The Use of Slow Release Nitrogen Management for Sugar Beet Production in the Imperial Valley of California

Dr. John A. Lamb
Department of Soil, Water, and Climate, University of Minnesota, St. Paul, MN

Justification: The importance of nitrogen management in sugar beet production has been researched for many years. Like most plants, sugar beet needs nitrogen for optimum root growth. Unlike most agronomic crops, the sugar beet plant can actually have a reduced yield of sucrose with excess nitrogen. In recent years, environmental concerns about losses of N have become part of the reality of sugar beet production in irrigated areas.

The Imperial Valley raises the largest tonnage of sugar beet in the world. It requires timely irrigation and fertilizer management. Most of the soils are fine textured and leaching of nitrate-N from one irrigation event is not a problem. Although with multiple irrigation events with furrow irrigation, it can be a problem. The nitrate-N is either lost in the tail water or loss through the drains used to control the salt build up in the soil. The nitrate-N does not stop at the field's edge; it can eventually end up in the Salton Sea. This lost nitrogen is nitrogen the plant could have used if it was not lost.

The current production practice is for a split application of fertilizer nitrogen. The pre-plant application is usually applied broadcast with the phosphate source such as mono ammonium phosphate (11-52-0) and then incorporated with the ridging operation before planting. The second application is at lay by about 60 days after planting. Liquid N as UAN 32 % is used. Depending on the harvest schedule this may be the last application. If it is not, then an application with the irrigation water as 20 % AN is used. The total amount of N, including residual soil nitrate-N plus fertilizer is around 250 lb N per acre. The use of split nitrogen applications and a slow release nitrogen source could keep the N in a form that would not be used until the sugar beet growth increases after the air temperatures warm up after the winter. The best possible split application system would be to apply a soluble form of N fertilizer, such as the N in the phosphate source pre-plant. This application would get the sugar beet plant up and growing fast. An improvement to the current split nitrogen application at lay by could be a combination of slow release N and soluble N to provide just enough nitrogen to keep the sugar beet plant growing.

Objectives: With these ideas in mind, a study was conducted with the objectives of 1) determine the best nitrogen fertilizer source for agronomic and environmental sugar beet production, 2) investigate the optimum application timing of a slow release nitrogen fertilizer source, and 3) determine what the mix of soluble and slow release nitrogen sources would be the best.

Method and Materials: To meet the objectives stated above, a field experiment was implemented in the Imperial Valley of California. The treatments were in a randomized complete block design with four or five replications. The treatments are listed in Tables 1, 2, and 3. The treatments were applied at layby in November. The actual N fertilizer rates were adjusted based on the initial nitrate-N soil test plus the amount of N applied by the grower with the preplant phosphorous application. One group of treatments gave us the optimum N application rate while another group of treatments gave the comparison of the slow release materials and combinations of them. Each year the number and N rate for the optimum N group chanced. This was to cover the needed N rates to form a N response for each site. The N rate for the slow release material comparison was at a suboptimum level to be on the most responsive part of the response curve. This gave us the best situation to separate the difference between the products and the mixes of the products.

Three sources of nitrogen fertilizer were used in this study. The soluble N source was liquid urea ammonium nitrate (UAN) (32-0-0). The slow release sources were two products from Agrium. Both products physically slow the release of nitrogen into the soil. The first was ESN (44-0-0). It has a 60 to 90 day release period. It has been used in the Midwest on corn and potato as a slow release product. The second was Duration 120 (D120 42-0-0). It has a release period of about 120 days. Originally developed for lawn use, Duration 120 was a product that may be adaptable for the longer sugar beet growing season in the Imperial Valley. Mixtures of the three materials were used to determine if having different availabilities through the season would affect sugar beet growth. The mixtures included 50 % UAN and 50 % ESN, 50 % UAN and 50% D120, 50 % ESN and 50 % D120, and a combination of all three materials 33 % UAN, 33 % ESN, and 50 % D120. During June or July, the sugar beet roots were harvested for root yield and root quality. The quality of the root was determined in the Spreckels Sugar Tare Laboratory near Brawley, California.

Table 1. List of N management treatments for 2012-13.

Treatment	Layby N		Total N applied
	lb N/A	Layby N source	lb N/A
1	0	Check	188
2	20	32 %	208
3	50	32 %	238
4	80	32 %	268
5	110	32 %	298
6	140	32 %	328
7	50	ESN	238
8	50	ESN/D120	238
9	50	D120	238
10	50	32 %/ESN	238
11	50	32 %/D120	238
12	50	32 %/ESN/D120	238

Table 2. List of N management treatments for 2013-14.

Treatment	Layby N		Total N applied
	lb N/A	Layby N source	lb N/A
1	0	Check	128
2	40	32 %	168
3	70	32 %	198
4	100	32 %	228
5	130	32 %	258
6	160	32 %	288
7	190	32 %	318
8	70	ESN	198
9	70	ESN/D120	198
10	70	D120	198
11	70	32 %/ESN	198
12	70	32 %/D120	198
13	70	32 %/ESN/D120	198

Table 3. List of N management treatments for 2014-15, Site 1 and 2.

	Layby N			Total N applied	
Treatment	Site 1	Site 2		Site 1	Site 2
	lb N/A		Layby N source	lb N/A	
1	0	0	Check	128	127
2	50	28	32 %	178	155
3	81	56	32 %	209	184
4	110	81	32 %	238	208
5	131	110	32 %	259	237
6	152	149	32 %	280	276
7	208	205	32 %	336	332
8	70	70	ESN	198	197
9	70	70	ESN/D120	198	197
10	70	70	D120	198	197
11	70	70	32 %/ESN	198	197
12	70	70	32 %/D120	198	197
13	70	70	32 %/ESN/D120	198	197
14	234	234	32 %	362	361
15	266	244	32 %	394	371
16	287	294	32 %	415	421

Results and Discussion:

N rate:

2012-2013: Two sites were established in the 2012-13 growing season. One was lost because of a harvesting issue. The results from the remaining 2012-13 site are reported in Table 4. The application of N statistically affected root yield, purity, extractable sucrose per ton, extractable sucrose per acre. This site unlike the other sites in this study was harvested in early June. The yields reflect the earlier harvest. The root yield response to N was positive with the greatest root yield occurring at the 300 lb N (soil test plus preplant plus layby N)/A. This was a 4.3 ton/A increase over no N applied at layby. Sucrose was not significantly affected by N application. Purity was decreased up to the 268 lb /A rate and then flatten out above 268 lb N/A rate. The reduction was 0.6 % on average. Extractable sucrose per ton was slowly reduced from 298 lb/ton to 291 lb/ton by the application of layby N. Extractable sucrose per acre was mainly increased with the first increment of N, 188 to 208 lb N/A, after that N rate there was no additional extractable sucrose from the addition of N.

Table 4. The effect of N fertilizer on sugar beet root yield, sucrose, purity, extractable sucrose per ton, and extractable sucrose per acre for the 2012-13 growing season in the Imperial Valley of California.

Total N – Soil test to 4 ft. plus N fertilizer applied	Root yield	Sucrose	Purity	Extractable sucrose	
lb N/A	ton/A	%	%	lb/ton	lb/A
188	45.9	17.4	91.5	298	13650
208	47.9	17.3	90.9	294	14057
238	44.7	16.3	90.1	274	11843
268	46.3	17.5	91.1	299	14028
298	50.2	17.3	90.6	292	14761
328	45.0	17.2	90.9	292	13070
Mean	46.6	17.1	90.9	291	13498
Statistic					
N rate	0.05	0.12	0.08	0.10	0.02
C.V. (%)	3.9	3.2	0.7	4.0	5.0

<u>2013 – 2014:</u> Two sites were established in the 2013-14 growing season. One site was lost because of late season rot. The results from the remaining 2013-14 site are reported in Table 5.

Table 5. The effect of N fertilizer on sugar beet root yield, sucrose, purity, extractable sucrose per ton, and extractable sucrose per acre for the 2013-14 growing season in the Imperial Valley of California.

Total N – Soil test to 4 ft. plus N fertilizer applied	Root yield	Sucrose	Purity	Extractable sucrose	
lb N/A	ton/A	%	%	lb/ton	lb/A
128	70.7	16.5	89.0	271	19180
168	76.2	15.6	87.7	250	19038
198	79.2	15.5	88.1	251	19874
228	78.6	16.0	89.0	263	20649
258	78.7	15.6	87.4	279	19619
288	76.3	15.1	87.4	241	18376
318	78.4	15.1	87.4	241	18895
Mean	76.8	15.6	88.0	252	19376
Statistic					
N rate	0.08	0.0001	0.08	0.0001	0.10
C.V. (%)	5.1	1.6	1.2	2.8	5.2

This site was harvested in July. One observation for this site is that an additional 100 lb N/A were applied by mistake in February 2014 at this site. This additional N is not reflected in the N rate in Table 5. With this in mind, significant differences from layby N application occurred for root yield, sucrose, purity, extractable sucrose per ton, and extractable sucrose per acre. Nitrogen application increased root yield up to the 198 lb N/A rate (298 lb/A if you consider the February N application). This increase was 8.5 tons/acre. Sucrose was reduced by the addition of N. The sucrose concentration went from 16.5 to 15.1 % for a difference of 1.4 %. This is very common in sugar beet, too much N reduces sucrose concentration. Purity and extractable sucrose per ton were also reduced with the addition of N fertilizer at layby. These reductions reflect the increased impurities in the sugar beet from the increased N application and thus the increase difficulty in refining the sugar beet in the factory. Extractable sucrose per acre was maximized at this location at the 228 lb N/A rate. Again this rate was affected by the accidental addition of N in February.

<u>2014 – 2015:</u> Two sites were established in the 2014-15 growing season. Both sites were harvested in July. The results from Site 1 are reported in Table 6. The root yields from this site were very good with an average root yield of 75.7 tons/acre. Additional layby N rates were added to understand what the effect of too much N on yield and quality. Of the measured properties, only purity was significantly affected by the layby N treatments. The effect of N application on purity was negative. As the amount of N applied increased, the purity was decreased. The increasing application of N did not increase root yield or extractable sucrose per acre. This indicates that extra N application will not increase profitability above the optimum N rate. Sugar beet top growth differences were noted in January. These growth differences were related to N treatments. By March these differences were not visible.

Table 6. The effect of N fertilizer on sugar beet root yield, sucrose, purity, extractable sucrose per ton, and extractable sucrose per acre for the 2014-15 growing season at site 1 in the Imperial Valley of California.

Total N – Soil test to 4 ft. plus N fertilizer applied	Root yield	Sucrose	Purity	Extractable sucrose	
lb N/A	ton/A	%	%	lb/ton	lb/A
128	76.6	14.0	87.7	224	17204
178	74.4	13.8	87.6	220	16315
209	77.1	14.3	88.2	231	17759
238	73.1	14.2	88.2	228	16676
259	74.8	12.8	87.2	202	15144
280	74.8	13.0	86.1	201	15044
336	78.2	12.6	85.1	192	15002
362	74.3	12.8	85.8	198	14692
394	73.5	12.8	85.1	195	14319
415	80.3	13.9	86.1	217	17301
Mean	75.7	13.4	86.7	211	15946
Statistic					
N rate	0.81	0.20	0.08	0.17	0.10
C.V. (%)	7.9	8.0	1.9	11.1	11.3

The results for Site 2 in the 2014-2015 growing season are reported in Table 7. Layby N treatments did not affect root yield, sucrose, extractable sucrose per ton, or extractable sucrose per acre. Purity was the only parameter significantly affected by layby N application. The significance was caused by a decrease in purity at the 208 and 276 lb N/A rates. The other purity values were very similar at 89.1 %. While there were some stand issues at this site, the variability was not large.

Table 7. The effect of N fertilizer on sugar beet root yield, sucrose, purity, extractable sucrose per ton, and extractable sucrose per acre for the 2014-15 growing season at site 2 in the Imperial Valley of California.

Total N – Soil test to 4 ft. plus N fertilizer applied	Root yield	Sucrose	Purity	Extractable sucrose	
lb N/A	ton/A	%	%	lb/ton	lb/A
127	67.3	17.1	88.9	282	18972
155	64.7	17.5	89.7	292	18924
184	67.7	17.3	89.4	288	19528
208	64.3	17.2	88.7	283	18200
237	65.5	17.4	90.3	293	19177
276	62.7	17.0	88.1	276	17326
332	70.4	17.5	89.1	289	20344
361	68.1	17.1	89.1	282	19224
371	66.3	17.5	89.1	289	19144
421	72.2	17.2	89.2	285	20585
Mean	66.9	17.3	89.2	286	19142
Statistic					
N rate	0.13	0.42	0.03	0.23	0.11
C.V. (%)	6.5	2.1	0.8	3.0	7.3

N Products:

The statistical analysis for the comparison of the N products across the four sites is presented in Table 8. The analysis indicates that there was a site by product interaction for sucrose. This interaction was caused by the results from the 2012-13 site. The means for all sites are presented in Table 9. There were no significant differences in the products or the combinations of the products for root yield, sucrose, purity, extractable sucrose per ton, or extractable sucrose per acre.

Table 8. The statistical analysis of the effect of UAN (32 %), ESN, D120, and the combinations of the three products on root yield, sucrose, purity, extractable sucrose per ton, and extractable sucrose per acre at all four sites in the study in the Imperial Valley of California.

Source of variation	Root yield	Sucrose	Purity	Extractable sucrose per ton	Extractable sucrose per acre
Site	0.0001	0.0001	0.0001	0.0001	0.0001
Product/combo	0.72	0.45	0.83	0.68	0.38
Site X Product	0.69	0.09	0.52	0.14	0.22
C.V. (%)	5.4	3.9	1.1	5.0	7.2

Table 9. The effects of UAN (32 %), ESN, D120, and the combinations of the three products on root yield, sucrose, purity, extractable sucrose per ton, and extractable sucrose per acre across all four sites in the study in the Imperial Valley of California.

	Root yield	Sucrose	Purity	Extractable sucrose	
Product/combo	ton/A	%	%	lb/ton	lb/A
UAN	67.7	15.9	88.8	260	17257
ESN	69.8	16.0	88.9	263	18114
D120	67.4	15.9	88.8	260	17291
UAN/ESN	67.6	16.1	89.0	264	17645
UAN/D120	67.4	16.0	89.2	264	17459
ESN/D120	67.0	15.6	89.2	256	17388
UAN/ESN/D120	69.6	16.0	88.9	264	17954
Mean	68.1	15.9	89.0	262	17583

Because of the interaction of product with site, the responsive site, 2012-2013 was separated out and the statistics and means for the treatments are reported in Table 10. The difference in sucrose was caused by the lower sucrose value for the ESN/D120 treatment in 2012-2013. The reduced sucrose could have been caused by a late season release of N from these products.

Table 10. The effects of UAN (32 %), ESN, D120, and the combinations of the three products on root yield, sucrose, purity, extractable sucrose per ton, and extractable sucrose per acre in 2012-13 in the Imperial Valley of California.

	Root yield	Sucrose	Purity	Extractable sucrose	
Product/combo	ton/A	%	%	lb/ton	lb/A
UAN	44.8	16.8	90.5	283	12456
ESN	46.1	17.1	90.7	289	13467
D120	46.5	17.1	90.7	290	13481
UAN/ESN	46.6	16.9	90.0	284	13188
UAN/D120	45.4	17.4	91.2	296	13453
ESN/D120	46.3	15.8	91.1	266	12226
UAN/ESN/D120	49.4	17.3	90.9	294	14478
$LSD_{0.05}$	3.1	0.8	NS	17	992

Summary:

The following are conclusions from this study:

1. Nitrogen applied at layby affected root yield at two of the four sites. The optimum N rate for recommendations is not evident from this study.
2. The use of N at rates greater than 250 lb N/A (soiltest N to 4 ft + preplant N + layby N) did not increase root yield or extractable sucrose per acre.
3. The use of N at rates greater than 250 lb N/A (soiltest N to 4 ft + preplant N + layby N) did not increase sucrose, purity, or extractable sucrose per ton or beet refined. In most cases it reduced these parameters.

4. The use of slow release N products at layby did not affect the parameters measured in this study. The use of these products will not be of advantage to sugar beet production in the Imperial Valley of California.