Enhanced Efficiency Nitrogen as Nitrogen Source in Sugar Beet Production

R-2013-K, MDA Contract # 58451, SPA # 00034945

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Half the sugar beets grown in the United States are grown in Minnesota and North Dakota with the majority in Minnesota, approximately 450,000 acres. Nitrogen (N) management is critical in sugar beet production as too little N in the first half of the growing season greatly limits sugar beet root yield. Too much N late in the growing season reduces sugar beet root quality requiring additional expense to process a given quantity of sugar. In the last couple of decades there has been major efforts in research and education reducing the amount of N applied to sugar beet crop while at the same time increasing root yield and root quality. This effort is on-going and continually refines the N recommendation in sugar beet production. However, there are areas in the sugar beet growing area that seem to require higher rates of N, in some cases substantially higher rates, than other areas. Recent research has identified high N use areas in the Red River Valley (RRV) and research has confirmed the requirement for additional N. Growers in those areas are asking if alternative N management strategies might reduce the N required to grow a satisfactory sugar beet crop. Several approaches are being considered and one is the use of polycoated urea (PCU). Many of these growers farm fine textured soils and there is concern that on some years, if not most, a large of amount of N is lost during the season to denitrification. In previous research the PIs on this proposal have found reduced denitrification loss with PCU compared to urea. Is PCU a viable option for these growers?

Spring application of N fertilizer to sugar beet has also increased interest in using PCU as a N source. Historically, N fertilizer was applied the fall prior to the sugar beet growing season. But, in recent years growers were either unable to fall apply N or wanted to try enhancing N use efficiency by spring N applications. Previous research has shown that large quantities of spring applied urea often reduce sugar beet stands. The PIs in this proposal have documented sugar beet stand loss with greater than 75 to 90 lbs. N Ac^{-1} as spring applied urea. Is this hazard reduced if the N source is PCU or a mixture of urea and PCU?

In the Southern Minnesota Beet Sugar Cooperative (SMBSC) growing area, less N is used to maintain root yield and quality. Duplicate efforts in the SMBSC and American Crystal Sugar Company (ACSC) growing areas broadens the scope of the research and helps develop, where possible, uniform management recommendations throughout the region. Primary treatments were identical in both the SMBSC growing area, hereafter referred to as the **Southern Site**, and the ACSC growing area in the RRV, hereafter referred to as the **Northern Site**. The difference between the two sites was the actual N rates that were used. Otherwise, all treatments were the same in 2014.

The objectives of this experiment are to: 1) Determine if sugar beet root yield and quality are effected by timing of N fertilization; 2) Determine if sugar beet stands, root yield and quality, and N use efficiency can be enhanced by using a polycoated urea (PCU) either alone or mixed with urea; 3) Determine if N loss through denitrification is effected by the source of N or the timing of its application.

Materials and Methods:

Northern Site:

A grower cooperator field was identified in the fall of 2013 and was in the same general growing area as previous experiments concerning N management in areas that require higher than normal N rates for sugar beet production. The experimental design was a randomized complete block with four replications or blocks. The treatment design was a factorial for a total of 20 treatments plus a 0 N control. The 20 treatments developed two experiments with some treatments serving in both experiments. The first experiment was a 2 x 3 x 2 factorial with two fertilizer application times (Fall or Spring), three N fertilizer sources (urea, PCU, 50:50 mixture), and two applied N rates (120 or 150 lbs. N ac^{-1}). The PCU used in this experiment was a product by Agrium Inc called Environmentally Safe Nitrogen (ESN) . The second experiment was also a factorial, but with a little more complication. Again one factor was two fertilizer application times (Fall or Spring), two N fertilizer sources (urea or PCU), and two applied N rates (120 or 150 lbs. N ac^{-1}). However, the N rates were applied differently. The actual pre-plant N rates, whether fall or spring applied, were 90, 120, or 150 lbs. N ac^{-1}. During the growing season, additional N was sidedressed, either 30 or 60 lbs. N ac^{-1}, to the 90 lbs. N rate treatments bringing the total N to 120 or 150 lbs. N ac^{-1}.

Fall fertilizer treatments were applied on November 5th, 2013 to experimental plots that were to be six planted rows wide (22 inch row spacing or 11 ft wide total) and 30 feet long. All pre-plant fertilizer treatments as well as a general broadcast of 60 lbs. P_2O_5 ac^{-1} as 0-46-0 were incorporated with a field cultivator immediately after application. Spring fertilizer applications took place on May 23rd, 2014 and the plots were planted to sugar beet a few hours later. All the plots were treated with starter fertilizer of 3 gals ac^{-1} of 10-34-0 in direct contact with the sugar beet seed. While the starter fertilizer did apply some N to all the plots, it was only about 3.5 lbs. N ac^{-1}.

After several weeks we assumed all seedlings that were going to emerge had in fact emerged; we counted all emerged seedlings in the middle four rows of each plot to estimate the effect of the treatments on seedling emergence. At the 10-12 leaf growth stage, the sidedress treatments were applied on July 7th using 28-0-0 (UAN) banded between the seed rows to a depth of about 3 to 4 inches. On July 24th and again August 4th, petiole samples were collected from the middle two rows of each plot. About 14, 7 from each row, petioles from the most recently fully expand leaf blades were removed from the crown, the leaf blade separated and discarded, and the petiole was placed in a zip-loc bag and placed in a cooler on ice. Petioles were taken back to the laboratory and placed in a freezer until they could be dried at a later date. At that later date, the petioles were broken to promote drying, heat dried, then ground in a coffee grinder to a fine powder. A sample of the ground petiole was then treated to extract nitrate-N. The relative concentration of nitrate-N is symptomatic of the relative nitrate-N availability to the sugar beet crop.

On September 15th, the middle four rows of the plots were detopped and the middle two rows of beets were lifted with a mechanical lifter. Lifted beets were weighed and 10 representative beets were collected from each plot, placed in a rubber tare bag, and sent to the American Crystal Quality Laboratory in East Grand Forks, Minnesota to be analyzed for tare, sugar concentration, and several impurity parameters that were combined through an algorithm to estimate Loss to Molasses (LTM). The sugar and LTM measures used to calculate sugar beet root quality (recoverable sucrose ton^{-1}). The tare calculated back to the weight of the lifted beets estimates root yield.

Southern Site:

The southern site was very similar in most cases to that of the northern site except the N rates were lower. In addition, the N gaseous losses were not measured on the southern site. Nitrogen rates at the southern site were 30, 60, 90, and 120 lbs. N Ac^{-1} as either urea, PCU, or a 50:50 mixture. Additional treatments were added where either 30 or 60 lbs. N Ac^{-1} were sidedressed during the growing season in addition to the pre-plant N applied. Beets were harvested similar to that of the northern site except a sample of harvested beets was sent the Southern Beet Sugar Cooperative Quality Laboratory for quality analysis.

Gas Emission of Northern Site:

The same day sugar beet was planted at the northern site, PVC cylinders were placed in each plot between rows 2 and 3. The cylinders were 12 inches in diameter and approximately 8 inches deep and were driven into the soil to a 4 inch depth. Periodically, approximately once a week, the cylinders were covered for a period of time to accumulate emission gas and a gas sample collected at 0, 20 and 40 minute intervals after the cover was placed on the cylinder. These gas samples were taken back to the laboratory at the University of Minnesota, Crookston and stored until they could be analyzed for greenhouse gases of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) , and ammonia (NH_4) to estimate N gaseous losses. Once collected, the concentration of the greenhouse gases in the sample was quantified using a gas chromatograph (GC) equipped with a thermal conductivity detector (TCD), flame ionization detector (FID), and an electroconductivity detector (ECD). The TCD detector detects the CO_2, the FID detector detects the CH_4, and the ECD detector detects gaseous N as N_2O. Concentration of these gases was quantified by comparison to standards which are also analyzed using the GC. Flux rate was determined by the change in gas concentration over time and fitting the data to either a linear or curvilinear model. This procedure is used by GRACeNET, a group of USDA ARS scientists monitoring greenhouse gas emissions across the country.

Results

Northern Site:

Experiment 1 compared treatment factors of N fertilizer application times (Fall vs Spring), N fertilizer sources (Urea, PCU, or a 50:50 mixture of the two) and two N rates (120 and 150 lbs. N ac^{-1}).

Table 1. Statistical analysis testing treatment factor effects on the 2014 sugar beet harvest data from the Northern Experimental Site.

	Root yield	Root Quality	Sucrose Yield	Sugar Conc.	LTM Conc.
Source of Variation	--------- PR > F --------				
Time (Fall vs Spring)	0.34	0.79	0.39	0.76	0.91
N Source (Urea vs PCU vs Mixed)	0.48	0.35	0.68	0.35	0.73
N rate (120 vs 150 lbs. N ac^{-1})	0.58	0.33	0.75	0.47	0.04
Time by N Source	0.29	0.11	0.55	0.13	0.17
Time by N rate	0.66	0.73	0.62	0.72	0.97
Source by N rate	0.17	0.15	0.10	0.10	0.95
Time by N Source by N rate	0.13	0.75	0.20	0.81	0.43

Statistical analysis of all the harvest variables suggest very little significant effects of any of the main factors in this experiment with one exception, that of N rate on LTM (Table 1). As expected, LTM increased with the higher rate of N, 1.35% and 1.40% with 120 and 150 lbs. N ac^{-1}, respectively. Averaged across all treatment factors root yield was 19.6 tons ac^{-1}, root quality was 293 lbs. sucrose ton^{-1}, sucrose yield was 5700 lbs. sucrose ac^{-1}, sugar concentration was 16.0% and LTM was 1.38%.

The values observed in all variables, except perhaps LTM, were substantially less in 2014 than in the previous two years of this trial. Growing conditions in 2014 were difficult. Late planting into a marginal seedbed followed by cool damp weather resulted in sugar beet plants that were yellow to light green in color and stunted growth. The commercial field in which this trial is located was almost uniformly yellow compared to the experimental site. In previous years, the early spring growing conditions frequently experienced excess soil moisture conditions, but temperature tended to be warmer. When soil conditions began to dry from both less frequent heavy rainfall and greater soil water use by the plants, the sugar beet plants showed a great recovery resulting in good root yield and quality with yields in the 30 ton ac^{-1} range. This recovery in the latter part of the growing season did not occur in 2014.

Single degree of freedom contrasts can separate different components of the main factors and their interactions. Sometimes these contrasts can identify differences in specific components that are masked when the entire main factor is considered.

There was a significant 3-way interaction (PR>F of 0.04) between time of N application and N source (urea vs PCU only) by N rate. When N fertilizer was fall applied there was little difference in root yield among the treatment factors or their levels (Table 2). However when spring applied, PCU was 2.6 tons ac^{-1} less than urea at the 120 lbs. N ac^{-1} rate and nearly 6 tons ac^{-1} greater than urea at the 150 lbs. N ac^{-1}

rate. In fact, the high rate of urea applied in the spring had the lowest root yield of any treatment by nearly 2 ton ac^{-1}.

Table 2. 2014 Sugar beet root yields for N rate, N source, and N application time combinations in the Northern Experimental Site

N rate	N Source	Fall Applied	Spring Applied
lbs. N ac^{-1}		-------- tons ac^{-1} -------	
	Urea	19.7	19.8
120	50:50 Mixture	18.9	20.2
	PCU	20.1	17.2
	Urea	20.4	15.4
150	50:50 Mixture	20.4	21.0
	PCU	20.3	21.2

High rates of spring applied urea have been shown to cause phytotoxicity in many cases. Early season stand counts of emerged sugar beet indicate plants were reduced 7 and 12% when 120 lbs. and 150 lbs. N ac^{-1}, respectively, were applied in the spring as urea instead of PCU. The yield data suggest the sugar beet plants compensated for the 7% stand reduction, but not the 12% under what was apparently harsh growing conditions.

The data suggest that spring applied PCU alone did not supply sufficient N for the crop at the low N rate, but at the higher N rate there was sufficient N (Table 2). PCU is designed to slow the release of N into the soil solution system. Assuming this did in fact occur with the PCU fertilizer, N that was released was insufficient when the total N applied was 120 lbs. N ac^{-1}. It is assumed the same relative rate of N is released regardless of N rate so that at 150 lbs. N ac^{-1} sufficient N was released from all PCU to achieve root yields similar that of urea at the 120 lbs. N ac^{-1} rate. Applying PCU in the fall apparently provided sufficient time for sufficient N to be released to meet crop needs. The lack of a 3-way interaction involving the mixture of N sources suggests that yield obtained when N sources are mixed were similar to yields averaged over urea and PCU alone treatments. Data in Table 2 suggest any detrimental effects of spring applied PCU at the lower N rates or urea at the higher N rate were neutralized by using the 50:50 mixture of the two N sources.

Contrasts suggest significant interactions between time of fertilizer application and N sources and between N sources (urea and PCU) and N rates. However, after evaluating differences among the treatments data values vary less than 4% (compared to the highest value). It is more useful to evaluate the actual sugar concentrations and LTM, which are used to calculate the root quality.

Sugar varied somewhat among the N sources and the time of their application. Urea tended to have slightly higher sugar concentration than PCU regardless when it was applied. But when the two sources are mixed compared to the either source alone, sugar concentration was somewhat greater when fall applied and lower when spring applied. At this point, this does not make sense suggesting the results may be artifacts of the data.

There were indications there may be some variation in sugar concentration between N sources (urea and PCU) depending on N rates. In this case, increasing the N rate from 120 to 150 lbs. N ac^{-1} increased sugar concentration when PCU was used and lowered sugar concentration when urea was used.. Again the differences were small.

The LTM was only differentially affected by N rates (Table 1). LTM increased from 1.35% when 120 lbs. N ac^{-1} to 1.40% when 150 lbs. N ac^{-1} was applied.

In the second experiment, the mixed N source treatment was removed from the analysis and those treatments that included a portion of the total N applied during the growing season as a sidedress were included. This added considerable complication to the statistical analysis (compare Table 3 to Table 1).

Table 3. Statistical analysis testing main treatment factor effects that include sidedressing a portion of the total N during the growing season. on the 2014 sugar beet harvest data from the Northern Experimental Site.

	Root Yield	Root Quality	Sucrose Yield	Sugar Conc.	LTM Conc.
Source of variation	--------- PR>F --------				
Fall vs Spring (Time)	0.54	0.08	0.85	0.07	0.61
Urea vs PCU (Source)	0.51	0.22	0.71	0.17	0.94
120 vs 150 lbs. N ac^{-1} (Nrate)	0.48	0.70	0.55	0.98	0.02
Yes vs No (Sidedress)	0.02	0.08	0.08	0.06	0.51
Time by Source	0.50	0.86	0.47	0.89	0.08
Time by Nrate	0.96	0.12	0.64	0.10	0.59
Time by Sidedress	0.06	0.77	0.07	0.84	0.47
Source by Nrate	0.18	0.01	0.05	0.01	0.21
Source by Sidedress	0.53	0.44	0.67	0.48	0.36
Nrate by Sidedress	0.63	0.93	0.62	0.93	0.96
Time by Source by Nrate	0.15	0.38	0.24	0.33	0.90
Time by Source by Sidedress	0.69	0.37	0.81	0.42	0.28
Time by Nrate by Sidedress	0.63	0.36	0.86	0.36	0.55
Source by Nrate by Sidedress	0.12	1.00	0.13	0.80.	0.19
Time by Source by Nrate by Sidedress	0.07	0.90	0.08	0.89	0.14

Sidedressing some N during the season to augment N applied preplant instead of all N applied preplant at first glance appears to affect root yields (Table 3). The data would suggest sidedressing N increased root yield from 19.3 tons ac^{-1} to 20.8 tons ac^{-1} when averaged over all other experimental factors. Though not significant at the 0.05 level, there appears to be a possible interaction among all four experimental factors. When N was applied in the fall, sidedressing some of the total N had no differential effect on the root yield regardless of the N source or the N rate. Averaged over all other factors, fall N resulted in a 20.3 ton ac^{-1} root yield. However when N was spring applied, sidedressing a portion of the total N increased root yields. When PCU was spring applied at the low total N rate, sidedressing some of that N increased root yields from 17.2 to 21.0 tons ac^{-1}. When the high rate of urea was spring applied, applying some of the N as sidedress increased root yields from 15.4 to 21.9 tons ac^{-1}.

As previous discussed, N release form PCU is supposed to be delayed due to the polycoating of the urea. Also previously discussed, the lower rate of PCU applied in the spring must not release sufficient N to meet the sugar beet crop demand. Reducing some the preplant PCU-N and applying the remainder of the N as in-season sidedress N with a readily available N source (UAN) must sufficiently augment the N needs of the crop. When urea was spring applied, sidedressing a portion of the total N also increased root yields. As previously discussed, high rates of spring applied urea can reduce crop emergence, the severity of which will determine if yield compensation is sufficient. Lowering the rate of spring applied urea and applying the remainder N as sidedress compared to all the N as spring applied probably may have even less negative impact on sugar beet stand emergence and potential phytotoxicity than the higher rates of spring applied urea. The data suggest that where preplant N is sufficient, higher rates of fall applied N regardless of source or higher rates of PCU, sidedressing a portion of the total N has little to no effect on root yield.

Again evaluating the root quality as a function of the sugar and LTM concentrations it is more informative to evaluate sugar and LTM concentrations for treatment factor effects. There was a highly significant effect of N source and rate interaction on sugar concentration (Table 3). Comparing the two N rates (120 vs 150 lbs. N ac^{-1}), sugar concentration increased at the higher N rate where PCU was used (15.7 to 16.0%) and decreased at the higher rate when urea was used (16.2 to 15.8%). There was no effect of time of fertilizer application or whether a portion of the total N was sidedressed or all N was applied pre-plant. Increasing the N rates increased the LTM concentration from 1.36% to 1.41% with no further effects of time fertilizer was applied, N source, or whether a portion of the total N was sidedressed or all it applied pre-plant.

Much data in studies conducted over many years indicate excess available N later in the growing season of sugar beet production reduces sugar concentration and higher rates of applied N tend to increase LTM concentration. The differences observed in this study of sugar concentration further suggests that spring applied PCU-N is less available than urea at these relatively high N rates and have less reducing effects on sugar concentrations than urea. Furthermore, the data in this trial indicate that if sufficient available N is applied preplant to a sugar beet crop, sidedressing N will likely have little to no effect on root yield. However, the data also suggest that if it is suspected that insufficient N is available for the crop either because too little was pre-plant applied or pre-plant applied N was lost to denitrification or leaching, sidedressing N can be effective at compensating for that N loss. Whether sidedressing will actually increase the root yield greatly depends if the suspicions of N loss are actually true or not.

Southern Site:2014 as Written by John Lamb

The southern site was established November 14, 2013 near Renville, Minnesota. The fall broadcast N treatments were applied and incorporated at that time. The site for 2014 had a fall soil nitrate-N test to a depth of four feet of 90 lb/acre and spring soil nitrate-N test to a depth of four feet of 100 lb N/A. The spring broadcast treatments were applied and incorporated shortly before planting on May 29, 2014. The sugar beet variety RR850 was used in this study. The sidedress treatments were applied on July 21, 2014. The plots were harvested October 15, 2014.

At this location, there was an increase in root yield to the application of N fertilizer. Extractable sucrose per ton (EST) was reduced 15 lb/ton with the addition of nitrogen fertilizer while nitrogen application had no effect on extractable sucrose per acre (ESA). Because of the lack of response to N application, the effect of N application methods on ESA could not be evaluated. Among the different nitrogen application timing treatments, only the source by N rate was significant. When urea or urea PCU mix was used as fertilizer N sources, root yield increased when the N rate increased from 60 lb N/A to 90 lb N/A. When PCU was the N source the root yield decreased when the N rate was increased from 60 to 90 lb N/A. When PCU was applied in the Spring pre plant and the rest of the N was applied as a side dress treatment, root yield was reduced with increasing the N rate from 60 to 90 lb N/A. With the other combination of preplant applications and source, Fall PCU, Fall urea, and Spring Urea, root yield was increased as the N application rate increased from 60 to 90 lb N/A. The use of a split N application, preplant and sidedress did not perform differently than a one-time preplant application.

Extractable sucrose per ton of refined sugar beet root (EST) was affected by the source of N and the rate of N application. Extractable sucrose per ton was the greatest when Urea was the N source followed by the PCU/Urea mix and the least EST was when PCU alone was used as the N source. The time of preplant application (Fall or Spring) did influence EST. The EST was also reduced with the increase in N rate. The use of a side dress application did not affect the EST.

Table 4. Statistical analysis of the effect of N application at the Southern site in 2014.

Statistical term	Root yield	Extractable sucrose per ton	Extractable sucrose per acre
	PR > F		
Treatment	0.15	0.0004	0.44
Check vs. rest	0.09	0.07	0.73
C.V. (%)	8.6	6.1	8.7
Means	ton/A	lb/ton	lb/A
Check	28.8	271	7768
Rest	31.2	256	7894

Table 5. Statisical analysis of the effect of source and time of pre-plant N application at the Southern site in 2014.

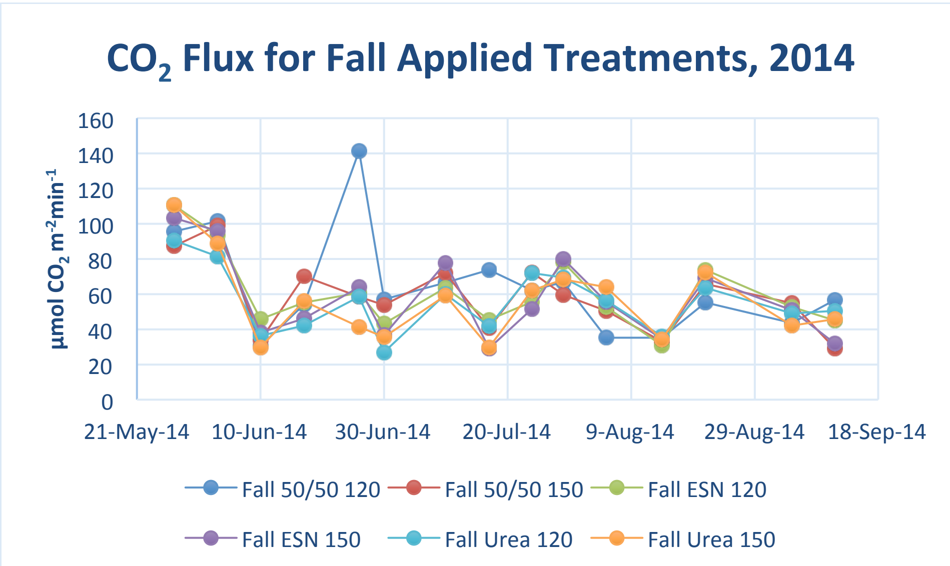
Statistical term	Root yield	Extractable sucrose per ton	Extractable sucrose per acre
Source	0.26	0.02	0.99
Time	0.94	0.36	0.69
Rate	0.70	0.007	0.37
Source X Time	0.47	0.97	0.27
Source X rate	0.07	0.22	0.58
Time X rate	0.48	0.80	0.52
S X T X R	0.58	0.33	0.85
C.V. (%)	8.5	5.8	8.8
Means			
Source	Root yield	Extractable sucrose per ton	Extractable sucrose per acre
	ton/A	lb/ton	lb/A
PCU	31.8	268	8327
PCU	29.6	263	7782
PCU/U	31.1	259	8049
PCU/U	32.1	248	7989
Urea	28.7	285	8083
Urea	31.2	259	7967

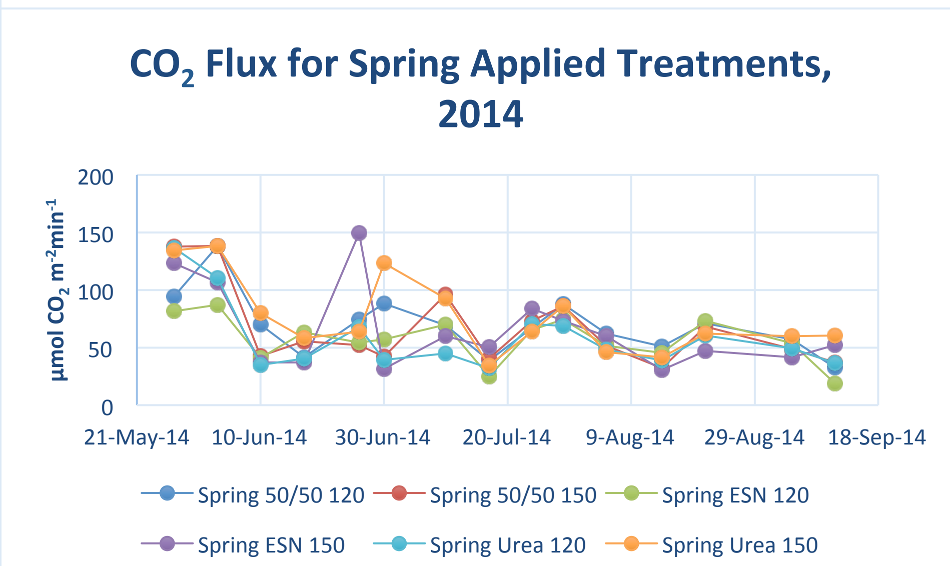
Table 6. Statisical analysis of the effect of source and time of pre-plant N and side dress N application at the Southern site in 2014.

Statistical term	Root yield	Extractable sucrose per ton	Extractable sucrose per acre
Source	0.40	0.04	0.49
Time	0.19	0.16	0.03
SD rate	0.98	0.67	0.86
Source X time	0.86	0.37	0.95
Source X SD rate	0.23	0.45	0.20
Time X SD rate	0.03	0.21	0.51
S X T X SD	0.10	0.65	0.14
C.V. (%)	8.0	6.0	8.6
Means	Root yield	Extractable sucrose per ton	Extractable sucrose per acre
Source	ton/A	lb/ton	lb/A
PCU	31.9	239	7551
Urea	31.4	250	7801
Time			
Fall	32.3	249	7995
Spring	31.1	240	7370
Source			
PCU	31.4	249	7782
PCU	33.9	241	8007
PCU	33.9	227	7697
PCU	28.8	238	6835
Urea	31.5	257	8173
Urea	32.7	247	8067
Urea	30.5	248	7240
Urea	30.9	248	7678

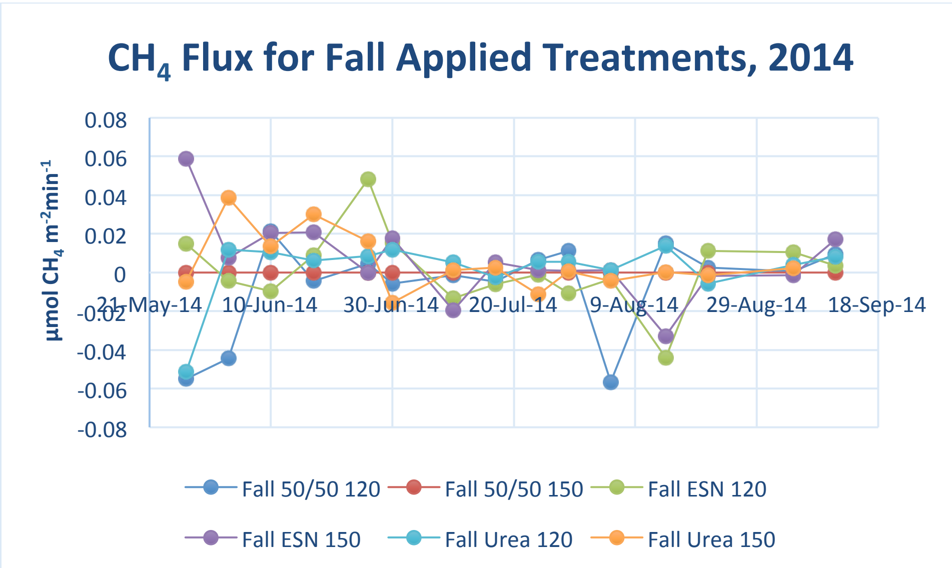
Gas Emission Results from Northern Site as Written by Katy (Smith) Nannenga:

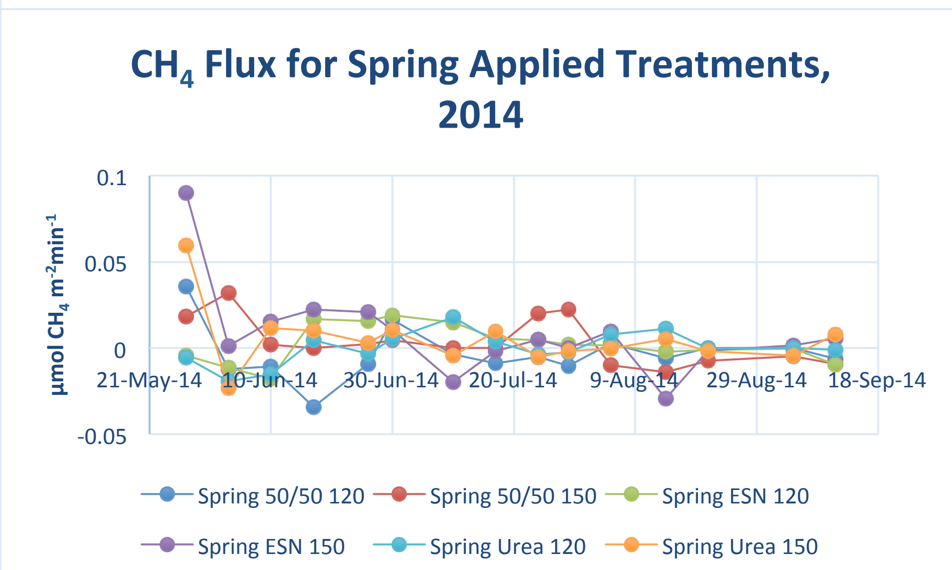
All three greenhouse gases showed a general trend of higher emissions in spring applied vs. fall applied treatments. Some of the largest differences between treatments occurred on the first sampling date. On the first sampling date CO_2 emissions were significantly higher in the spring applied treatments that had pure urea, and the 50/50 mix with a higher application rate had significantly higher emissions than all other spring applied treatments. For the fall applied treatments on this date no significant CO_2 flux differences were observed between treatments. In the spring applied treatments two significant CO_2 fluxes were observe in late June; one with the ESN 150 treatment and one with the Urea 150 treatment indicating the higher application rates were still fluxing at higher rates into June. For the fall applied treatments, no major differences in fluxes were observed except for one date in late June showing a significant flux for the 50/50 120 treatment.





Significant differences in methane flux were also observed on the first sampling date for both fall and spring applied treatments. As with the CO_2 flux, CH_4 fluxes also tended to be higher in the spring applied treatments. In the fall applied treatments on the first sampling date, treatments with ESN had significantly higher CH_4 emissions than treatments with either pure urea or the mix of urea and ESN at the higher application rate, and these treatments had significantly higher emissions than the mix and the pure urea at the lower rates with these treatments actually showing a negative CH_4 flux. Later in the season, two other treatments showed a negative CH_4 flux; the low Urea rate and the two ESN treatments. In the spring applied treatments, on the first sampling dates, the treatments with higher rates tended to have higher emissions with no treatments showing a negative CH4 flux. Otherwise, there were no major differences in treatments throughout the growing season.





As with CO2 and CH4; most of the significant differences in N2O flux were observed in the first few sampling dates. As with the other two gases; spring applied treatments also tended to flux at higher rates than fall applied treatments. For the fall applied treatments, on the first sampling date, the fall ESN treatment at the higher rate had the highest N2O emissions followed by the low rate of Urea. All other treatments showed a negative flux on that date. Otherwise only two other significant fluxes occured during the growing season. On both of those dates, the 50/50 mixture at the higher application rate had the highest flux and on one of those dates, the high rate of ESN fluxes just slightly less than the 50/50 mix at the high rate. Otherwise there were no major fluxes of N2O for the fall applied treatments throughout the remained of the growing season. For the spring applied treatments, the first two sampling dates showed significant fluxes and significant differences between treatments. On both of these days, both rates of urea and the high rate of the 50/50 mix showed significantly higher emissions than all other treatments. These results indicate that the higher rates of nitrogen applications are prone to higher emissions of N2O fluxes regardless of time of year for the application. These results also show higher fluxes of spring applied treatments during the growing season. This does not mean that fall applied treatments are losing less nitrogen, they likely lost a lot of the nitrogen applied prior to the sampling period.