NITROGEN MANAGEMENT STRATEGIES FOR FIELD CORN BEFORE SUGARBEET

John A. Lamb[1], James Radermacher[2], Mark W. Bredehoeft[2], Chris Dunsmore[2], Nicole VanOs[2], and David Kee[2]

[1]Department of Soil, Water, and Climate, University of Minnesota, St. Paul, MN and [2]Southern Minnesota Beet Sugar Cooperative, Renville, MN

Justification

Nitrogen management for quality sugar beet production has been a focus of nutrient management research for a number of years. A key factor in being able to manage N for sugar beet production is to have a smaller amount of residual soil nitrate-N before planting sugar beet. Close to 70 % of the sugar beet grown in the Southern Minnesota Beet Sugar Cooperative is preceded by corn. Corn needs proper N application to optimize grain yield. Corn grain yield is not hurt by over application of nitrogen when compared to sugar beet.

The use of corn stalks for bedding and a possible biofuel has increased in the last few years. The removal of the corn stalks could affect the soil mineralization processes of nitrogen. This mineralization change could affect the nitrogen management for sugar beet production following corn.

Research is needed to optimized nitrogen management throughout the whole crop rotation with or without removal of corn stalks for the greatest profit. To answer questions about nitrogen management in a corn/sugar beet production system a study with the objectives of 1. determine the effect on residual soil nitrate-N by different nitrogen and residue management systems for corn production, and 2. determine the effect of different nitrogen and residue management systems for corn grown previous to sugar beet production on sugar beet yield and quality.

Materials and Methods: This study started in 2011 and ended in 2014. Two sites were established in 2011, 2012, and 2013 with corn grown as the first crop in the two year sequence. Nitrogen treatments applied before the corn crop included a check, 120 lb N/acre, 160 lb N/acre, 200 lb N/acre, and 300 lb N/acre. The 120 lb N/acre is the University of Minnesota guideline for corn following soybean. The 160 lb N/acre treatment is based on SMBSC corn guideline when using a nitrate-N soil test (soil test nitrate-N to 2 ft. plus fertilizer = 160). The 200 and 300 lb N/acre are aggressive and excessive N applications for corn production. The nitrogen fertilizer was applied as urea or as a mix of ¼ urea and ¾ ESN. ESN is a polymer coated urea that is designed as a slow release nitrogen product. All plots received 3 gal/acre of 10-34-0 in-furrow at planting. There were 4 replications of the treatments. Corn was hand harvested in the fall and on half of the plots the corn residue was removed by raking and baling with farm sized equipment. Soil samples were taken after harvest to a depth of four feet. Nitrate-N was determined and the results determined the amount of fertilizer N applied for sugar beet production in following year. The total nitrogen applied was soil test nitrate-N (0 to 4 ft.) + fertilizer (urea) equaled 100 lb N/A at sites 1110 and 1111 and 110 lb N/A at sites 1210, 1211, 1310, and 1311. A summary of the treatments applied before corn can be found in Table 1.

Table 1. Summary of the fertilizer and residue treatments. The residue treatments were only applied to the sugar beet year of the study.

Product	N rate	Residue removed
Check	0	Yes/No
Urea	120	Yes/No
Urea/ESN	120	Yes/No
Urea	160 (SMBSC)	Yes/No
Urea/ESN	160 (SMBSC)	Yes/No
Urea	200	Yes/No
Urea/ESN	200	Yes/No
Urea	300	Yes/No
Urea/ESN	300	Yes/No

Results

Initial soil test results: The initial soil test results are reported in Table 2. The pH ranged from 7.1 to 8.0 at the six sites while the organic matter ranged from 3.5 to 5.9%. Phosphorus and potassium were applied recommended rates at sites with lower soil tests. The soil nitrate-N values were used to calculate the amount of N fertilizer to apply for the 160 (SMBSC) treatments. The amounts were 88 lb N/A for site 1110, 142 lb N/A for site 1111, 88 lb N/A for site 1210, 140 lb N/A for site 1211, 151 lb N/A for site 1310, and 139 lb N/A for site 1311.

Table 2. Initial soil test values for all sites.

Soil test	1110 (T)	1111 (S)	1210 (MC)	1211 (MI)	1310 (L)	1311 (MII)
pH	7.9	7.2	7.8	7.6	8.0	7.1
Organic matter (%)	3.5	4.8	5.9	4.9	5.2	5.4
Nitrate-N (0-2 ft.) lb/A	72	18	72	20	9	21
Olsen-P (ppm)	19	14	22	26	4	9
K (ppm)	175	164	300	259	193	127
Zinc (ppm)	1.33	1.37	4.12	1.31	0.78	1.12

Corn grain yields: Corn grain yields were increased at five of the six sites, Table 3 and Table 4. There was no grain yield response from the addition of N at the 1110 site. While the soil nitrate-N test would indicate a need for N, it was not needed at site 1110. None of the treatments, N source or N rates, affected corn grain yield at site 1110.

In 2011, there was a significant corn grain yield response to N fertilization at site 1111. The grain response was from the addition of N and not the source of the N. Corn grain yield was the best at the 200 lb N/A rate. This is 15 bushels per acre more than the corn grain yield with the 120 lb N/A application. The addition of an extra 100 lb N/A did not increase grain yield.

At the 1210 and 1311 sites, there was an increase in corn grain yields caused by the addition of N fertilizers. The rate of N applied did not affect the grain yield, only the N source. At the 1210 site the Urea/ESN mix treatments had corn grain yields that were 11 bushels per acre greater than the grain yields treated with urea while at 1311 the difference was 5 bushels per acre.

The 1211 site had an increase in corn grain yield for the addition of N fertilizer but the different N rates and N sources did affect grain yield.

At the sixth site, 1310, corn grain yield was increased with the use of N fertilizer. At all N rates, urea produced greater grain yields compared to the urea/ESN mix. The differences in grain yield between urea and urea/ESN N sources were different at each N rate.

Table 3. Corn grain yields as affected by nitrogen rate and source.

		Corn grain yield					
Treatment		1110	1111	1210	1211	1310	1311
N source	N rate (lb/A)	---------- Bushels/acre ----------					
Check	0	214	95	159	121	115	162
Urea	120	211	194	207	189	177	207
Urea/ESN	120	211	188	224	176	170	213
Urea	160 (SMBSC)*	210	203	202	188	172	207
Urea/ESN	160 (SMBSC)*	203	194	203	177	165	210
Urea	200	202	205	204	188	173	206
Urea/ESN	200	203	206	227	169	177	220
Urea	300	207	199	212	177	188	206
Urea/ESN	300	205	208	216	196	165	204

* N application rates for this treatment were 88 lb N/A for site 1110, 142 lb N/A for site 1111, 88 lb N/A for site 1210, 140 lb N/A for site 1211, 151 lb N/A for site 1310, and 139 lb N/A for site 1311.

Table 4. Statistical analysis for corn grain yield.

	1110 (T)	1111 (S)	1210 (MC)	1211 (MI)	1310 (L)	1311 (MII)
Source of variation	---------- Pr > F ----------					
Treatment	0.70	0.0001	0.0006	0.0001	0.0001	0.0001
Check vs rest	0.42	0.0001	0.0001	0.0001	0.0001	0.0001
N source	0.62	0.72	0.03	0.92	0.02	0.06
N rate	0.39	0.009	0.22	0.33	0.32	0.19
N source X Nrate	0.87	0.22	0.33	0.20	0.04	0.22
C.V.%	6.6	6.4	9.1	13.0	7.5	5.0

Corn basal stalk nitrate-N concentrations: The nitrate-N concentrations of the basal portion of the corn stalk were measured at each site each fall, Table 5 and Table 6. The basal corn stalk nitrate-N concentration can be used to evaluate if the corn plant had enough N for growth in the season. IT IS NOT TO BE USED AS A TOOL TO DETERMINE HOW MUCH N NEEDS TO PUT APPLIED FOR THE FOLLOWING CROP! The basal stalk nitrate-N concentration increased with increasing N application at all sites. At sites 1110 and 1310, N source, urea or urea/ESN mix affected the basal stalk nitrate-N concentrations. At site 1110, the use of urea/ESN mix produced greater basal stalk nitrate-N concentration, 5479 vs 5959 ppm. At site 1310, the use of urea/ESN produced less basal stalk nitrate-N concentrations than urea, 824 vs 1084 ppm. This was opposite of the 1110 site. The differences although of some statistical significance are not large.

Table 5. Corn basal stalk nitrate-N concentrations as affected by nitrogen rate and source.

		Corn basal stalk nitrate-N concentration					
Treatment		1110	1111	1210	1211	1310	1311
N source	N rate (lb/A)	---------- ppm ----------					
Check	0	3246	10	14	9	7	68
Urea	120	5660	304	1069	1412	342	525
Urea/ESN	120	5263	792	1471	1616	197	314
Urea	160 (SMBSC)	4585	1053	1086	1330	680	892
Urea/ESN	160 (SMBSC)	5043	441	1110	1381	540	285
Urea	200	5316	2681	3424	4294	960	1134
Urea/ESN	200	6009	2692	2589	4251	1101	1551
Urea	300	6357	4630	4100	4768	2354	2594
Urea/ESN	300	7424	5935	4040	5649	1462	2871

Table 6. Statistical analysis for corn basal stalk nitrate-N concentrations.

	1110 (T)	1111 (S)	1210 (MC)	1211 (MI)	1310 (L)	1311 (MII)
Source of variation	---------- Pr > F ----------					
Treatment	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Check vs rest	0.0001	0.005	0.0001	0.0001	0.0004	0.0002
N source	0.09	0.46	0.70	0.49	0.13	0.88
N rate	0.0001	0.0001	0.0001	0.0001	0.001	0.0001
N source X Nrate	0.40	0.37	0.55	0.76	0.17	0.31
C.V.%	18.1	66.4	51.9	45.6	70.0	66.2

Residual soil nitrate-N: Each plot was soil sampled to a depth of 4 feet in the fall after corn harvest. The information from the soil samples was used to determine the amount of N that was left after corn production and also to determine how much N to apply to the following year's sugar beet crop. Except for sites 1110 and 1311, as the N rate increased, the residual soil nitrate-N increased, Table 7. This residue soil nitrate-N increase is not consistently affected by the N source. Site 1110 had elevated residual soil nitrates for all treatments while the residual soil nitrate-N at 1311 had some unexplainable results. The increases in residue nitrate-N at the other four sites are reflected in the amounts of fertilizer applied for the following year's sugar beet crop, Table 8. The greater the amount of N fertilizer applied for the previous corn crop, the less N fertilizer is needed for the upcoming sugar beet crop.

Table 7. Residual nitrate-N to 4 ft. following corn.

		Soil nitrate-N to a depth of 4 feet					
Treatment		1110	1111	1210	1211	1310	1311
N source	N rate (lb/A)	---------- lb/acre ----------					
Check	0	60	13	22	25	21	49
Urea	120	184	21	34	32	42	38
Urea/ESN	120	141	17	33	52	44	45
Urea	160 (SMBSC)	92	34	48	44	71	47
Urea/ESN	160 (SMBSC)	135	20	38	44	77	99
Urea	200	180	53	91	72	93	92
Urea/ESN	200	174	54	68	75	158	46
Urea	300	207	83	193	109	157	70
Urea/ESN	300	271	90	214	235	126	54

Table 8. Nitrogen fertilizer rate applied before sugar beet production.

		N application					
Treatment		1110	1111	1210	1211	1310	1311
N source	N rate (lb/A)	---------- lb/acre ----------					
Check	0	40	87	88	85	89	61
Urea	120	0	80	77	78	68	72
Urea/ESN	120	0	84	77	59	66	65
Urea	160 (SMBSC)	8	67	62	66	39	64
Urea/ESN	160 (SMBSC)	0	80	72	66	33	11
Urea	200	0	47	19	38	17	18
Urea/ESN	200	0	46	42	36	0	64
Urea	300	0	18	0	2	0	40
Urea/ESN	300	0	10	0	0	0	56

Sugar beet root yield: The effects of the N fertilization practices for corn production on sugar beet root yield are presented in Table 9. The sugar beet root yields at site 1210 were below 10 ton per acre and did not reflect the treatments applied in this study. For this reason, the data was discarded.

The residual N treatments and the removal of residue did significantly affect the sugar beet root yield, Table 9. These differences were different at each site. The check was compared to rest of the treatments because in the previous year it did not have any N fertilizer applied to it. In two of the five sites, the check root yield was different than the other previous treatments. At the 1111 and 1310 sites the root yield for the previous year's check was 2.5 and 7 tons per acre less than the mean root yields for the other residual N fertilizer treatments, Table 10. In most cases, the check treatments from the previous years had to most N applied before the sugar beet production year. At three of the five sites, root yields were not different from the check treatment, sites 1110, 1211, and 1311. At four of the five sites, there was a significant interaction between the N source and N rate from the previous year for root yield, Table 9. For site 1110, the interaction indicates that root yield was affect by N rate differently if urea was the N source as opposed to a urea/ESN mix, Table 11. The differences are small and not consistent. At site 1211, as N rate increased, the root yield increased up to the 200 lb N per acre application in the previous. The interaction occurred because the root yield at 120 lb N/A was greater for the urea/ESN N source compared to root yield for the urea N source treatments. The root yield increased with increasing N rate when urea was used while the root yield decreased with increasing N rates when urea/ESN was the N source at site 1310. At site 1311, the root yield was not affected by N rate when urea was the N source while the root yield decreased with increasing N rate when urea/ESN was the N source. At site 1111, there was no effect of any of the previous N treatments on root yield. Overall, the use of urea/ESN in the previous corn crop did not have a large or consistent effect on the root yield the following year.

At site 1211, root yield was also affected by the removal of residue. Overall, the removal increased root yields at the 120 and 200 lb N/A previous year treatments by 2.5 to 3.0 tons per acre, while at the 160 and 300 lb N per acre treatments, the root yield was greater with the residue left and incorporated with tillage 0.6 to 2.2 tons per acre. At site 1310, the removal of residue did not affect root yield when urea was the N source while the removal decreased root yield when urea/ESN was the N source.

Table 9. Statistical analysis of sugar beet root yield.

	1110 (T)	1111 (S)	1211 (MI)	1310 (L)	1311 (MII)
Source of variation	---------- Pr > F ----------				
Treatment	0.02	0.07	0.0001	0.0001	0.01
Check vs rest	0.15	0.05	0.14	0.0001	0.70
Residue	0.90	0.81	0.16	0.11	0.17
N source	0.07	0.94	0.52	0.002	0.41
N rate	0.03	0.53	0.0001	0.91	0.58
N source X N rate	0.02	0.85	0.04	0.003	0.08
N rate X Residue	0.97	0.30	0.002	0.50	0.11
N source X Residue	0.55	0.47	0.36	0.01	0.24
N source X N rate X Residue	0.27	0.65	0.54	0.83	0.32
C.V. (%)	11.9	7.3	5.3	15.1	13.4

Table 10. Root yield of the previous year's check vs the rest of the previous N treatments.

	1110	1111	1211	1310	1311
Previous year's treatments	Root yield (ton/acre)				
Check	26.2	30.8	32.0	14.8	18.2
Rest	27.2	33.3	32.7	21.8	21.5

Table 11. The effect of N source and N rate from the previous production year on sugar beet root yield.

	1110		1211		1310		1311	
N rate	Urea	Urea/ESN	Urea	Urea/ESN	Urea	Urea/ESN	Urea	Urea/ESN
lb/A	Root yield (tons/acre)							
120	28.5	27.0	30.8	33.5	21.5	22.6	20.7	24.2
160	31.2	23.9	32.1	32.0	22.1	20.6	22.5	18.9
200	24.0	23.8	35.2	34.6	24.3	19.0	21.0	21.2
300	28.6	29.7	32.0	31.3	26.2	17.3	23.0	20.1

Extractable sucrose per ton: The residual treatments affected extractable sucrose per ton (quality) at only two of the five sites, 1110 and 1111. The extractable sucrose per ton from the check treatment from the corn year of production was different for the rest of N treatments at only site 1110. The difference was a reduction in extractable sucrose per ton, 278 lb sucrose per ton for the check treatment versus 269 lb per ton of sugar beet processed. At both sites, 1110 and 1111, there was a N source by N rate interaction for extractable sucrose per ton. At both sites, as N rate application increased, the extractable sucrose per acre decreased. The rate of decrease was different for each N source at each site.

Table 12. Statistical analysis of sugar beet extractable sucrose per ton.

	1110 (T)	1111 (S)	1211 (MI)	1310 (L)	1311 (MII)
Source of variation	---------- Pr > F ----------				
Treatment	0.0003	0.08	0.16	0.66	0.43
Check vs rest	0.0007	0.16	0.89	0.91	0.35
Residue	0.75	0.15	0.11	0.98	0.85
N source	0.05	0.25	0.14	0.46	0.34
N rate	0.0001	0.33	0.31	0.37	0.37
N source X N rate	0.007	0.002	0.41	0.32	0.69
N rate X Residue	0.06	0.94	0.10	0.39	0.45
N source X Residue	0.42	0.21	0.43	0.96	0.13
N source X N rate X Residue	0.53	0.64	0.58	0.96	0.75
C.V. (%)	3.0	3.9	3.4	4.5	3.4

Extractable sucrose per acre: Extractable sucrose per acre is affected mainly by root yield and tempered by the extractable sucrose per ton (quality). The N management treatments and residue removal did not affect extractable sucrose per acre at the 1110 site. At sites 1111 and 1211, the residual N from the N rate application to corn the

previous year increased extractable sucrose per acre up to the 200 lb N per acre treatment and was reduced at the 300 lb N per acre. At site 1211, the removal of corn residue did decrease the amount of extractable sucrose per acre. At each N rate it was different in the amount but the trend was the same with increasing N rate. There were significant N rate by N source and N rate by residue removal interactions at sites 1310 and 1311. Generally, at both sites, as N rate increases when urea was the N source in the previous year, the extractable sucrose per acre increased, when the N source was the urea/ESN mix then the extractable sucrose per acre decreased, Table 14. The effect of residue removal is mixed at the two sites. At site 1310, when urea was the N source the previous year, the extractable sucrose per acre was not affected by the residue removal but if urea/ESN was the N source, the removal of residue did increase extractable sucrose per acre. The opposite is true at site 1311. When the N source was urea, extractable sucrose per acre was increase with the removal of residue while when urea/ESN was the N source, the removal of residue did not affect the extractable sucrose per acre.

Table 13. Statistical analysis of sugar beet extractable sucrose per acre.

	1110 (T)	1111 (S)	1211 (MI)	1310 (L)	1311 (MII)
Source of variation	---------- Pr > F ----------				
Treatment	0.15	0.002	0.0001	0.0001	0.002
Check vs rest	0.70	0.20	0.13	0.0001	0.75
Residue	0.74	0.75	0.61	0.11	0.31
N source	0.22	0.91	0.20	0.005	0.23
N rate	0.04	0.10	0.0001	0.76	0.56
N source X N rate	0.08	0.20	0.20	0.009	0.03
N rate X Residue	0.93	0.15	0.004	0.66	0.17
N source X Residue	0.64	0.68	0.65	0.02	0.09
N source X N rate X Residue	0.48	0.24	0.72	0.88	0.23
C.V. (%)	12.9	7.0	6.3	14.8	14.2

Table 14. The extractable sucrose per acre as effected by the N rate X N source and N source by N rate interactions at sites 1310 and 1311.

	1310		1311	
N rate previous year	Urea	Urea/ESN	Urea	Urea/ESN
lb N/A	Extractable sucrose per acre (lb/A)			
120	5258	5778	5731	6799
160	5478	5033	6323	5210
200	5886	4636	5897	5949
300	6225	4354	6494	5433
Residue removal				
No	5739	4426	5770	5864
Yes	5643	5474	6440	5839

Conclusions: This study was designed to investigate the effect on sugar beet production of N rate and N source used for a previous corn crop, and also the effect of corn residue removal. The N rate ranged from University based guideline of 120 lb N/A to 300 lb N/A. The N sources for the corn crop, were urea or a ¾ urea and ¼ ESN mix. The urea/ESN mix has been suggested for corn production as a slower release N product that would increase the efficiency of N fertilizer use by the corn plant. In general the following was learned from this study:

1. Additional N applied to corn has no negative effect on corn grain yield. The down side is the economic lost from buying more N fertilizer than you need to get optimal corn grain yield.
2. In this study and several other studies conducted in Minnesota, the use of ESN with urea did not consistently increase corn grain yields.
3. Basal stalk nitrate-N concentrations are affected by the amount of N applied. The N source does not generally affect the concentrations. THE BASAL STALK NITRATE-N TEST IT IS NOT TO BE USED AS A TOOL TO DETERMINE HOW MUCH N NEEDS TO PUT APPLIED FOR THE FOLLOWING CROP!

4. At most of the sites, the over application of N to corn will result in increased residual soil nitrate-N at a depth to 4 feet. At times this increase puts soil test N above the recommended guideline for N application.
5. Sugar beet production after corn can be affected by extreme application rates of N.
6. The use of slow release products in the previous production year will not consistently affect the root yield, extractable sucrose per ton, or extractable sucrose per acre.
7. The removal of corn crop residue one time, does consistently affect sugar beet production in the proceeding year.

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