Nitrogen Management for Sugarbeets on Pullman Soil with Residual Nitrate Problems

S. R. Winter *

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INTRODUCTION

Sugarbeets (Beta vulgaris L.) produce maximum sucrose only if nitrogen (N) is available in the proper amount at the proper time. A slight N deficiency during the middle of the growing season may not be detrimental (4); however, a severe deficiency will reduce root yield (4, 5). Low available N late in the growing season promotes sucrose accumulation and only slightly reduces root yield (7, 8).

Soil testing for nitrate-nitrogen (NO_3-N) content is a proven and widely used practice in the drier sugarbeet growing areas (1, 3, 5). For research purposes, soil samples have been taken to a depth of 0.6 to 1.8 m or to a limiting layer (5, 9). In many situations, a sample to 0.3 to 0.6 m depth is adequate because the highest concentration of NO_3-N is near the surface (9). Sugarbeets used N to a 135-cm depth in a permeable, sandy loam (1) and to 152-cm in a silty clay (11). In Colorado, fertilizer N did not increase recoverable sucrose when soil residual NO_3-N was 120 kg/ha or higher to a 60-cm soil depth (3). Residual NO_3-N levels were quite variable over short distances in Colorado fields (12).

Pullman clay loam, the predominant sugarbeet soil on the Texas High Plains, is very slowly permeable with almost no leaching even under irrigation. Therefore, NO_3-N accumulates in this soil if amounts supplied by fertilization and mineralization

*Contribution from the Texas Agricultural Experiment Station, Texas A & M University, as Technical Article 16087 in cooperation with the USDA Science & Education Administration. The author is Associate Professor, Texas Agricultural Experiment Station, Texas A & M University System, 6500 Amarillo Blvd. W., Amarillo, TX 79106.

exceed amounts removed by crops. Residual NO_3-N amounts of 400 kg/ha to a 1-m depth are not uncommon. Sugarbeets grown on Pullman soil frequently have increased petiole NO_3-N contents and top growth in the fall. This effect is not due to flushing of surface accumulated NO_3-N into the root zone by late season rainfall (16) as can occur in drier climates (14). Furrow irrigated sugarbeets on Pullman soil frequently have larger, greener tops on the lower end of the field near harvest than on the upper end. The implications of this condition on sucrose content have not been reported previously.

Personnel at Holly Sugar Corporation soil sample every prospective sugarbeet field in the Texas High Plains to a 120-cm depth, take petiole samples for NO_3-N determination, and determine brei NO_3-N (root NO_3-N) content at harvest. Because of Holly's concern for N management, local sugarbeet growers have been aware of the problem for many years. Unfortunately, little improvement has been made and Texas' sugarbeets consistently average below 15% sucrose.

The objective of this research was to better delineate the N management problem and determine how to produce high-sucrose sugarbeets while maintaining root yield.

MATERIALS AND METHODS

Ten nitrogen rate trials (experiments 1 to 10, Table 1) were conducted on Pullman clay loam (15) at Bushland, Texas, in 1972 to 1979. These trials had four to eight replications and a minimum plot size of 3 m wide by 9 m long with rows 75 cm apart. All data were collected from center rows Ammonium nitrate fertilizer was applied preplant or broadcast and lightly incorporated prior to thinning. Sugarbeets ('HH10', 1972; 'HH23', 1973; and 'Mono-Hy D2', 1974 to 1979) were seeded in March or April and harvested in November with a lifter-wheel harvester. The preceeding crop was winter wheat except experiment 2 (grain sorghum) and experiment 3 (corn for silage). From 36 to 80 soil cores were taken from the plot area of each experiment in December or January prior to planting sugarbeets. These cores were taken to depths of 1.8 m the first 2 years and to 3.0 m thereafter.

Table 1. Sugarbeet response to residual and fertilizer nitrogen on Pullman clay loam soil at Bushland, Texas.

Experiment Number	Year	Sucrose Yield Response[a]	Optimum Nitrogen Rate[b]	Preplant Residual NO_3-N Depth m 0-1.2	1.2-1.8	1.8-3.0	Root Yield[c]	Sucrose[c]
		%	kg/ha	kg/ha			metric tons/ha	%
1	1972	0	0	174	50	--	76	14.7
2	1972	14	112	75	35	--	72	16.1
3	1973	27	168	83	38	--	65	17.0
4	1974	26	134	64	101	54	72	14.6
5	1975	91	235	40	29	38	63	17.5
6	1975	42	157	38	174	222	64	15.5
7	1978	148	291	22	11	22	100	17.4
8	1979	134	246	26	13	24	96	17.5
9	1979	7	34	156	177	131	83	15.3
10	1979	13	67	172	38	47	87	17.8

[a]Percent increase in sucrose yield at optimum nitrogen rate compared to check. All responses significant at 5% level except experiments 1 and 9.

[b]Nitrogen rate that maximized sucrose yield.

[c]Root yield and sucrose % at the optimum nitrogen rate.

In 1975, for experiments 5 and 6, one core was taken from each plot of all four replications to depths of 3.0 m before planting, after harvest, and on five dates during the growing season. The plots were 6 m (eight rows) wide and 12 m long. Soil samples were taken from one side (four rows) of the plot and yield samples from the other four rows. Petiole nitrate content was determined by taking 20 petioles/plot from all reps at one month intervals.

All soil samples were dried, extracted with 0.1 N KCl, and ppm NO_3-N content was determined by autoanalyzer (6).

In 1977, root and soil samples were collected from 10 commercial fields within 50 km of Bushland and two research fields at Bushland. All fields were watered by graded furrows with water applied on one end (upper end) and flowing to the other end (lower end). The commercial fields were 600 to 700 m long and samples were taken 75 m from each end. The research fields were 200 and 310 m long and samples were taken 25 m from each end. Sugarbeets from a 5.9-m^2 area were harvested for yield determination at each sampling site. Soil samples for NO_3-N determination were taken from the center of each harvest area to a depth of 1.8 m.

RESULTS AND DISCUSSION

Response to fertilizer nitrogen was dependent on the amount and distribution of residual soil NO_3-N. Sucrose yield was more than doubled by N fertilization when residual NO_3-N was low to a depth of 3.0 m (experiments 7 and 8, Table 1). There was little response to fertilizer N when residual NO_3-N exceeded 210 kg/ha in the 0 to 1.8 m soil profile, provided the NO_3-N was properly distributed. In experiments 1 and 10, most of the residual NO_3-N was near the surface and response to fertilizer N was small. In experiment 6, there was excessive deep NO_3-N; however, the upper 1.2 m profile was low in NO_3-N and fertilizer N was required to avoid severe early season N deficiency. It appears that a minimum of 170 kg/ha of residual or fertilizer N must be available to sugarbeets early in the growing season on Pullman clay loam soil to avoid early nitrogen deficiency even when there is excessive NO_3-N below 120 cm.

Detailed soil and petiole NO -N samples taken in 1975 help to explain the problems encountered with residual NO_3-N. Sugarbeets did not use significant amounts of residual NO_3-N from deeper than 1.2 m until August (Figure 1). Sugarbeets in the unfertilized check plots in experiment 6 were visibly N deficient in late June and grew slowly until late August at which time top growth greatly increased. In this case, fertilizer N was needed to maintain growth during June, July, and August even though there was excessive NO_3-N below 1.2m. From August until harvest in November, NO_3-N in the 1.2 to 2.7 m depth was utilized (Figure 1). Where deep nitrate was excessive (experiment 6), petiole nitrate content increased during the fall and sucrose content was 2.0% points less than with experiment 5 (Table 2).

Sucrose content was more than 2.0% points less in 1979 when excessive deep residual NO_3-N was present (Table 1). High sucrose content is possible on Pullman soil if N is properly controlled as evidenced by the fact that sucrose content was 17% or higher in half of the experiments with concurrent high root yield

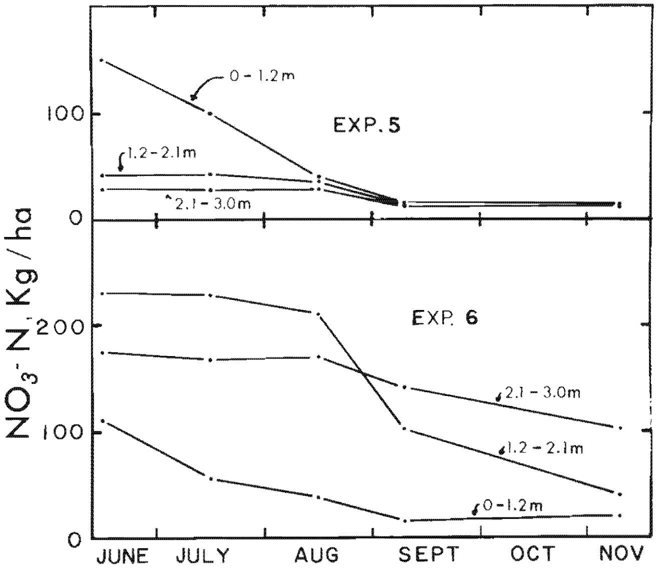

Figure 1. Time course of soil NO_3-N under sugarbeets on Pullman clay loam in experiments 5 and 6 in 1975.

(Table 1).

Early season root extension of sugarbeets on Pullman Clay loam is probably limited by the dense B22t horizon from 20 to 60

Table 2. Root yield, surcrose %, and petiole nitrate of sugarbeets grown on Pullman clay loam with low residual nitrate experiment 5) and high residual nitrate (experiment 6) at Bushland, Texas in 1975.

Experiment Number	Applied Nitrogen Rate	Root Yield	Sucrose	Petiole NO_3-N 3 July	1 Aug.	4 Sept.	2 Oct.
	kg/ha	metric ton/ha	%	ppm (10^3)			
5	0	33.2d[a]	17.7a	2.0c	0.5b	0.7b	0.6b
	78	46.1c	17.5a	2.6c	0.5b	0.7b	0.4b
	157	56.4b	17.4ab	8.0b	1.2b	1.0b	0.9b
	235	63.1a	17.5a	15.4a	5.2a	2.0b	1.2ab
	314	63.4a	17.2b	19.5a	7.0a	4.2a	2.4a
6	0	45.0c	15.5a	1.6c	0.8d	1.5b	10.8a
	78	51.5b	15.8a	4.3c	3.1c	1.3b	6.2b
	157	63.8a	15.5a	9.9b	4.1bc	2.2b	6.2b
	235	63.6a	15.2ab	12.4b	5.4ab	4.6a	10.3a
	314	65.0a	14.6b	17.1a	7.8a	5.8a	11.7a

[a]Treatment means followed by the same letter are not significantly different by Duncan's test at 5% level.

cm. Below 60 cm the soil is more friable. Eck and Taylor (2) plowed Pullman clay loam to 90 cm to disrupt the B22t horizon. Sorghum used water to a 2.4-m depth on the modified soil compared to 1.3 m on the unmodified soil. Sugarbeet root extension in Pullman clay loam seems to be more rapid after August than before (Figure 1). Thus, the physical characteristics of Pullman clay loam may inhibit the use of deep residual NO_3-N until late in the year when reduced N availibility would be desirable.

Sugarbeet growers on furrow irrigated Pullman soil face another serious problem with N management. Many fields are 650 m long and tend to have more residual NO_3-N on the lower end than on the upper end. The ten commercial fields sampled in 1977 had twice as much residual NO_3-N on the lower than on the upper end after sugarbeet harvest. Average sucrose content was 14.2 and 12.8% on the upper and lower ends, respectively (Table 3). The five worst fields averaged 2.5% points lower sucrose content on the lower end. In 1978, one 700-m long field had sugarbeets with 18.3% sucrose on the upper end and 13.5% on the lower end. Soil sampling and fertilizing a field in four or five segments would eventually help to alleviate this problem.

Table 3. Field position effects on sugarbeet performance and residual nitrate nitrogen remaining at sugarbeet harvest in 1977.

Location	Field Position[c]	Root Yield	Sucrose	Residual NO_3-N[d]
		metric tons/ha	%	kg/ha
Commercial[a]	Upper	51a	14.2a	43b
	Lower	44b	12.8b	83a
Research[b]	Upper	66a	15.6a	25a
	Lower	67a	15.6a	28a

[a]A mean of 10 commercial fields near Bushland, Texas.

[b]A mean of 2 research fields at Bushland, Texas.

[c]Upper refers to the end of the field where irrigation water was applied. Water then ran down graded furrows to the lower end.

[d]Nitrate-nitrogen in the 0 to 1.8 m soil profile at sugarbeet harvest.

The foregoing data indicate two major N management problems with Pullman soil that are not now being adequately considered. The most difficult problem exists if excessive NO_3-N is present below 1.2 m. Systematic variability in residual NO_3-N level within a field will compound the problem. Many fields undoubtedly have both problems and also significant random variability in residual NO_3-N as well.

Sugarbeets are usually grown in a 5-year or longer rotation with corn, sorghum, wheat, or cotton. The grain crops do not root much below 1.2 m on Pullman clay loam and must have adequate, readily available N to produce satisfactory yields. Therefore, when sugarbeets are grown in rotation with grain crops, no removal of deep NO_3-N can be expected and reducing systematic variability in surface NO_3-N will require rigorous soil sampling and precision fertilization. This program could eventually succeed if the occasional sugarbeet crops were relied on to eventually remove deep NO_3-N and N fertilization were adequately controlled. The grower would need to understand why his sugarbeets had lower than maximum sucrose when the 0 to 1.2 m soil sample showed no excessive NO_3-N. Soil sampling below 1.2m would be prohibitatively slow and expensive and would not be of much value since a minimum level of available N must be maintained in the 1.2 m profile for satisfactory growth of all crops.

Growing alfalfa in a cropping sequence may be the best way to remove excess profile NO_3-N even though it is a legume. Alfalfa will remove NO_3-N from Pullman soil to a depth of 1.8 m the first year and 3.6 m the second (10). In Northeastern Colorado, soil NO_3-N content under alfalfa was near zero, lower than under any other irrigated crop (13). Since all NO_3-N would probably not be removed during the first drying cycle, heavy irrigation might be required overwinter to rewet the profile and allow further NO_3-N removal. Alfalfa should reduce random and systematic NO_3-N variability within a field with less chance of yield reduction due to N deficiency. A grain crop might need to be grown for one year between alfalfa and sugarbeets to reduce N released by decomposition of the alfalfa. Field research is needed to determine if alfalfa will perform as suggested.

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