Nitrogen and Potassium Effects on Sugar Beet Quality

Dr. John A. Lamb
Department of Soil, Water, and Climate
University of Minnesota
St. Paul, MN 55108

Justification: Growers in the Imperial Valley have been concerned about optimum nutrition of sugar beet plant. Potassium is one of the more important nutrients for sugar beet growth. Potassium is needed for root growth, but can be an impurity in the extraction of sucrose at the refinery. There are no current published fertilizer recommendations for growing sugar beet in the Imperial Valley of California. If growers are using a soil test to base their K applications on, it is from the advise of fertilizer dealers or consultants. The information used can be at least 30 years old. In view of the lack of recent research on sugar beet and K, there is a need to investigate this. The objective of this study is to determine the effect of nitrogen and potassium applications on sugar beet root yield and quality.

Materials and Methods: An experiment was established at two locations in the fall of 2013 and the fall of 2014 in the Imperial Valley of California. The experiment included the factorial combination of four nitrogen application rates (0, 45, 90, and 135 lb N/A in the 2013-14 production year and 0, 50, 100, and 150 lb N/A in the 2014-15 production year) and six potassium rates (0, 30, 60, 90, 300, and 500 lb K_2O/A). The two highest potassium rates are extreme to assess the effect of potassium on the root quality, percent sucrose and beet purity. The study had five replications. The potassium as broadcast applied as potassium sulfate (0-0-50) preplant while the nitrogen was injected urea ammonium nitrate solution (UAN, 32-0-0) at layby. Roots were harvested during late June or early July. Root yield and quality was determined at the Spreckels Sugar tare laboratory in Brawley, California.

Results and Discussion:

2013-2014: Two sites were established in the 2013-14 growing season. The statistical analysis for site 1 is reported in Table 1. For root yield there was a significant interaction between N application and K application. The means for this interaction are reported in Table 2. The interaction indicates that there is a significant increase root yield by potassium application at the lowest N level (only N from the residual N and preplant fertilizer application, no fertilizer N applied at layby). This increase was 7.5 ton/acre. This increase did not occur at the other N application rates. Except in the case of the interaction, potassium did not significantly affect root yield. Also potassium application did not significantly affect sucrose, purity, extractable sucrose per ton, or extractable sucrose per acre, Table 3. Nitrogen application did not significantly affect purity or extractable sucrose per acre. The application of nitrogen at layby did affect the root yield, sucrose concentration and extractable sucrose per ton, Table 4.

Table 1. Statistical analysis for root yield, sucrose (%), purity, extractable sucrose per ton of sugar beet, and extractable sucrose per acre for site 1 in the 2013-14 growing season.

	Root yield	Sucrose	Purity	Extractable sucrose per ton	Extractable sucrose per acre
Source of variation	Probability of greater F				
N	0.0002	0.0001	0.28	0.0001	0.40
K	0.63	0.82	0.71	0.84	0.53
N X K	0.08	0.57	0.55	0.56	0.36
C.V. (%)	5.5	3.1	1.1	4.2	6.0
Overall mean	78.4 ton/A	15.6 %	89.0 %	256 lb/ton	20041 lb/A

Table 2. The interaction of nitrogen and potassium application on root yield for site 1 in 2013-14 growing season.

	Total N – soil test to 4 ft. plus fertilizer applied (lb N/A)			
Potassium applied	128	173	218	263
lb K_2O/A	Root yield (ton/A)			
0	69.4	81.5	82.5	80.0
30	76.9	77.3	79.1	82.5
60	78.6	77.9	78.3	83.7
90	75.5	82.0	76.9	79.5
300	75.6	78.2	76.6	81.6
500	73.9	80.5	77.7	75.8

Table 3. The effect of potassium application on root yield, sucrose, purity, extractable sucrose per ton of sugar beet, and extractable sucrose per acre for site 1 in 2013-14 growing season.

Potassium applied	Root yield	Sucrose	Purity	Extractable sucrose per ton	Extractable sucrose per acre
lb K_2O/A	ton/A	%	%	lb/ton	lb/A
0	78.3	15.5	89.0	255	19932
30	78.9	15.7	89.1	258	20371
60	79.6	15.6	89.1	256	20346
90	78.5	15.6	88.8	256	20087
300	78.0	15.5	88.8	254	19778
500	76.9	15.6	89.2	257	19729
Statistic	NS	NS	NS	NS	NS

The application of N at layby significantly increase root yield from the 128 lb N/acre level to the 173 lb N/acre level. The increase was 4.6 tons/acre. Sucrose concentration was reduced from 16.1 % to 15.3 % as N was increased from 128 to 263 lb N/acre while the extractable sucrose per ton of sugar beet processes decreased 15 lb/ton. The results from this site could have been affected by an accidental N application of 100 lb N/A in February, 2014. This could explain the small yield response to N.

Table 4. The effect of nitrogen application on root yield, sucrose, purity, extractable sucrose per ton of sugar beet, and extractable sucrose per acre for site 1 in 2013-14 growing season.

Soil test to 4 ft. plus N fertilizer applied	Root yield	Sucrose	Purity	Extractable sucrose per ton	Extractable sucrose per acre
lb N/A	ton/A	%	%	lb/ton	lb/A
128	75.0	16.1	89.3	266	19930
173	79.6	15.6	88.8	255	20275
218	78.5	15.4	88.9	252	19744
263	80.5	15.3	88.9	251	20214
Statistic	0.0002	0.0001	NS	0.0001	NS

The statistical analysis for Site 2 in the 2013-14 growing season is reported in Table 5. There was no N by K interaction at this site. The application of potassium fertilizer did not significantly affect root yield, sucrose concentration, purity, extractable sucrose per ton, or extractable sucrose per acre at this site, Table 6.

Table 5. Statistical analysis for root yield, sucrose (%), purity, extractable sucrose per ton of sugar beet, and extractable sucrose per acre for site 2 in the 2013-14 growing season.

	Root yield	Sucrose	Purity	Extractable sucrose per ton	Extractable sucrose per acre
Source of variation	Probability of greater F				
N	0.03	0.08	0.07	0.24	0.03
K	0.89	0.45	0.90	0.57	0.71
N X K	0.46	0.42	0.88	0.46	0.56
C.V. (%)	13.9	3.5	1.5	4.9	14.8
Overall mean	36.1 ton/A	16.4 %	88.3 %	267 lb/ton	9658 lb/A

Table 6. The effect of potassium application on root yield, sucrose, purity, extractable sucrose per ton of sugar beet, and extractable sucrose per acre for site 2 in 2013-14 growing season.

Potassium applied	Root yield	Sucrose	Purity	Extractable sucrose per ton	Extractable sucrose per acre
lb K_2O/A	ton/A	%	%	lb/ton	lb/A
0	36.4	16.4	88.1	266	9684
30	36.2	16.5	88.4	270	9814
60	36.4	16.5	88.2	268	9753
90	35.8	16.5	88.4	268	9597
300	36.9	16.5	88.6	270	9947
500	34.8	16.2	88.2	262	9155
Statistic	NS	NS	NS	NS	NS

The application of N at layby did not significantly affect extractable sucrose per ton while it did significantly affect root yield sucrose concentration, purity, and extractable sucrose per acre, Table 7. The application of N at layby increased root yield up to the 194 lb N/acre level. Root yields were depressed at this site because of late season root rot. Sucrose was decreased from 16.6 to 16.3 % by the addition of N. Root purity decreased

0.5 % from the application of N while extractable sucrose per acre, similar to root yield, was increased up to the 194 lb N/acre level.

Table 7. The effect of nitrogen application on root yield, sucrose, purity, extractable sucrose per ton of sugar beet, and extractable sucrose per acre for site 2 in 2013-14 growing season.

Soil test to 4 ft. plus N fertilizer applied	Root yield	Sucrose	Purity	Extractable sucrose per ton	Extractable sucrose per acre
lb N/A	ton/A	%	%	lb/ton	lb/A
104	35.7	16.6	88.3	271	9668
149	36.7	16.5	88.3	269	9855
194	38.2	16.2	88.9	267	10191
239	33.8	16.3	87.8	263	8919
Statistic	0.03	0.08	0.07	NS	0.03

2014-2015: Two sites were established in the 2014-15 growing season. At Site 1 there was a significant interaction between N and K for root yield, Table 8. The interpretation of this interaction does not make biological sense, Table 9. The response to potassium changes with each N level and there is no consistent trend for root yield.

Table 8. Statistical analysis for root yield, sucrose (%), purity, extractable sucrose per ton of sugar beet, and extractable sucrose per acre for site 1 in the 2014-15 growing season.

	Root yield	Sucrose	Purity	Extractable sucrose per ton	Extractable sucrose per acre
Source of variation	Probability of greater F				
N	0.41	0.03	0.06	0.02	0.52
K	0.14	0.69	0.56	0.60	0.03
N X K	0.04	0.15	0.82	0.27	0.11
C.V. (%)	7.1	4.1	1.6	6.0	7.9
Overall mean	73.3 ton/A	13.3 %	88.0 %	213 lb/ton	15577 lb/A

Table 9. The interaction of nitrogen and potassium application on root yield for site 1 in 2014-15 growing season.

	Total N – soil test to 4 ft. plus fertilizer applied (lb N/A)			
Potassium applied	128	178	228	278
lb K_2O/A	Root yield (ton/A)			
0	75.9	70.3	76.6	72.1
30	75.9	71.4	73.2	69.7
60	71.4	67.1	75.0	75.8
90	67.5	78.1	67.0	72.3
300	74.0	74.2	80.1	76.2
500	73.8	71.1	75.3	76.1

The effect of potassium fertilizer on root yield, sucrose, purity, extractable sucrose per ton, and extractable sucrose per acre at site 1 in the 2014-15 growing season is reported in Table 10. Only extractable sucrose per acre was significantly affected by potassium addition. The addition of potassium increased extractable sucrose per acre at the 300 and 500 lb K_2O /acre rates. This increase was close to 500 lb extractable sucrose per acre.

Sucrose, purity, and extractable sucrose per ton were not affected by potassium fertilization. Even though potassium is an impurity in the extraction of sucrose, the high rates applied in this study did not affect the quality.

Table 10. The effect of potassium application on root yield, sucrose, purity, extractable sucrose per ton of sugar beet, and extractable sucrose per acre for site 1 in 2014-15 growing season.

Potassium applied	Root yield	Sucrose	Purity	Extractable sucrose per ton	Extractable sucrose per acre
lb K_2O/A	ton/A	%	%	lb/ton	lb/A
0	73.7	13.3	87.9	213	15682
30	72.5	13.2	87.7	211	15230
60	72.3	13.2	88.0	211	15345
90	71.2	13.2	87.6	210	14902
300	76.1	13.3	88.2	213	16198
500	74.1	13.5	88.5	218	16091
Statistic	NS	NS	NS	NS	0.03

The application N fertilizer did not affect root yield or extractable sucrose per acre, Table 11. Sucrose concentration, purity, and extractable sucrose per ton were reduced by the N additions. This is similar to what is reported in other sugar beet studies.

Table 11. The effect of nitrogen application on root yield, sucrose, purity, extractable sucrose per ton of sugar beet, and extractable sucrose per acre for site 1 in 2014-15 growing season.

Soil test to 4 ft. plus N fertilizer applied	Root yield	Sucrose	Purity	Extractable sucrose per ton	Extractable sucrose per acre
lb N/A	ton/A	%	%	lb/ton	lb/A
128	73.1	13.4	88.3	216	15689
178	72.0	13.5	88.5	218	15719
228	74.5	13.2	87.9	210	15662
278	73.7	13.1	87.4	207	15243
Statistic	NS	0.02	0.06	0.02	NS

The statistical analysis for Site 2 in the 2014-15 growing season is reported in Table 12. At Site 2 there were no significant interactions between N and K applications. The application of potassium did affect the root yield and extractable sucrose per acre while not significantly affecting sucrose concentration, purity, or extractable sucrose per ton.

Table 12. Statistical analysis for root yield, sucrose (%), purity, extractable sucrose per ton of sugar beet, and extractable sucrose per acre for site 2 in the 2014-15 growing season.

	Root yield	Sucrose	Purity	Extractable sucrose per ton	Extractable sucrose per acre
Source of variation	Probability of greater F				
N	0.0003	0.07	0.05	0.03	0.0003
K	0.10	0.32	0.49	0.27	0.04
N X K	0.95	0.54	0.84	0.67	0.91
C.V. (%)	11.4	2.1	1.0	3.0	11.3
Overall mean	53.6 ton/A	17.8 %	90.7 %	303 lb/ton	16201 lb/A

Root yield was increased only at the 300 lb K2O /acre rate. The increased yield was 4 ton/acre. Root yield at the other applications was not affected. A similar response occurred for extractable sucrose per acre. Potassium was increased at the 300 lb K_2O / acre rate. This response was 1182 lb /acre of extractable sucrose per acre.

Table 13. The effect of potassium application on root yield, sucrose, purity, extractable sucrose per ton of sugar beet, and extractable sucrose per acre for site 2 in 2014-15 growing season.

Potassium applied	Root yield	Sucrose	Purity	Extractable sucrose per ton	Extractable sucrose per acre
lb K_2O/A	ton/A	%	%	lb/ton	lb/A
0	53.3	17.8	90.8	303	16149
30	54.7	18.0	90.9	306	16708
60	51.3	17.7	90.4	298	15309
90	52.0	17.9	90.9	305	15847
300	57.3	17.8	90.8	303	17331
500	52.8	17.8	90.5	301	15861
Statistic	0.10	NS	NS	NS	0.04

Nitrogen level significantly affected all parameters measured, Table 14. The root yield was increased with increasing N level. The root yield at a N level of 277 lb/A was 6.9 tons/acre greater than the root yield at 127 lb /A. This effect is reflected in the extractable sucrose per acre results. Increased extractable sucrose per acre occurred with increased N levels. The significant effects of N level on sucrose concentration, purity, and extractable sucrose per ton occurred because of the reduction of these parameters at the 177 lb/A N level. The values for these parameters were greater for the 127, 227, and 277 lb N/A levels compared to the 177 lb/A N level.

Table 14. The effect of nitrogen application on root yield, sucrose, purity, extractable sucrose per ton of sugar beet, and extractable sucrose per acre for site 2 in 2014-15 growing season.

Soil test to 4 ft. plus N fertilizer applied	Root yield	Sucrose	Purity	Extractable sucrose per ton	Extractable sucrose per acre
lb N/A	ton/A	%	%	lb/ton	lb/A
127	51.0	18.0	91.1	307	15650
177	51.1	17.7	90.4	299	15246
227	54.4	17.8	90.7	302	16387
277	57.9	17.8	90.7	302	17520
Statistic	0.0003	0.07	0.05	0.03	0.0003

Summary:

The following are conclusions from this study:

1. There is little interaction between N and K for the parameters measured.
2. The use of substantial amounts of K did not reduce sugar beet quality at the sites in this study.
3. More work is needed to predict when a positive response to K will occur.