

Some Effects of Excess Water Application on Utilization of Applied Nitrogen by Sugar Beets¹

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Over-irrigation is a major problem in many irrigated areas. On the new lands in the Columbia Basin Project, most of the soils have relatively high water holding capacities and infiltration rates. Applying irrigation water too frequently and for excessive durations on these soils has made this problem particularly acute.

In addition to contributing to drainage problems in the area, over-irrigation may, by leaching, materially affect the response of crops to fertilizers. This is especially true of nitrogen, which is the nutrient most commonly deficient in these soils.

The effects of over-irrigation in the area have been most noticeable in sugar beet production because of the long irrigation season, the high nitrogen requirement of the crop, and the low nitrogen content of the soils in the area. In many fields, this crop has developed severe nitrogen deficiency symptoms in midseason even where nitrogen applications were relatively high.

Most of the reported irrigation and nitrogen fertilization work on sugar beets has been designed to determine either the effects of depleting the soil moisture to predetermined levels or the effects of nitrogen rates and placement methods on yield, sugar content and purity. Some attention also has been given to certain interrelationships between soil moisture and nitrogen fertilization.

Little evidence exists, however, relative to nitrogen utilization under various conditions of irrigation practice. This is especially true of practices involving application of excess irrigation water³.

The study reported here was designed to determine the effects of application of excess irrigation water on utilization of nitrogen and the resulting effects upon sugar beet yield, sugar content, and nitrogen status.

Certain of the yield and water application efficiency information has been previously reported (2, 3)⁴. This paper presents two season's data pertaining primarily to nitrogen status and sugar content of sugar beets as affected by excess water application and by nitrogen rate and placement method.

1953 Experiments

Experimental Procedure

Six experiments were conducted in 1953 in the Columbia Basin Project in Washington. At each site, three irrigation treatments were established as follows:

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³ "Excess irrigation water" as used in this paper refers to irrigation water added in excess of that which the soil will retain.

⁴ Numbers in parentheses refer to literature cited.

Treatment Number	Relative Quantity of Water Added per Irrigation
1	X
2	2X
3	3X

The magnitude of the quantity "X" was determined from pan evaporation measurements (1) in conjunction with plant size and cover. Irrigation frequently was determined from the quantity "X" and the moisture retention characteristics of the profiles. All three treatments at a given site were irrigated simultaneously at frequencies of 14 to 28 days.

Nitrogen rate sub plots were established in each main irrigation plot by sidedressing about thinning time. These rates were 60, 120, 180, and 360 pounds per acre of N at four of the six sites. At the remaining two sites, pre-planting applications of about 120 and 155 pounds per acre of N had been made so the final rates will not conform to the other sites. All nitrogen was applied as NH_4NO_3 .

Fifteen to 20 recently-matured petioles were obtained periodically from each plot for nitrogen status evaluations. Two rows 25 to 30 feet in length were harvested for yield and sugar content evaluations.

Results and Discussion

Effects on yield.

Yield and irrigation information for 1953 have been previously reported (2). Deep percolation losses for the 2X treatment varied from 7 to 20 inches and for the 3X treatment from 18 to 39 inches at the six locations. Even with deep percolation losses of these magnitudes, no significant yield depressions were apparent. As will be discussed later, failure to remove sufficient nitrogen to depress yields is attributed to the fact, that little excess irrigation water was applied early in the growing season.

Effects on sugar content

Results of sugar content determinations at harvest for certain of the 1953 locations are presented in Table 1. No measurable effect of irrigation treatment was noted and in general only the highest nitrogen rate resulted in appreciable depression of the sucrose percentage.

Table 1.—Sugar Content at Harvest as Influenced by the Irrigation and Nitrogen Rate Treatments for Certain of the 1953 Locations.

Location	Sucrose Percentage							L.S.D. (5%)
	Irrigation			N Rate (lbs./acre)				
	X	2X	3X	60	120	180	360	
1	16.3	16.7	16.5	17.4	16.6	16.4	15.6	0.61
3	18.4	18.5	18.2	18.7	18.7	18.7	17.4	0.65
5	18.7	18.5	18.8	19.3	19.0	18.6	18.2	0.62
				N Rate (lbs./acre)				
				155	180	240	360	
4	18.2	17.8	17.9	18.1	18.2	18.2	17.2	0.71

Effects on plant nitrogen level

Results of total- and nitrate-nitrogen determinations on petiole samples are depicted in Figures 1 and 2 for location 1. All nitrogen levels, except the 360 pound rate, were either below or approaching the critical level of Ulrich (4) by September 3, which was about seven weeks before harvesting. This explains the relatively small sugar content differences obtained.

Of particular interest are irrigation-sampling date interactions obtained in these measurements. The irrigation treatments receiving excess water had the highest nitrogen levels in the beet petioles at the first sampling. Differences were greatest at the two highest nitrogen rates indicating that the excess water applied prior to the first sampling date increased the availability of the shallow sidedressed nitrogen. Lower nitrogen levels noted on treatments receiving no excess water were probably due to one or both of two factors: (A) Excessive fertilizer concentration in the area of placement restricting root growth until the nitrogen was moved by the irrigation water, or (B) Dry soil in the surface layer restricting root activity and nitrate movement.

1954 Experiments

Experimental Procedure

In 1954, three experiments were conducted; two near Moses Lake, Washington, in the Columbia Basin Project and one at Toppenish, Washington, in the Yakima Valley. At Toppenish, the irrigation treatments were the same as those used in 1953. At the two Moses Lake locations, the following irrigation treatments were established.

Location 1—Moses Lake

Treatment Number	Irrigation Frequency	Relative Quantity of Water Added per Unit Time
1	2 weeks	X
2	4 weeks	X
3	2 weeks	2X
4	4 weeks	2X
5	2 weeks	3X

Location 2—Moses Lake

Treatment Number	Irrigation Frequency		Relative Quantity of Water Added per Unit Time	
	Before 7/15	After 7/15	Before 7/15	After 7/15
1	4 weeks	4 weeks	X	X
2	2 weeks	4 weeks	2X	X
3	2 weeks	4 weeks	4X	X
4	4 weeks	2 weeks	X	2X
5	4 weeks	2 weeks	X	4X

The quantity "X" was again determined from pan evaporation measurements (1), plant size, and cover. Since fixed irrigation frequencies were used on different treatments, the quantities of water added at each irrigation were determined from the irrigation frequency and the magnitude of

"X" during the interval in question. The frequencies used were determined from soil moisture retention characteristics of the profiles and peak consumptive use information previously determined.

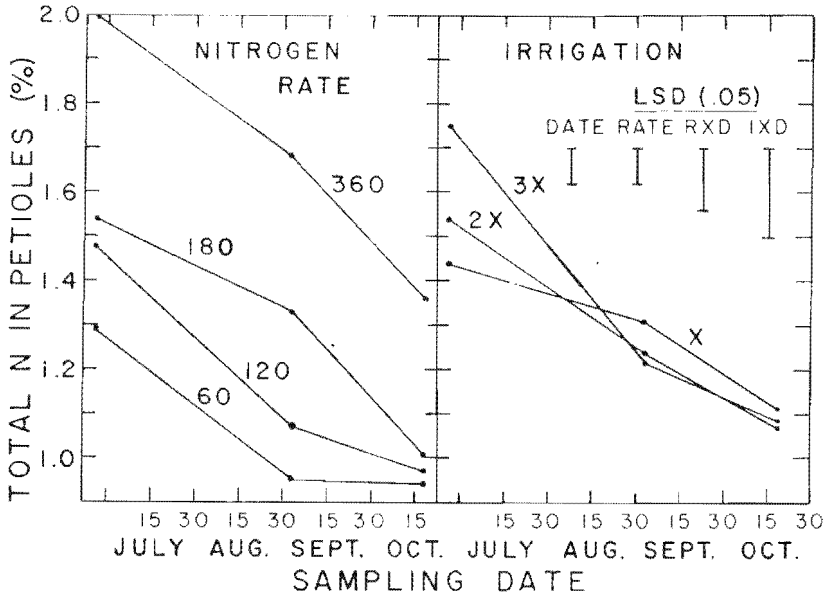


Figure 1.—Effects of nitrogen and irrigation on total-nitrogen level of beet petioles at location 1, 1953.

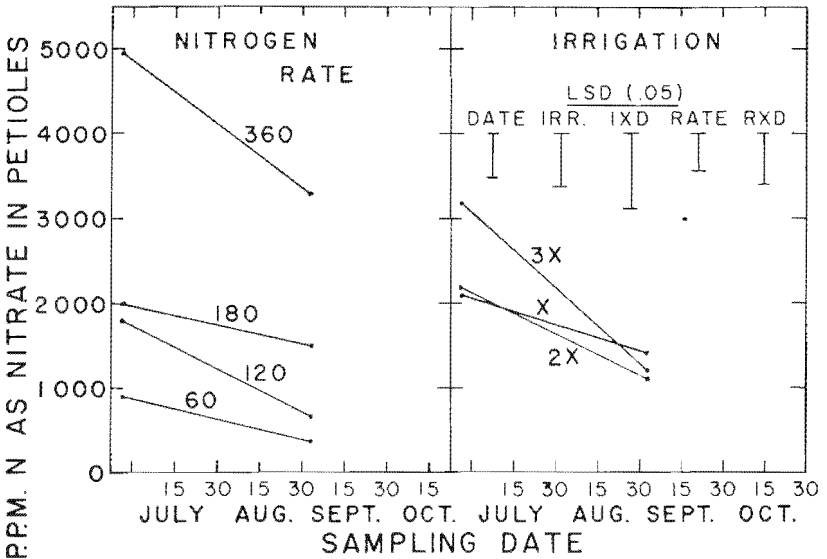


Figure 2.—Effects of nitrogen and irrigation on nitrate-nitrogen levels of beet petioles at location 1, 1953.

Nitrogen was applied at three rates by each of four methods of placement within each irrigation plot. The rates, in addition to the 0 N plots, were 120, 240, and 360 pounds of N per acre; the placement methods were plowed-down, disced-in, shallow sidedressed, and deep sidedressed. All nitrogen was applied as NH_4NO_3 .

Fifteen to 20 young mature petioles were again obtained periodically from each plot for nitrogen status evaluations. Two rows, 20 or 25 feet in length, were harvested for yield and sugar content determinations.

Results and Discussion

Effects on yield

Yield and irrigation information for the 1954 experiments has been reported previously (3). Yields were again unaffected by excess irrigation water at the Toppenish location, which received the same three irrigation treatments as were used in 1953.

The irrigation phases of the remaining two locations were designed to study the effects of higher rates of deep percolation and to compare early-season and late-season applications of excess water. Yield data for these two locations (1954) are presented in Figure 3.

Marked reductions in yield resulted from excess water applications at both locations. Failure to obtain such depressions in yield by late excess applications at location 2 indicates that only the early season applications are important in reducing yield by leaching of nitrogen. This explains the failure to obtain yield depressions in 1953 and at the Toppenish location in 1954, since no early excess water applications were made in these cases.

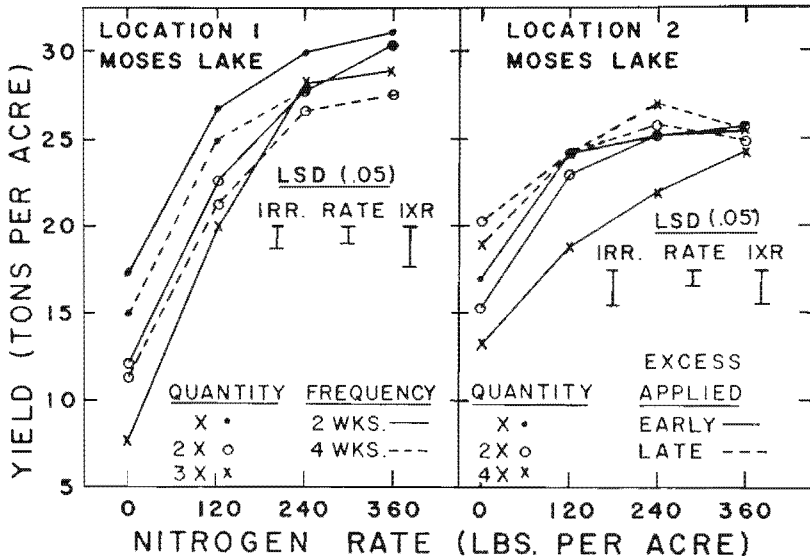


Figure 3.—Effects of irrigation and nitrogen rate on yield of beets at two locations, 1954.

Yield reductions resulting from excess water were considerably greater at low rates than at high rates of nitrogen. This behavior could be expected since a large excess of nitrogen was available at the higher rates. From this supply, the crop could accumulate a high concentration before leaching of nitrogen from the root zone limited the supply. Also, a considerable portion of the applied nitrogen probably was still in the ammoniacal form when the early water applications were made.

An apparent moisture response was noted between the two- and four-week frequencies at location 1. This indicates a possible confounding in the location 2 data, since different frequencies were used at this location also. This probably accounts for the tendency for higher yields on the treatments receiving late excess applications at location 2.

Placement effects are shown in Table 2. No difference in yield was obtained at location 2 as a result of placement. At location 1 and at Toppenish, however, disced-in applications were inferior to the other three methods of application and at Toppenish, the plowed-down application was superior to the sidedressed treatments. These differences in behavior are

Table 2.—Effects of Nitrogen Placement on Yield of Beets for Three Locations, 1954.

Placement Method	Yield (Tons per Acre) ¹		
	Loc. 1—Moses Lake	Loc. 2—Moses Lake	Toppenish
Plowed-down	27.4	24.3	29.1
Disced-in	24.7	24.3	26.3
Sidedressed, shallow	27.5	24.2	27.9
Sidedressed, deep	28.0	24.7	27.9
L.S.D. (5%)	1.2	N.S.	0.9

¹ Mean yield for 120, 240, and 360 lbs. per acres N and all irrigation treatments.

attributed to differences in water retention characteristics of the profiles. The soil at location 2 was deep and well-drained, whereas the other two were shallow, stratified soils in which water is retained at low tensions following irrigation. Thus surface evaporation, with accompanying accumulation of nitrate-nitrogen at the soil surface, persisted for a considerable time following irrigation on the stratified soils. This surface isolation was probably appreciable on these soils for the shallow placement whereas such accumulations were negligible on the well-drained soil.

Effects on sugar content

Results of sugar content determinations are presented in Figure 4. In view of the placement effects noted previously and the probability of confounding by these effects, only data on the plowed-down applications for Moses Lake location 1 and the Toppenish location are presented.

Sugar contents were significantly reduced, as expected, at increasing nitrogen rates. Pronounced irrigation effects were apparent at the two Moses Lake locations. Higher sugar contents resulted from excess water applications, especially at the high nitrogen rates, indicating a reduced plant nitrogen level in the over-irrigated treatments. Failure to obtain such behavior at the Toppenish location is probably due to the high indigenous nitrogen level and the earlier harvesting.

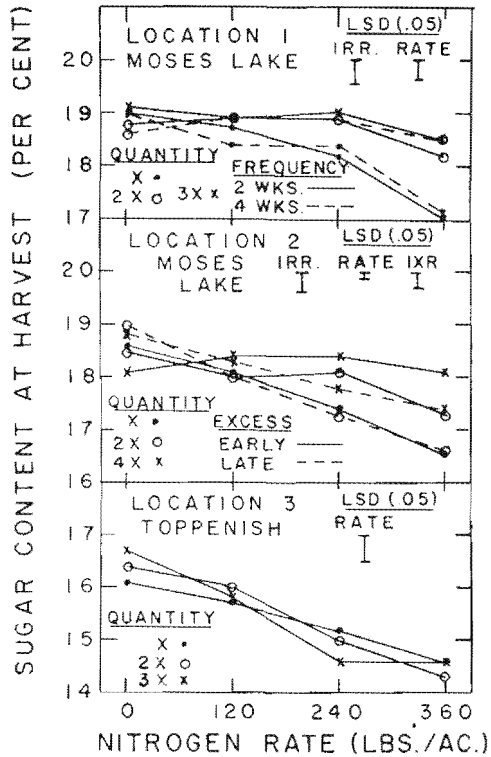


Figure 4.—Effects of nitrogen rate and irrigation on sugar content of beets at harvest for three locations, 1954.

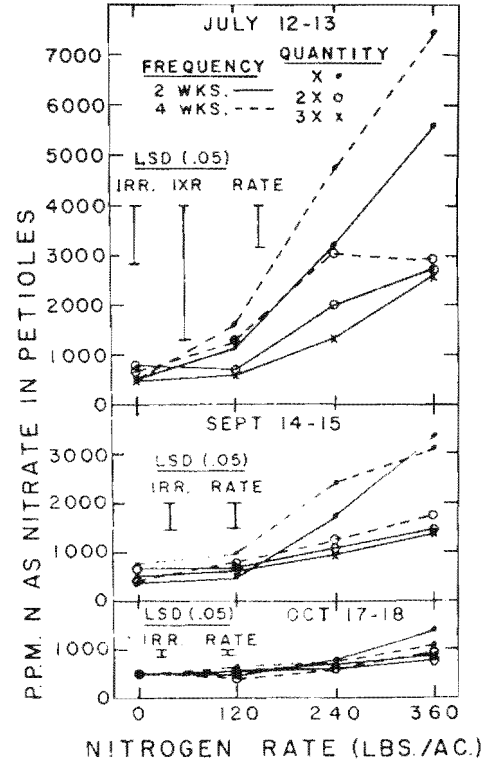


Figure 5.—Effects of nitrogen rate and irrigation on nitrate-nitrogen level of beet petioles from the plowed down placement at location 1, 1954.

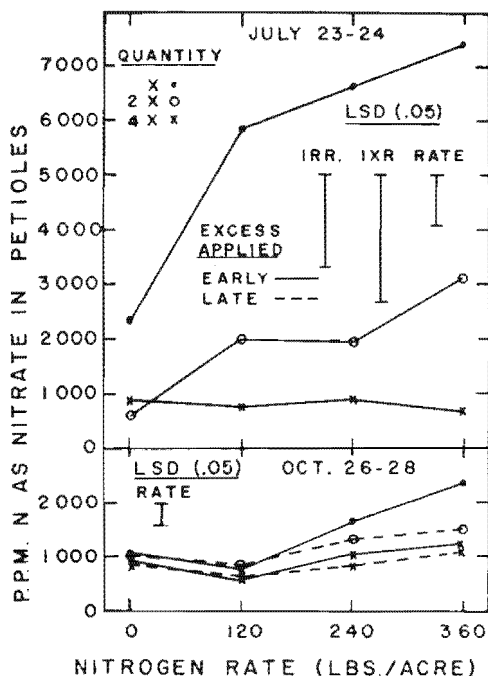


Fig. 6.—Effects of nitrogen rate and irrigation on nitrate-nitrogen level in beet petioles from the plowed-down placement at location 2, 1954.

Effects on plant nitrogen level

Results of nitrate-nitrogen determinations for the plowed-down nitrogen placement at locations 1 and 2 are presented in Figures 5 and 6.

Marked reductions in nitrate concentration resulted from the excess water applications. The effects of the excess applications early in the season, shown in Figure 6, again emphasize that the early irrigations are most critical with regard to nitrogen loss by leaching.

At location 1, the nitrate concentration was higher in the petiole samples from the plots irrigated at the four-week frequency than from the plots irrigated at two-week intervals. However, this condition cannot be assumed to hold true for the entire irrigation cycle for the two frequencies. The nitrate concentration in the plants irrigated at 4-week intervals may, in fact, drop considerably below that of those irrigated every two weeks, since the samples were taken about seven to ten days following irrigation of all treatments. Further, the nitrate levels determined do not accurately portray the total nitrogen uptake by the treatments.

However, the fact that the nitrate levels were well above the critical level on the four-week frequency indicates that the yield differences obtained between frequencies was not due to a nitrogen-irrigation interaction but were probably real moisture responses.

Nitrate determinations for the disced-in applications at location 1 showed the nitrate level to be as high or higher than that of the plowed-

down applications at the July 12-13 sampling. However, it is impossible to determine the total nitrogen uptake for these treatments from the material available. Thus, the yield differences between placement methods cannot be definitely explained from the present data.

Summary

1. Application of irrigation water in excess of that storable in the root zone early in the growing season materially reduced sugar beet yields. Similar late-season applications did not affect yield. Yield reductions were considerably greater at low nitrogen rates than at high rates.

2. Lower yields were obtained on shallow, stratified soils where applied nitrogen was disc'd-in than where the nitrogen was plowed-down or side-dressed. On a deep, well-drained soil, placement effects were negligible. The reductions obtained on the stratified soils are believed to result from surface isolation of nitrogen by water moving upward and evaporating at the soil surface.

3. Sugar content at harvest was considerably higher on treatments receiving early excess water applications than on the control irrigation treatments. The differences were greatest at high nitrogen rates. Late-season excess water applications increased the sugar content to some degree, also. This further indicates a reduced nitrogen status of the plants prior to harvest, and that even late-season excess applications may remove sufficient nitrogen to affect sugar content.

4. Nitrate-nitrogen levels in sugar beet petioles was greatly reduced by early excess water applications and, to a lesser degree, by similar applications late in the season. In 1953, excess applications appeared to increase the availability of shallow sidedressed nitrogen. No conclusive evidence was obtained in 1954 relative to the effect of irrigation practice on availability of nitrogen applied by different methods.

References

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