Uptake Patterns of ^{15}N Tagged Nitrate by Sugarbeets as Related to Soil Nitrate Level and Time[1]

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Nitrogen fertilization of most crops involves yield responses only. Sugarbeets are unique in the sense that the effect of the N on the sugar content of the beet root must also be considered. Alexander (1)[3] reported that N applications lowered the sucrose concentration of sugar beets with any combination of nutrients. Rhoades (9) found a highly significant correlation of –0.73 between soil N content and percent sucrose of the storage roots. The decrease in sucrose percentage associated with soil or fertilizer N increases are usually accompanied by increases in tonnage of beet roots and tops. Therefore, the N fertilization rate must be optimized with regard to sucrose content as well as root yield.

Peterson *et al.* (8) demonstrated the need for an adequate soil test for N on sugarbeets in a survey of soils in the North Platte Valley in Nebraska. They showed that 50% of the sites studied had excess N at harvest which resulted in depressed sucrose contents. Excessive soil N at harvest is the result of improper fertilization practices either on the current crop or on preceding crops in the rotation. Depressed N fertilizer prices in the late 1960's also increased the chance for excessive use of N in crop rotations which include sugarbeets.

Several sources report accumulations of NO_3^--N in soil profiles. Harmsen and Kolenbrander (6) quoted authors who report 11 to 150 kg of NO_3^--N per hectare accumulated a depths from 20 to 150 cm. Herron *et al.* (7) found only limited movement of N below the corn rooting zone during a 3-year study on irrigated loess derived soils in eastern Nebraska. Allison (2) quoted authors who showed that N did not leach from the root zone when the soil water did not exceed field capacity. This is often the case between irrigation seasons in the semiarid intermountain areas of western United States. The literature thereby indicates that N accumulation is probable in the sugarbeet growing areas of the western United States.

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[3] Numbers in parentheses refer to literature cited.

It is apparent from the foregoing discussion that a measure of the residual soil NO_3^--N test would be most helpful in determining an optimum N fertilizer rate for a particular sugarbeet field. The experiment reported here was planned as a part of an overall project initiated to calibrate the NO_3^--N soil test for sugarbeets. The objectives of this study were to determine the depth to which sugarbeet roots extract NO_3^--N and the relationship of extraction depth to time during the season. These results would then be used to determine a proper soil sampling depth for the NO_3^--N soil test.

Materials and Methods

The amount of ^{15}N available for the study limited the number of sites to two. The first (Site No. 1) of these was selected with a medium soil NO_3^--N level (142 kg/ha) and the second (Site No. 2) was selected with a very high (471 kg/ha) soil NO_3^--N level. Chemical properties of each soil are shown in Table 1 and Figures 2F and 2L. The soil at site #1 is a Tripp very fine sandy loam which was developed in alluvium on a terrace position. This soil is a deep, well drained and nearly level Typic Haplustoll. The field had been a bromegrass pasture for the previous five years and had received no fertilizer N. The soil at Site #2 is a Bayard fine sandy loam developed in a colluvium weathered mainly from sandstone on a footslope position. This soil is an Entic Haplustoll and had received large amounts of cattle and sheep manure over a period of many years. The manuring history is reflected in the organic matter levels shown in Table 1. Site #2 had been cropped to a rotation of corn, field beans, and sugarbeets in past years. Site #1 received 68 kg/ha of N as NH_4NO_3 prior to sampling while the grower at site #2 had applied 136 kg/ha of N prior to sampling.

Sugarbeets (GW Monogerm Blend A) were planted by the sugarbeet grower in 22 inch rows at each site on April 20, and were thinned to a 10 inch spacing within the row. On June 5, 100 mg of ^{15}N as labeled KNO_3 was applied to each 3.35×3.35m area in the pattern shown in Figure 1. Six borings 56 cm apart and to depths of either 15, 45, 75, 105 or 135 cm were made in each plot with a 4.5 cm hydraulic probe. Twenty-five milliliters of dilute $K^{15}NO_3$ (16.7 mg ^{15}N) followed by a rinse of 25 ml of water were added through a glass tube inserted full length into each hole as reported by Gass *et al.* (5). The holes were refilled with soil after placement of the ^{15}N. The depth treatments were arranged in a randomized complete block design with three replications. All cultivation and irrigation operations were conducted by the grower at each site and therefore no control of irrigation timing or amount was possible.

Table 1.—Chemical properties of the soils at the two experimental sites.

Depth	Residual Nitrate		Phosphorus Bray No. 1		Organic Matter Content	
	Site #1	Site #2	Site #1	Site #2	Site #1	Site #2
cm	ppm		ppm		%	
0- 15	16.8	13.8	23	114	1.04	1.62
15- 30	19.5	30.5	16	111	0.95	1.81
30- 60	7.0	40.0	11	94	0.45	1.90
60- 90	5.0	25.2	2	67	0.09	1.49
90-120	4.0	12.0	2	45	0.09	0.67
120-150	.6	8.2	5	29	0.08	0.20
150-180	1.4	12.5	7	14	0.09	0.12

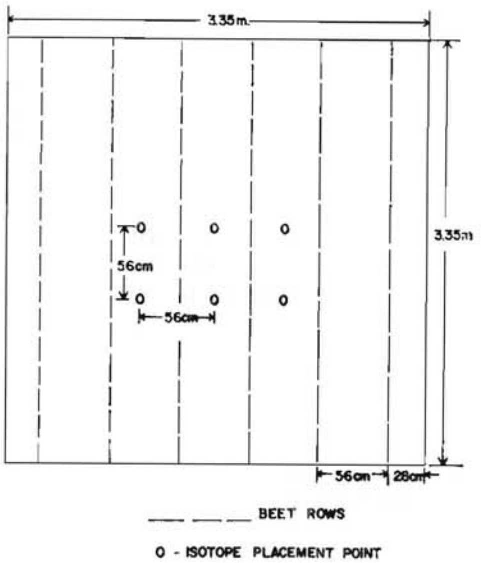

Figure 1.—Isotope placement points in relation to sugarbeet plant distribution.

Tissue samples consisting of twelve of the most recently matured petioles as suggested by Ulrich (10) were taken from each plot on July 15, August 8, September 22 and October 10. A Macro-Kjeldahl procedure was used to determine total N in the beet leaf petioles and to prepare the samples for ^{15}N analysis. Isotope-ratio analyses were performed at the TVA mass spectrophotometer laboratory, Muscle Shoals, Alabama using the methods outlined by Bremner (3) and suitable precautions against cross-contamination (4).

Final root and top yields were obtained by harvesting two rows 2.29 meters long from each plot. Tops and roots were separated, weighed and the roots analyzed for sucrose content by a tare lab of the Great Western Sugar Company. At the medium nitrate site (#1), an average of 31.1 tons (metric) of tops/ha and 36.1 tons (metric) of roots/ha, with 15.2% sucrose were produced. The high nitrate site (#2), yielded 53.1 tons (metric) of tops/ha and 46.6 tons (metric) of roots/ha with 13.2% sucrose.

Results and Discussion

The percent excess ^{15}N in the beet leaf petioles was used as an index of nitrogen uptake from the various profile depths. The NO_3^--N extraction patterns over the season were established by sampling the beet petioles at several times and are shown in Figure 2. Sites #1 and #2 will be referred to as the medium and high N regimes respectively.

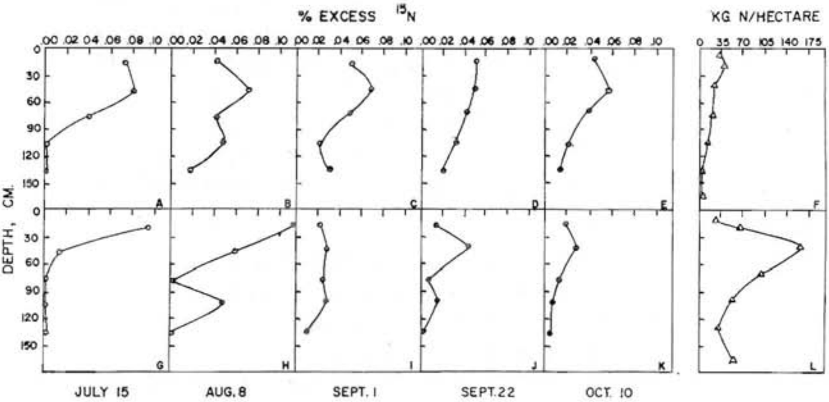

Figure 2.—Percent excess ^{15}N in sugarbeet leaf petioles as affected by depth of isotope placement and date of sampling at site 1 (upper tier), A, B, C, D, E, F, and site 2 (lower tier), G, H. I, J, K, L, which contained 142 and 471 kg NO_3^--N/ha, respectively.

A comparison of Figures 2A and 2G indicates that in July the beets growing in the medium N regime were extracting NO_3^--N from the surface to a depth of 90 cm, while the beets growing in the high N regime were not extracting appreciable N from below 60 cm. Figures 2F and 2L show the NO_3^--N content of the soil profile at the two sites on June 5. It can be seen that the beets growing in the high N regime had about 2-1/2 times more NO_3^--N available to them in the upper 60 cm of soil than did the beets growing in the medium N regime. These data indicate that the level of residual NO_3^--N at a given depth affected the ^{15}N extraction from other depths, and on July 15 actually prevented extraction of ^{15}N from the lower depths of the high N profile.

The beets growing in the medium N regime were extracting ^{15}N from the surface to a depth of 135 cm on August 8 as shown in Figures 2B and 2H, while the beets in the high N regime were extracting ^{15}N from the surface to a depth of 100-120 cm. These results are also explained by the difference in the original NO_3^--N profile. The high absorption of ^{15}N at the 105 cm depth in the high N regime contrasted to the low absorption at the 75 cm placement depth can be attributed to a dry soil zone that limited root activity at the 75 cm depth and which was rewetted by subsequent irrigation prior to the September 1 sampling.

Figures 2C and 2I depict the extraction pattern at the September 1 sampling. Note that beets at both sites were extracting ^{15}N from the surface to depths of 135 cm. However, the beets in the high N regime were extracting less ^{15}N from the lower depths than those growing in the medium N regime. This came as the result of the greater amount of residual NO_3^--N available to the beets in the upper portion of the high N profile. The surface soil at the high N site on this date was relatively dry and remained this way until the October 10 harvest date. Therefore, ^{15}N extraction was restricted in the upper profile during the latter part of the season as is apparent when Figure 2H is compared to 2I, 2J, and 2K.

Samplings on September 22 and October 10 reflect the same extraction patterns as those observed on September 1 as is shown in Figures 2D, 2E, 2J, and 2K. Note the accentuated uptake of ^{15}N between the 30 and 60 cm depths at the last two dates in both N regimes. This occurred in the zone of maximum NO_3^--N accumulation in both profiles. The accentuated uptake in the zone of maximum NO_3^--N accumulation was apparent even at the first sampling date in the medium N regime.

The analysis of variance in Table 2 indicated that linear depth treatments were significant at both locations and uptake changes over time were significant at the 5% probability level. However, interactions of depth and time were also significant, which means that uptake of ^{15}N at a given depth changed significantly over time. Extraction patterns of ^{15}N in root N regimes were quite similar as indicated by Figure 2 and Table 2 with only the magnitude of the curves and time sequence being different.

Magnitudinal differences in the extraction patterns would be expected because of ^{15}N dilution differences between the medium and high regimes. The extraction pattern of the beets growing in the high N regime on September 22 (Figure 2J) began to re-

Table 2.—Analysis of variance mean squares for percent excess ^{15}N in sugarbeet leaf petioles as related to depth of ^{15}N placement and time of sampling.

Source	d.f.		Mean Squares Loc. 1		Loc. 2	
Blocks	2		.00346		.00077	
Depth	4		.00444*		.00391	
Lin		1		.01279**		.01162**
Quad		1		.00090		.00112
Dev		2		.00204		.00145
Error A	8		.00087		.00053	
Time	4		.00080*		.00123*	
Lin		1		.00072		.00185*
Quad		1		.00156*		.00057
Dev		2		.00005		.00125
Time x Depth	16		.00070		.00126	
$T_L \times D_L$		1		.00086		.00503**
$T_L \times D_Q$		1		.00365**		.00165*
$T_Q \times D_L$		1		.00001		.00451**
$T_Q \times D_Q$		1		.00000		.00212*
$T_L \times D_{DEV}$		2		.00202**		.00046
$T_Q \times D_{DEV}$		2		.00002		.00007
$T_{DEV} \times D_{DEV}$		8		.00033		.00071
Error B	40		.00026		.00040	

* Denotes significance at the 5% probability level

** Denotes significance at the 1% probability level

semble the pattern for the medium N regime on July 15 (Figure 2A). This was probably due to the beets having removed enough of the soil N so that the amount of N remaining in the high regime on September 22 was equal to the amount present in the medium regime on July 15. This means that the beets grown in the high N regime had a more than adequate N supply present even on September 22, which was responsible for the low sucrose percentage (13.2%) in the beet roots at harvest.

Summary

The data support the conclusion that sugarbeet plants can effectively extract labeled NO_3^--N from depths greater than 135 cm. Extraction patterns of ^{15}N over time were related to the level of residual NO_3^--N. A high level of residual NO_3^--N delayed the uptake of ^{15}N from the lower profile. Where a medium level

of residual NO_3^--N was present in the soil profile substantial uptake of ^{15}N from the 135 cm depth had occurred by August 8, whereas uptake from this depth in the high N regime did not occur even by October 10.

It was concluded that a soil profile of at least 150 cm should be sampled for a residual NO_3^--N soil test, because NO_3^--N accumulations in the lower portion of a soil profile were absorbed by the beet roots late in the season. Sucrose content of the beet roots at harvest was influenced by the late absorption of the NO_3^--N.

Acknowledgment

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