NITROGEN USE MANAGEMENT IN SUGAR BEET CULTURE AS RELATED TO SOIL TYPE AS WELL AS TIMING OF APPLICATION

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Introduction:

Nitrogen uptake and assimilation for beet growth and root development and hence sugar production is of importance not only because of the amount required in relationship to other nutrient inputs to the crop but also because of the effect that too much availability of N can have on the quality extraction of sugars from the roots at processing. Mineralization of N and its coming available for crop use, in season, is the forever hard to determine part of the N management equation. Attempts to 'predict' how much N might be available in season have been made by various researchers throughout various sugar beet production areas. None have been totally successful due in part to the unpredictability of the affects which weather, crop rotation, soil type, etc. can have on the outcome of the mineralization process.

For over three decades Amalgamated consultants and producers have used the constant that eight lbs. of N should be required to produce each ton of beets. With improvements in seed genetics in general and the effects of Round-Up ready culture in specific it has become apparent that further refining of this approach should be undertaken. Because soil type has an inherent effect upon the potential mineralization of N, we determined to discover if the amount of N required could be further refined by whatever varying amount the soil type might dictate. In taking this approach it was hoped that at least a general degree of effect could be determined and not necessarily specific mineralized amounts of N. Where we approach N input requirement as lbs. required per projected tons to be yielded (basis of previous yield and quality history) we were hoping to refine the input down from eight lbs. per ton by whatever amount would improve sugar percentage and other quality factors without compromising tonnage, (basis of soil type).

A second aspect of N management involves the timing of application of N in season. Since the major uptake and use period for N is within the fifth and twelfth weeks of growth any additional N should be in place and available ahead of when it is required. In irrigated production areas where overhead irrigation is the norm, too early placement of N on some soils, i.e. sands and even silt loams, could potentially result in leaching of N into lower profile levels out of the effective seedling rooting zone for the developing crop. Therefore it was determined to better understand if the timing for placement of all additional N fertility up front, shortly after planting, or as a split application with 60 % up-front and the rest between 4-6 leaf stage of plant growth would be more beneficial.

Methodology:

Over a three year period, 2008-2010, we selected sites in our production areas where we could look at the response of varying lbs. of N per projected tons to be produced on varying soil types. The first year, because silt loam comprised the greater balance of soil in our production areas, two sites of silt loam were chosen. The second year, we chose another site of silt loam and two sites of sandy loam soil. The third year we looked at one site with silt loam soil, one with sandy loam and two sites with clay loam soils.

All plot sites were located inside a commercial field. Attempts were made to choose an area inside each fields' boundaries that was uniform. The grower-cooperators' 5 year average for tons per acre production was used as treatment yield goal. All plots were arranged in randomized complete block design. Each treatment for projected N-usage was replicated 6 times. Plot size was 6 rows (22" rows), 11 feet wide x 30-40 feet in length.

Soil samples of first, second and third foot depth were pulled and analyzed separately for each replication area within the study. The number of treatments were determined by the various lbs. input which we looked at in the given year. In 2008-09, N treatments of 5, 6, 7 & 8 lbs. per historical ton per acre were used. In 2010, we used N treatments of 4, 6, 8, and 11 lbs. per historical ton. The change in treatments came from the desire to look at the effects beyond top and bottom of potential yield and quality ranges to further define if we were "in the zone" for potential yield, (top end on N input), as well as for quality, (low N at harvest for maximizing quality factors).

Soil sample results from each foot increment were added together and multiplied by the factor of 4 to convert ppm N to lbs. N. The result was considered as the carry-over, available N contained in each replication area. Each plot had an assigned lbs. N per projected ton to be produced, (as per the above mentioned treatments) which was multiplied by the historical five year average T/A yield goal. This determined the overall lbs. N required per treatment which also would be the overall lbs. N available. The carried-over lbs. N figure was then subtracted from each overall lbs. N required figure to determine how many lbs. of N should be applied to each plot. In regard to overall lbs. N available it should be explained that the variable of mineralizable N potential is considered as the unknown, which in part we were seeking to further refine basis of soil type and the crops response to varying lbs. N input on a ton produced basis and the quality factors of sugar %, brei N and conductivity.

The prescribed amounts of additional N were applied in the form of Urea to each plot with a Scotts® bottom-drop type, lawn fertilizer spreader. Since each of the study sites was irrigated with over-head irrigation, the urea was then incorporated via irrigation water. The application timing of N varied some, dependent on weather conditions etc. but was between 2-6 leaf stage of growth overall, which was considered adequately ahead of when there would be demand for it.

The second part of this study involved the timing of the application of the fertilizer and at the same time looking at a high and low rate of lbs. N input. The interest here lies in knowing that heavier clay soils and silt loams, generally have greater holding capacity as well as mineralizing ability vs. a sandy soil which generally has an O.M. percent under 1 and much more propensity to leach N early in the season, particularly under over-head irrigation systems. These trials were conducted in 2009-10, both years in which we had sandy soil sites in trials. The timing differentials were 1) application of N fertilizer shortly after planting or emergence dependent on weather interruption, and 2) applying the N fertilizer at 60 % of it shortly after planting or emergence and the remaining 40 % between 4 and 6 leaf stage of plant growth. As mentioned, two rates, a high and a lower rate were looked at, and these rates varied depending on soil type.

Stands were evaluated in each plot and numbers of plants/100 feet of row were compared. Any plot which did not conform within reasonable comparison on stand was eliminated from inclusion in the results. Plots which were interrupted by other abnormal physical intrusions were also excluded. All other cropping practices performed in the plots were the same and the results considered as typical to all plots.

Borders between plots were not distinguished until at harvest time in order to eliminate border effect. At harvest, 3-5 feet of row between plots was hand dug and discarded to facilitate separation of harvesting of plots. The center two rows in each plot was defoliated with a 2 row double drum defoliator and harvested with a single row plot harvester. All of the roots in each row were weighed for yield determination and two 25-35 lb. samples were taken for sugar and quality analysis.

Observations:

In season observations of the response to the varied rate of N input were as follows. Plots with the lowest rates of input started showing slower growth in size and lighter coloration of tissues, i.e. (smaller petioles and leaf blades as well as fewer leaves formed), at about the end of June to the first ten days in July. These observations continued until harvest. At harvest, the least fertilized were much yellowed and had noticeable less foliage as well as root size as indicated by the lower yield rates for these plots. The plots which were heavier fertilized showed continued growth and more green coloration into harvest. The petiole and leaf sizing as well as numbers of leaves were much more extensive than that of the lower rates of N fertility. The sizing of roots and of course weights was greater, indicating the increase in yield.

The degree of variation for these observations also changed with the soil type for the most part. In sandy loam soil the variation was more pronounced as would be expected. In the silt loam soil the observations varied but at a lesser degree and in the clay loam soil the sizing of leave blade and petioles decreased with lower N input but the coloration was less diminished, yet observable.

Data Results:

Silt loam soils, were assessed all three years of this study at at least one site. The data for 2008-09 were included in statistical analysis but 2010 was not, due to irrigation difficulties which skewed the results. (Table 1) indicates that there is significant difference between using 5-6 lbs. N per ton, rate of fertilizing vs. 7-8 lbs. per ton.

Table 1.

Nitrogen Use Rate Study

Silt Loam Soils, Hansen 2008, Trail Ranches 2009 The Amalgamated Sugar Co.

Treatment	Tons/acre	Sugar %	Nitrate ppp	cond. mmhs	Recov. Sugar lbs / ton	Recov. Sugar lbs / ton	Gross $ value / ton	Gross $ value / acre	Net $ value / acre		
Five Lbs Nitrogen	36.06	17.85	56	0.601	310.9	11186	$ 49.24	$ 1,770.00	$ 1,680.00	avg.	difference
Six Lbs Nitrogen	37.19	17.85	57	0.601	310.9	11557	$ 49.23	$ 1,830.00	$ 1,729.00	$ 1,704.50	$ 72.00
Seven Lbs Nitrogen	36.04	17.57	79	0.621	304.9	10983	$ 48.27	$ 1,739.00	$ 1,632.00	avg.	
Eight Lbs Nitrogen	37.08	17.29	101	0.645	298.8	11062	$ 47.30	$ 1,751.00	$ 1,633.00	$ 1,632.50	
LSD (0.05)	ns	0.36	19	0.025	7.0	ns	1.24	ns	ns		
LSD (0.1)	ns	0.30	16	0.021	5.8	ns	1.03	ns	65		
CV (%)	6.0	3.0	36.8	6.0	3.3	6.7	3.7	6.7	6.8		
PR > F	0.2049	0.0151	0.0001	0.0009	0.0044	0.1650	0.0152	0.1688	0.0762		
Grand Mean	36.59	17.63	74	0.618	306.2	11190	$ 48.48	$ 1,771.00	$ 1,667.00		
Five Lbs Nitrogen		a	a	a	a		a		ab		
Six Lbs Nitrogen		a	a	a	a		a		a		
Seven Lbs Nitrogen		ab	b	ab	ab		ab		b		
Eight Lbs Nitrogen		b	c	b	b		b		b		

The root yield, even though higher by one ton at the 8 lb/ton rate was not significant. This would indicate that the lower rate of N input did not compromise any T/A yield potential. The quality factors were all enhanced by lowering the rate of N input. Though gross $ per acre did not show significantly greater at any N treatment level, when the additional costs of fertilizer and hauling expense are applied for the additional tonnage, the net result favors lower N rates by $72 per acre increase. This fact of course is the most important to a producers bottom economic line.

Sandy loam soil was looked at in 2009 at two locations and at one in 2010. The location in 2010 showed no significant differences between rates of input, largely due to unexpected high mineralization experienced late in the season. When soil sample results were assessed at this site it was noted that the Organic Matter % was higher than normal for sandy soil. The readings per replication ranged from 2.4 – 2.94 % O.M. Because of timing and inputs already made to the site we continued the study. Differences in foliage size and even coloration were noted until about the middle of July and then things started to rapidly assimilate. By harvest, differences could still be observed but not as clearly defined as would be expected concerning the differences of input N. Even though there were 3 t/a difference between the 4 lbs. and the 10 lbs. input rates there was no significance statistically. The quality factors were very close to the same. The nitrate N readings were quite excessively high, even in the low rate treatment plots, which further suggests the point of high mineralization having occurred. I mention this site, mainly to reference the fact that what we are trying to better manage is resultant from the very thing illustrated by what happened with this trial site. Mineralization is one of the hardest variables of N management which we work with.

The other two sites dealing with sand that we looked at in 2009 also showed similar differences in growth and coloration as just described. Results on one of the sites were essentially the same as described above. Even though visually, at harvest, it looked like there would be differences in treatments, statistically it did not turn out that way. In respect to trying to understand what occurred in this particular sand situation, there was 2.3 t/a difference between the low N rate of 6 lbs. and the high rate of 8 lbs. which favored the higher rate. There were no differences in the quality factors as they were very similar.

One of the main considerations in trying to manage N use in sandy soils has always been the concern of losing use of N in season to excessive leaching through the profile, as well as not accomplishing adequate mineralization level of N. This relates to our approach or method of basing management of N on projecting what tonnage may be produced and how many lbs. per ton it might take to do that. Some field situations make it hard to adequately gauge what the tonnage outcome might be (even basis of past years production), and then the weather factors complete the disconnect from your best management projections and the reality of what actually happens in the season.

We had one site (K. Bowen), out of the three which were sand that showed statistically what we had supposed. In sand, the main concern is to supply adequate N so as to maintain adequate tons production without over fertilizing and damaging quality. Because of leaching and lower mineralization rate, N availability does usually drop low enough later in season so as to not interfere with sugar formation. If levels drop too low too early however, they can short tonnage potential.

The results from this trial are shown in Table 2. There was 7.92 t/a difference between the low rate of 5 lbs/ton input and the 8 lbs/ton rate. There was a difference of 2282 lbs/acre of sugar produced between the 5 lbs. and 8 lbs. N rates. To a producer this would equate to

$287/acre difference in income. The results indicate that for sandy soils the higher rates of 7-8 lbs. N per ton would be more correct for N management.

Clay loam soil sites were trialed in 2010, one site in western Idaho and one in south central Idaho. Whereas clays have higher organic matter content and greater nutrient holding capacities, it was expected that a lower input rate of N would show more favorable without diminishing yields, yet potentially increasing quality factors and hence overall sugar per acre production. Table 3 shows the results from the south central Idaho site which supports the above expectation.

Table 2.

SANDY SOIL, NITROGEN USE RATE TRAIL, 2009 - K. BOWEN FARM

Treatment	Root Yield (T/A)	Sugar %	Nitrate ppm	conduc. Mmhs	Recov. Sugar lbs / ton	Recov. Sugar lbs /	Gross $ per ton value	Gross $ per acre value
Five Lbs Nitrogen	20.67	15.62	49	0.452	276.5	5729	$ 41.59	$ 861.00
Six Lbs Nitrogen	24.29	15.62	55	0.432	277.3	6759	$ 41.59	$ 1,014.00
Seven Lbs Nitrogen	28.59	15.78	59	0.44	280	8011	$ 42.16	$ 1,206.00
Eight Lbs Nitrogen	27.64	15.57	60	0.448	275.7	7636	$ 41.42	$ 1,148.00
LSD (0.05)	2.70	NS	NS	NS	NS	895	NS	138
LSD (0.1)	2.22	NS	NS	NS	NS	736	NS	114
CV (%)	8.7	3.8	41.9	8.8	4.3	10.3	4.9	10.6
PR > F	0.0001	0.9271	0.8397	0.8107	0.9258	0.0003	0.9270	0.0004
Grand Mean	25.30	15.65	56	0.443	277.4	7034	41.69	1057

Treatment	Root Yield	Recov. Sugar lbs /	Gross $ per acre value
Five Lbs Nitrogen	c	c	c
Six Lbs Nitrogen	b	b	b
Seven Lbs Nitrogen	a	a	a
Eight Lbs Nitrogen	a	ab	ab

Table 3.

CLAY LOAM SOIL, NITROGEN USE RATE TI TRIAL 2010 B. BOWEN FARM

Treatment	Root Yield (T/A)	sugar %	Nitrate ppm	Conduc. Mmhs	Recov. Sugar lbs./ton	Recov. Sugar lbs./acre	Gross $ per Ton	Gross $ per Acre	Net $ per Acre		
Four Lbs Nitrogen	31.57	18.40	67	0.766	313.0	9879	51.71	$1,632.00	$ 1,553.00	avg. 4 & 6	
Six Lbs Nitrogen	32.30	18.10	110	0.810	305.5	9866	50.67	$1,636.00	$ 1,538.00	$1,545.50	differ.
Eight Lbs Nitrogen	32.48	17.78	161	0.882	296.6	9629	49.58	$1,610.00	$ 1,494.00	avg. 8 & 11	$80.50
Eleven Lbs Nitrogen	33.44	17.12	289	0.967	281.2	9394	47.27	$1,580.00	$ 1,436.00	$1,465.00	
LSD (0.05)	NS	0.36	71	0.066	9.1	NS	1.26	NS	NS		
LSD (0.1)	NS	0.30	58	0.055	7.5	NS	1.03	NS	NS		
CV (%)	4.3	1.6	34.6	6.1	2.4	4.7	2.0	4.4	4.6		
PR > F	0.2088	0.0001	0.0001	0.0001	0.0001	0.2730	0.0001	0.5395	0.2359		
Grand Mean	32.49	17.82	161	0.860	298.5	9684	49.72	1614	1503		

Treatment	sugar %	Nitrate ppm	Conduc. Mmhs	Recov. Sugar lbs./ton	Gross $ per Ton
Four Lbs Nitrogen	a	a	a	a	a
Six Lbs Nitrogen	ab	ab	a	ab	ab
Eight Lbs Nitrogen	b	b	b	b	b
Eleven Lbs Nitrogen	c	c	c	c	c

Root yield was statistically not significantly different which counters the concern that reducing N input levels might cost a grower potential tonnage which could be produced. The sugar percent was greatly enhanced, by 1.28 % more from the 11 lbs. rate to the 4 lbs. rate of input. It was increased by .62 % from the 8 lbs. to the 4 lbs. rate. Even though the nitrate N levels would be considered adequately low at the 4-8 lb. input levels, there was still a statistical break between the 6 and 8 lb. rates suggesting that not going over 6 lbs. N per ton is more favorable. This break in statistical significance applied to all the quality factors as well as the gross dollar per ton valuation. Though the gross $ per acre and net $ per acre determinations did not show significantly different, largely due to the overriding effect of tonnage, at the break between 6 and 8 lbs. N input, there is a $80.50 per acre difference favoring the input of 6 lbs. or less of N per ton produced when the additional grower expenses of freight and fertilizer cost are subtracted.

Results from varying the timing of the application of N treatments as well as the amounts of N per treatment did vary as per soil type and more specifically in reference to sandy soil. Two sites for each soil type were looked at over a two year period. In 2009 the sand site we looked at yielded statistical differences for root yield and recoverable sugar per acre which translated to difference in gross $ per acre as well as net $ per acre increase which was statistically relevant when 5 lb/ N per ton was compared with 8 lb/N per ton. The increases favored the 8 lbs. N per ton rate. These two amounts were applied at the afore-mentioned time differentials of all-up front and 60-40% split. The split application showed almost 4.5 t/a increase over applying all up-front, but was statistically significant only at LSD (0.1). At LSD (0.5) there was 1209 lbs. recoverable sugar per acre difference in significant increase by applying 60 % of the N up-front and 40 % between 4-6 leaf growth stage, vs. applying all of the requirement up-front. Quality factors showed no differences on either rate or timing of application. Here again it should be stated that in sand, because of potential leaching of N over the cropping season and the normally lower mineralization of N potential, detrimental amounts of N carried late into season root growth and sugar formation are usually less of a problem. The usual observed concern is for potential early season shortage of N due to excessive movement of N lower in the profile relevant to rooting depth and up-take need for the crop point-in-time.

The silt loam soil sites showed no significant differences for increase or decrease of yield or quality factors by varying the timing of application. The applying of all N requirement up-front was numerically better on tonnage over the other combinations but not statistically better.

The clay loam sites showed significant difference as to the amounts of N rate applied. The lower rate showed higher sugar % and nitrate ppm as would be expected. The timing of application made no significant difference in outcome. This was more or less expected relevant to the greater nutrient holding and mineralizing capacities of clay soils.

Summary:

It appears that rate of N per projected ton to be produced should be lower than 8 lbs. depending on soil type. In silt loam soils the rate of 4-6 lbs. per projected ton proved most favorable by increasing quality factors, without compromising tonnage production. A rate of 5 lbs. per ton produced was shown to be the most favorable. For sandy soils, the higher rate of 7-8 lbs. per ton should be maintained in order to retain optimal tonnage production. The variation in rates made little significant difference on quality, most probably due to other mechanical features relevant to sandy soils which facilitate decrease in availability of N later in season. This should be qualified on basis of Organic matter content and hence mineralization potential for N basis of past cropping history. Clay soils showed significant increase in quality and productivity of sugar produced by lowering the input rates of N to 4-6 lbs. N per ton produced, leaning more toward 4 than 6. Decreasing N input made no difference in tons produced potential.

Making N inputs up-front or split applying 60-40% between up-front and 4-6 leaf stage of development made little difference in silt loam or clay loam soils. The amount of N applied only showed differential basis of amount and not timing; no interaction statistically; but the lower amounts were favored.

In sandy soils, the timing of application favored the 60-40 split as regarded yield or t/a but only was significant at the LSD (0.1) level. Quality factors showed no difference relevant to timing. At the LSD (0.5) level of confidence there was greater increase of lbs. sugar/ acre when split applying the N input to the crop on sandy soils.

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