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Effect of Nitrogen and Irrigation on Sugarbeets Production in Southern Idaho

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Most of the nitrogen fertilizer is applied to sugarbeet fields in southern Idaho before planting. During the early stages of plant growth the soil and fertilizer N is subject to leaching because the NO_3-N concentrations in the soil usually are higher than later in the season. The rate of N uptake in this area, under conditions where N does not limit plant growth, increases rapidly beginning early in June, reaches a peak early in July, and begins to decrease in late July. If inadequate N is available to meet crop needs then the addition of N fertilizer just prior to the period when the demand rate increases should increase the efficiency of sucrose production and N fertilizer use.

The practice of supplemental, midseason application of N in irrigation water is increasing in southern Idaho. It is not known whether this practice is resulting in more efficient use of N fertilizer, increasing yields, or whether or not midseason applications have an adverse net effect on sucrose production. The objective of this study was to evaluate current N fertilizer practices and the effect of irrigation management on root and sucrose yields. Major emphasis was placed on the effects of N and irrigation management on petiole NO_3-N concentrations to refine the use of petiole analysis as a diagnostic tool in managing N fertilizer.

Procedure

Three field experiments were conducted in 1968 and 1969 on loam and silt loam soils in southern Idaho. These soils have a weakly cemented hardpan at the 16- to 24-inch depth that has little effect on water movement when saturated, but may restrict root penetration. Adequate phosphorus fertilizer (44 lbs P/A) was broadcast on all experimental areas prior to seedbed preparation. Adequate potassium was present from soil and irrigation water sources.

Experiment 1 (1968) was conducted on a Portneuf silt loam soil following unfertilized corn near Twin Falls, Idaho using

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four replications of a randomized block. Nitrogen fertilizer rates of 0, 50, 100 and 200 lbs N/A were applied preplant, on July 15. and part preplant with the remainder on July 15.

Experiment 2 (1968) was conducted on a Declo loam soil following potatoes that had received 120 lbs N/A near Pocatello, Idaho using three replications with two irrigation levels (M_1 and M_3) as main plots, and N fertilizer treatments as subplots. N fertilizer rates of 0, 90, 120, and 150 lbs N/A were applied preplant and part preplant with the remainder during midseason.

Experiment 3 (1969) was conducted on a Pancheri silt loam soil following potatoes that had received 100 lbs N/A near Idaho Falls, Idaho, using three replications with three irrigation levels (M_1, M_2, and M_3) as main plots and three N fertilizer rates as subplots. A uniform application of 100 lbs N/A was applied preplant, with three rates of 0, 40, and 80 lbs N/A applied on July 9.

The preplant fertilizer in all experiments was broadcast and worked into the upper soil layer. Midseason application of N fertilizer was broadcast prior to a sprinkler irrigation. The N fertilizer rates of 100, 120, and 140 lbs N/A in Experiments 1, 2, and 3, respectively, represent fertilizer rates common for these areas.

The soils in southern Idaho have a very high mineralization and nitrification capacity. Soil samples taken from the root zone before planting and incubated for three weeks at 30° C produced 190 lbs N/A for the Portneuf, 139 for the Declo, and 168 for the Pancheri. When combined with the NO_3-N present at that time, a potential supply of 280, 255, and 225 lbs N/A was available for the Portneuf, Declo, and Pancheri, respectively, before any fertilizer was applied. Since approximately 12 lbs of N is needed for each ton of beet roots produced, only limited response to N fertilizer was expected.

Sugarbeets were planted April 11 in 24-inch rows in Experiment 1, April 24 in 22-inch rows in Experiment 2, and April 22 in 22-inch rows in Experiment 3. The beets were thinned to a 9- to 12-inch spacing in early June. Sprinkler irrigation was used in all experiments (Figure 1). Complete control of irrigations was limited because of the remote location of Experiments 2 and 3, and the schedule had to be coordinated with the farmers' other irrigation requirements.

Three irrigation treatments were used (Figure 1):

M_1 — Considered to be a level adequate for optimum sucrose production. Irrigations were scheduled on the basis of estimated soil water depletion (3). The computer first

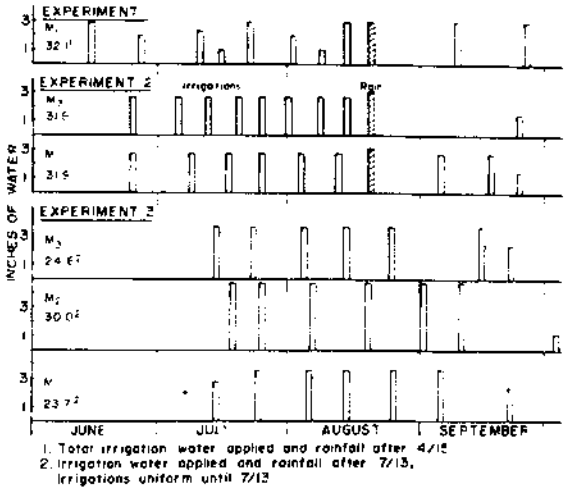

Figure 1.—Irrigation water applied and rainfall.

estimates the daily potential evapotranspiration rates since the last date of computation using climatic data. Then a crop coefficient, which is primarily a function of growth stage is applied to estimate daily evapotranspiration. Crop coefficients, derived from experimental data, are automatically adjusted to account for surface wetness caused by irrigation or precipitation. Optimum soil water depletions are based on maximum available soil water, crop tolerance to soil water stress, rooting depth, and other experimental data. With some irrigation systems optimum depletion is that amount of soil water that normally can be replenished by the irrigation system.

M_2 — (Experiment 3). Soil water depletion before irrigation was intended to be 25% greater than M_1, with more water applied at each irrigation. Normally this treatment would have resulted in about three more days between irrigations. The 7/25 and 8/6 irrigations were inadvertently applied earlier than necessary.

M_3 — Common irrigation practice in the area. In Experiment 2, two more irrigations were applied on this treatment from 6/24 to mid-August as compared to M_1, but no irrigations were applied in early September. The total number of irrigations and amount of water applied for the season were about the same as that applied to the M_1 treatment. This treatment resulted in higher soil water levels and more water being applied in midsummer as compared to M_1.

Petiole samples were taken at varying intervals in the three experiments and were analyzed for nitrates by methods suggested by Ulrich (4).

The beet roots in Experiments 1, 2, and 3 were harvested for yield measurements on October 24 using eight 20-foot rows, October 1 using three 50-foot rows, and October 14 using fifteen 70-foot rows, respectively. Random selection of beet roots was made during harvest for sucrose analysis. Sucrose analyses were made by the Amalgamated Sugar Company (Experiment 1) and the Utah-Idaho Sugar Company (Experiments 2 and 3) using their standard procedures.

Results and Discussion

Experiment 1

Root yields were significantly higher when N was applied preplant than for the July 15 application (Figure 2). The greatest

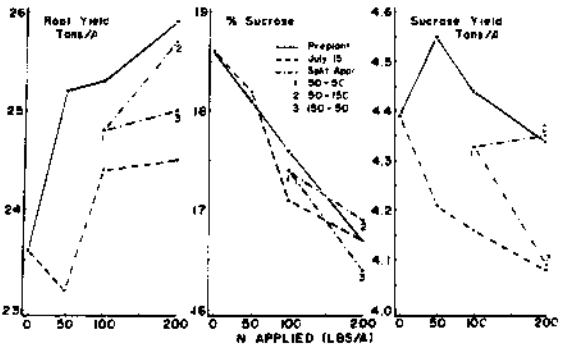

Figure 2.—Effect of time of application and level of N fertilizer on sucrose production by sugarbeets (Experiment 1).

increase in yield was obtained with the first 50 lb increment of preplant application. Sucrose percentages in the beet roots decreased as N fertilizer rates increased with no significant effect of time of application of N on sucrose percentages. Consequently, sucrose yields were significantly higher for preplant than for July 15 application of N. The highest sucrose yield occurred on the 50 lb preplant rate.

Maximum yields of sucrose were obtained if the NO_3-N concentration in the petioles was above 12,000 ppm early in July and about 1,000 ppm on August 20 (Figure 3). The optimum concentration during the peak period of N-uptake appears to have a greater effect on sucrose yields than the concentration about August 20 (Figures 2 and 3). All the treatments on which N fertilizer had been applied July 15 had NO_3-N concentrations greater

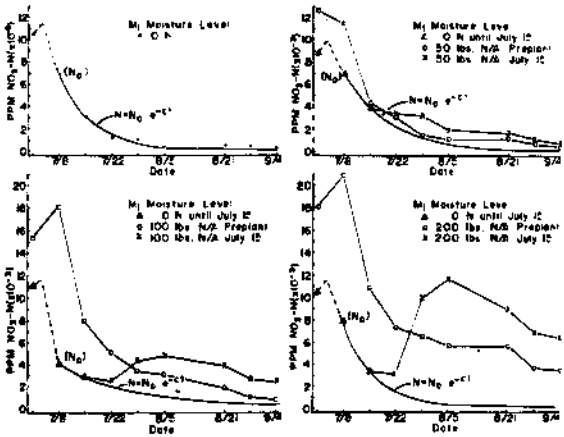

Figure 3.—Effect of midseason application of N fertilizer on the NO_3-N concentration in beet petioles (Experiment 1).

than 1,000 ppm near August 20, but maximum sucrose production occurred only if the NO_3-N concentration was near or slightly above 12,000 ppm early in July.

The NO_3-N level in the petioles projected for the balance of the season from two midseason samples were based on the following equation (2):

$$N = N_o e^{-Ct} \qquad [1]$$

where N is the NO_3-N concentration at time t, N_0 is the concentration at the first sampling date after the peak occurs, t is any time after the first sampling date (t = 0), and C is a constant for any given treatment or beet field.

The constant C can be evaluated by determining the NO_3-N concentration at two dates any time after the peak occurs using either of the following equations:

$$C = (\ln N_o - \ln N)/t \qquad [2]$$

$$C = (2.3/t)\ (\log_{10} N_o - \mathrm{Log}_{10} N) \qquad [3]$$

where N_0 is the concentration at the first sampling date, N is the measured NO_3-N conceneration at time t. C can be determined graphically by plotting the concentrations on semi-logarithmic paper. With NO_3-N on the log scale and t on the linear scale, the data can be represented by a straight line. If the points 10,000 and 1,000 ppm are used, then

$$C = 2.3/\Delta t \qquad [4]$$

where Δt equals the days for NO_3-N concentration in the petioles to go from 10,000 to 1,000 ppm. The number of days required for N to decrease from N_0 until N = 0.3678 N_0 is 1/C.

The time required for NO_3-N to decrease from N_0 to 1,000 ppm can be calculated as follows:

$$t' = \ln (N_0/1000) \times (1/C) \qquad [5]$$

where t' is the number of days.

The sucrose percentage at harvest was inversely related to the amount of fertilizer that had been applied, but there was no difference between the preplant, July 15, or split treatments (Figure 4). The sucrose percentage also was inversely related to

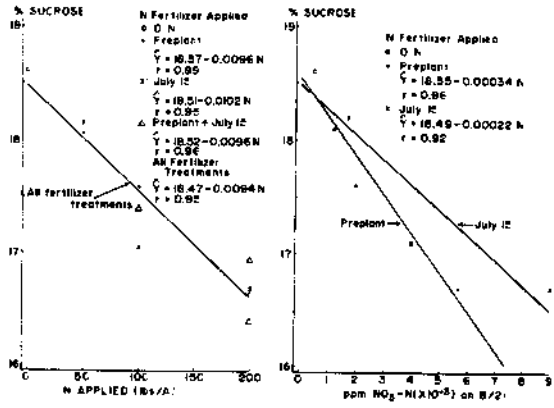

Figure 4.—Effect of applied N and petiole NO_3-N concentration on sucrose percentage of sugarbeets (Experiment 1).

the NO_3-N concentration on August 21 (Figure 4) with a tendency for a more sensitive relationship when the fertilizers was applied before planting. In other experimental work (1), when soil NO_3-N was intentionally moved out of the root zone by heavy water application late in August with a corresponding decrease in petiole NO_3-N, there was little, if any, effect on sucrose concentration. These data indicate that even though the sucrose concentration in late August is inversely related to sucrose contrations, the N level at midseason, when the growth and N uptake rate are highest, may have a greater effect on sucrose yield and sucrose percentage.

The sucrose percentage was also inversely related to the average NO_3-N concentration in the petioles from July 8 to August 21 (Figure 5). The integrated average is preferred because it can be predicted at midseason using equation [1]:

$$\bar{N} = -\frac{N_o}{C} \frac{(e^{-Ct_2} - e^{-Ct_1})}{t_2 - t_1} \quad [6]$$

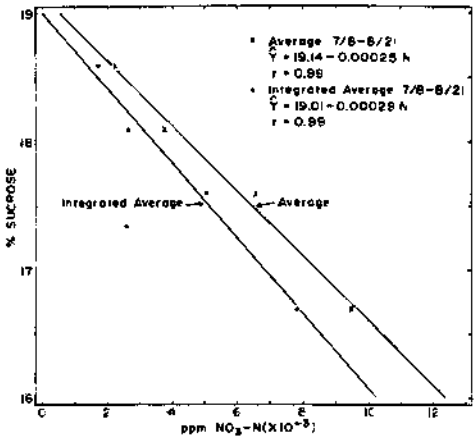

Figure 5.—Effect of the average petiole NO_3-N when N fertilizer was applied preplant on sucrose percentage of sugarbeets (Experiment 1).

where $\bar{N}$ is the integrated average, t_1 is the first sampling date after the peak, and t_2 is anytime after t_1, but preferably in late August. This method enables a midseason prediction of the sucrose content and sucrose production (Figure 6). However, in this experiment a midseason decision and application (about July 15) to

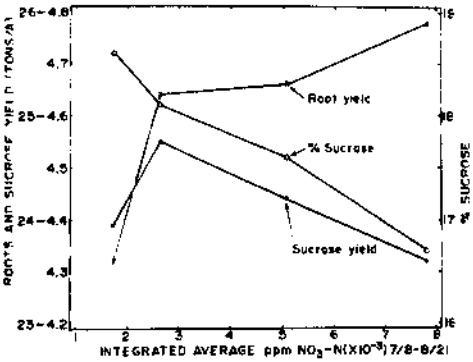

Figure 6.—Effect of the integrated average of petiole NO_3-N when N fertilizer was applied preplant on sucrose production of sugarbeets (Experiment 1).

correct a N deficiency ($\bar{N}$<2500 ppm), would not have increased sucrose yields (Figure 2). These data indicate also that the NO_3-N concentration in the petioles prior to July 1 would be needed to determine if greater net returns from an additional application of N fertilizer are to be obtained. If excess N is present at midseason for maximum sucrose production, maintaining a much higher irrigation level throughout the remainder of the season should lower the N available to the sugarbeets and increase sucrose concentration, yield, and purity.

Experiment 2

Beet root and sucrose yields also increased significantly in this study with the first increment of N application on both moisture levels (Table 1). There were no further significant increases

Table 1.—Significance of irrigation treatment, N level, and time of N application on sucrose production (Experiment 2).[1]

Treatment	Beet root yeld			Sucrose			Sucrose yield		
	M_1	M_2	Fert. means	M_1	M_2	Fert. means	M_1	M_2	Fert. means
lbs N/A	Tons/A			%			Tons/A		
0	20.6	18.1	19.4b[2]	18.6	18.6	18.6a[3]	3.83	3.36	3.60b[3]
90 preplant	21.8	21.8	21.8a	17.9	18.5	18.2ab	3.90	4.02	3.96a
90 split[4]	22.4	20.6	21.5a	18.3	18.1	18.2ab	4.11	3.79	3.95a
120 preplant	22.5	22.5	22.5a	17.7	17.9	17.8 b	3.97	4.03	4.00a
120 split[4]	22.2	21.3	21.8a	18.1	18.0	18.1ab	4.01	3.87	3.94a
150 preplant	22.9	22.1	22.5a	17.7	18.0	17.9 b	4.05	3.97	4.01a
Moisture means	22.2a	21.0b[2]			18.1a	18.1a[5]		4.01a	3.80b[5]

[1] Means within moisture or N levels followed by the same letter are not significantly different at the given level according to Duncan's multiple range test.

[2] Significance at the 5% level.

[3] Significance at the 10% level.

[4] Average of preplant and midseason application on 6/30, 7/16 and 7/31:

90 = 60 + 30 + 0 + 0; 60 + 15 + 15 + 0; and/or 30 + 30 + 15 + 15

120 = 90 + 30 + 0 + 0; 90 + 15 + 15 + 0; and/or 60 + 30 + 15 + 15

in root or sucrose yields by rate or time of N application. Yields were not affected by split application of N on the M_1 moisture level, but on the M_2 treatments, yields on all split applications were slightly lower than on the preplant application. After the initial yield increase with the first 30 lb/A of N applied before

planting, sucrose production on the M_1 moisture treatment was not affected by additional preplant N treatments. In contrast, sucrose production on the M_3 moisture treatment increased with up to 120 lb/A of preplant N application (Figure 7). These data, along with the petiole data, indicate that more frequent irrigations from June to mid August on the M_3 treatment resulted in a more severe N deficiency early in the season (8,160 vs 12,500 ppm petiole NO_3-N on July 9) (Figure 7).

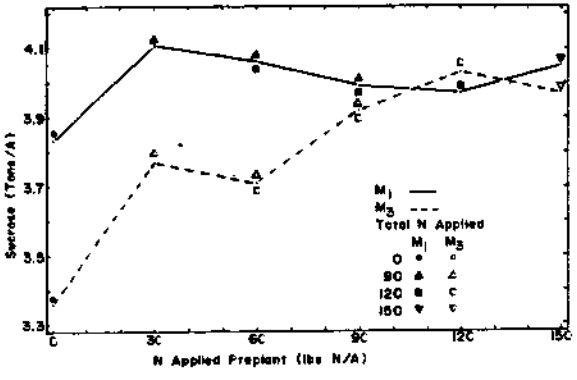

Figure 7.—Effect of preplant N fertilizer application and moisture level on sucrose production (Experiment 2).

Sucrose percentages in the beet roots decreased with increasing levels of N applications as in Experiment 1 (Table 1). Light midseasonal applications of N did not reduce the sucrose percentage in the roots over similar amounts of N applied before planting. The irrigation treatments caused only small, insignificant changes in sucrose percentages.

Experiment 3

There was no significant variation in root or sucrose yield due to the N fertilizer or irrigation treatments. Preplant application of N increased the N level in the soil, as shown by petiole analysis, to give maximum root and sucrose yields.

Summary and Conclusions

Experiments were conducted to evaluate current practices of applying split applications of N and the effects of irrigation on root and sucrose yields. Major emphasis was placed on the use of petiole NO_3-N concentration to evaluate the effects of these practices.

These investigations have shown that maximum root and sucrose yields are obtained if adequate N fertilizer is applied before planting. Midseason applications of N to correct obvious deficiencies did not result in maximum sucrose production since

the greatest requirements of the plants had already occurred. Split applications of N did not increase root or sucrose yields over similar amounts applied preplant. Over-irrigation early and in midseason amplified the effects of limited N levels. However, when adequate N was present for maximum yields, excess midseason levels of applied irrigation water produced comparable yields.

The results of these studies emphasize the importance of determining the available N in the soil early in the season or before planting. A reliable soil test for this purpose would enable applying adequate N fertilizer as a broadcast before planting or as a sidedressing early in the season to maximize root and sucrose production. The results also showed that the exponental relationship of NO_3-N concentration in the petioles with time can provide additional guides to the efficient nitrogen-irrigation management and the production of high quality sugarbeet roots.

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