10.2
8/26	3.7	3.7	3.7	3.7
9/4	---	---	---	7.8
9/9‡	3.7	3.7	3.5	3.5
10/1	3.8	3.8	---	---
10/6	---	---	3.5	3.5
TOTAL	35.3	53.3	34.8	52.8

* Furrow irrigated
† Every furrow irrigated
‡ 0.63 inch rain on 9/11

Weekly petiole samples consisting of 24 of the youngest fully mature petioles were taken at random from each plot at each sampling date. The petioles were cut into 1/4-inch sections, dried at 65° C, ground to pass through a 420-micron sieve, subsampled, and analyzed for NO_3-N. The NO_3-N concentration in the petioles was determined by the phenoldisulfonic acid method using a water extract of the beet petioles (7).

The beet roots were harvested on October 27, taking eight 30-foot rows for yield determination. Random selection of beet roots was made during harvest for sucrose analysis. The beet roots were analyzed for sucrose by the Amalgamated Sugar Company using their standard procedures.

RESULTS AND DISCUSSION

Irrigation Method

Sugarbeets grown under sprinkler irrigation consistently produced slightly greater root yields at the three lower N levels when compared to those furrow-irrigated (Table 2); yet the differences were significant only at the 100-lb N level. The sucrose percentage decreased as N level increased on both methods of irrigation. However, there were no significant differences in sucrose percentages between the two methods. Nevertheless sprinkler-irrigated areas produced an average of 5% more sucrose than did furrow-irrigated areas at the three lower N levels.

Table 2. Effect of nitrogen, method of irrigation, and leaching on root yield, sucrose yield and sucrose percentage of beet roots.

N applied	Nonleached Root yield	Nonleached Sucrose yield	Nonleached Sucrose	Leached Root yield	Leached Sucrose yield	Leached Sucrose
lbs/A	tons/A	tons/A	%	tons/A	tons/A	%
			Furrow			
50	22.4	3.59	16.2	21.0	3.58	17.1
100	21.6	3.44	15.9	21.0	3.42	16.3
150	22.6	3.47	15.4	22.0	3.45	15.7
200	22.9	3.45	15.1	23.6	3.69	15.6
Average	22.4	3.49	15.7	21.9	3.54	16.2
			Sprinkler			
50	22.6	3.70	16.4	21.6	3.68	17.0
100	23.8	3.83	16.1	22.5	3.68	16.3
150	24.4	3.76	15.4	21.7	3.47	16.0
200	23.0	3.45	15.0	22.2	3.49	15.7
Average	23.5	3.69	15.7	22.0	3.58	16.3

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Table 2 - Continued

Analysis of Variance

Component	df	mean squares Root yield	Sucrose yield	Sucrose %
Replication (R)	3	23.3	0.64	7.56*
Method Irrig. (M)	1	6.1	0.25	0.13
Error a	3	25.2	0.75	0.43
Leaching (L)	1	14.6*	0.02	4.26
M × L	1	3.3	0.10	0.02
Error b	6	2.3	0.13	1.05
Nitrogen (N)	3	3.4*	0.05	5.71**
M × N	3	4.2*	0.12*	0.03
L × N	3	1.8	0.06	0.16
M × L × N	3	1.3	0.01	0.09
Error c	36	1.0	0.04	0.25
TOTAL	63			

* Significant at the 5% level
** Significant at the 1% level

Although significant differences in root and sucrose yields between the two forms of irrigation occurred at the 100-lb N rate, there is a question as to their validity. Petiole analyses indicated a substantial reduction in NO_3-N in the petioles from midseason of the furrow-irrigated beets receiving 100 lbs N, as compared to the same N treatment that was sprinkled (Fig. 1). This large difference did not occur on the other N levels. This indicated a growth factor or N difference on this treatment that could not be accounted for.

No rainfall was received from July 7 to September 11, which favored the accumulation of NO_3-N in the ridges of the furrow-irrigated beets. Rainfall was received on September 11, 19, 20, and 21 in sufficient quantities (0.82 inch) to move the NO_3-N accumulated in the ridges into the root zone. Contrary to expectations, the NO_3-N concentration in the petioles of sprinkled beets generally was higher than in those of furrow-irrigated beets during the latter part of the growing season (Table 3). The sucrose percentages with the two forms of irrigation, however, were comparable.

The differences in sucrose production between the irrigation methods resulted mainly from differences in root production. There was no indication from petiole analysis that N nutrition was a contributing factor in these differences (Fig. 1). Probable contributing factors were the higher leaf area index and a more erect type of growth of sugarbeets grown using sprinkler irrigation.

The two highest levels of applied N significantly increased beet root yields as compared with the 50-lb rate (Table 2). However, because the sucrose percentage decreased significantly with each increased applied-N level, there was no change in sucrose production at different N levels.

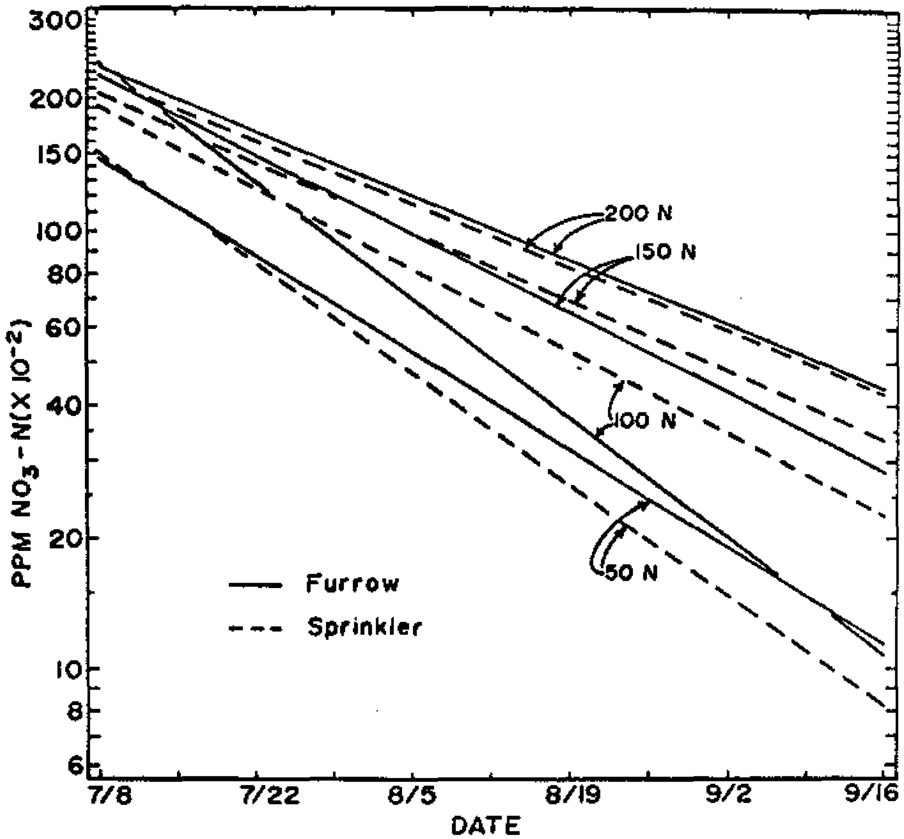

Fig. 1. Nitrate-nitrogen concentration in sugarbeet petioles at various sampling dates using two methods of irrigation and four nitrogen rates.

Table 3. Effect of fall rains on petiole NO_3-N concentration of sugarbeets grown using furrow and sprinkler irrigation.

Date	Irrigation	lbs N/A 50	100	150	200	Average
		ppm NO_3-N				
Sept. 3	Furrow	1,830	2,043	4,273	4,643	3,197
	Sprinkler	1,587	3,778	4,821	6,228	4,104
Sept. 9	Furrow	1,350	1,365	3,036	5,082	2,708
	Sprinkler	1,000	2,930	4,901	3,253	3,021
Sept. 16	Furrow	1,430	883	2,322	4,116	2,188
	Sprinkler	1,501	2,653	2,780	4,100	2,759
Sept. 23	Furrow	1,314	918	2,739	2,705	1,919
	Sprinkler	1,274	2,406	2,937	4,268	2,721

The spring soil test indicated that approximately 110 lbs of applied N/A would be required for maximum sucrose production. However, the 50-lb rate was adequate at the relatively low production level attained because of replanting. Petiole analysis confirmed that sufficient N (7) was available for maximum root yield on all N treatments (Fig. 1). Root yields were 3 to 4 tons below those grown in nearby areas, which did not require replanting. To produce the extra 3 to 4 tons of beets would have required an additional 50 lbs of N.

Leaching

Increased water application to leach N from the root zone late in the growing season significantly reduced beet root yields (Table 2). However, leaching increased sucrose percentage by about 0.5. As a result, leaching had no effect on sucrose production.

The lower root yield on leached plots may have been caused by adverse conditions during and immediately after the leaching period. The sugarbeet plants, during this period, wilted and the leaves on the sprinkled plots had a white appearance. The wilting could be attributed to partial anaerobic conditions in the root zone during leaching (8). The cause of the whitish appearance of the beet leaves was not determined, but was probably due to salt accumulation. Both factors are believed to have contributed to the reduced beet root yield.

Petiole analysis indicated a decreased available N supply after the period of heavy water application with both irrigation methods (Figs. 2, 3). Sufficient

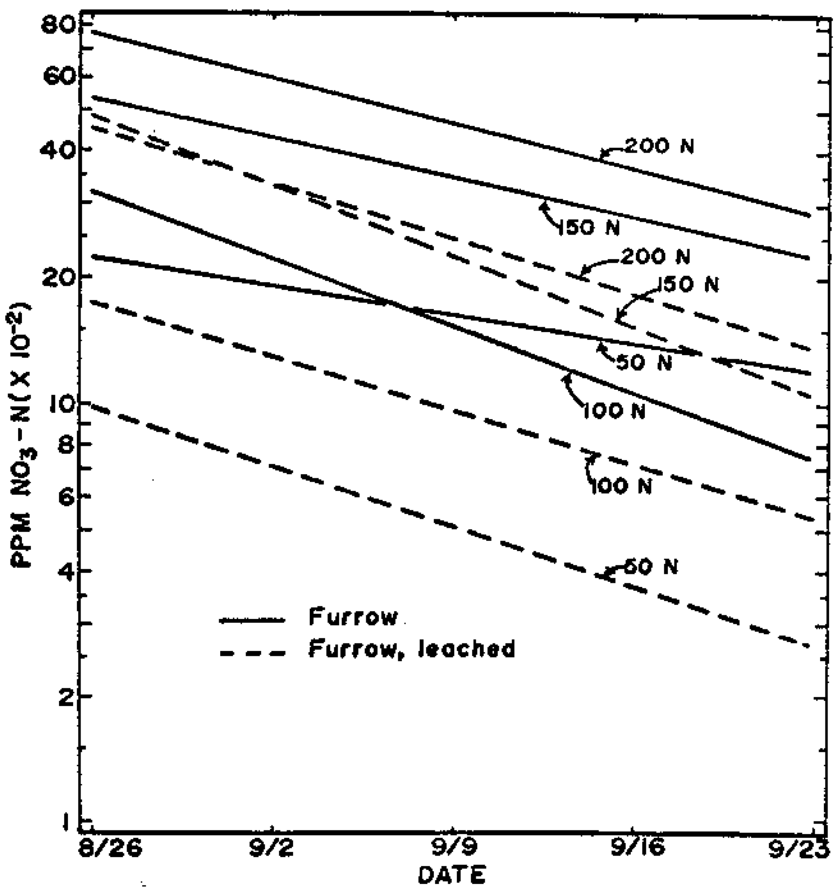

Fig. 2. The effect of leaching of the available nitrate-nitrogen from the root zone on petiole NO_3-N concentration of sugarbeets grown using furrow irrigation.

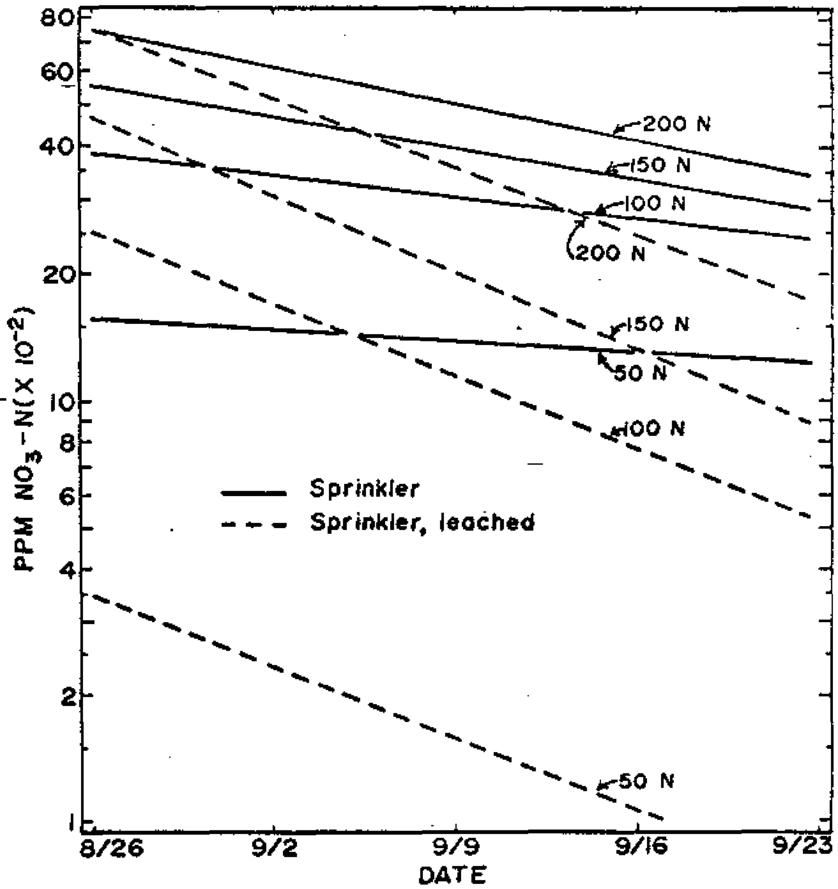

Fig. 3. The effect of leaching of the available nitrate-nitrogen from the root zone on petiole NO_3-N concentration of sugarbeets grown using sprinkler irrigation.

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amounts of N were still available to keep the plants at a high NO_3-N level, particularly on the higher levels of applied N, which confirmed the results of earlier studies (1). Earlier leaching of N might have achieved a more desirable decrease in available soil N and a sufficient sucrose percentage increase to make leaching a potentially feasible practice. Also, the plant NO_3-N level should be controlled more easily on a sandy, low mineralization capacity soil than on the silt loam used in this experiment.

In conclusion, results indicate that, except for one anomaly, the type of irrigation used has little effect on the N nutrition or sucrose production of sugarbeets when adequate water is applied as needed. The petiole NO_3-N level on the higher N treatments confirmed earlier studies relating concentration and changes in petiole NO_3-N to sucrose production. Leaching N from the root zone late in the growing season was not a desirable practice because there was no increase in sucrose production and such a practice may contaminate the ground water with NO_3-N.

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