NITROGEN MANAGEMENT IN SUGAR BEET GROWN IN FINER TEXTURED SOILS OF THE RRV

Albert L. Sims (Associate Professor), University of Minnesota Northwest Research and Outreach Center

Nitrogen (N) is an essential nutrient for all plant life and is the most managed nutrient in crop production. Careful management of N in sugar beet production is especially critical. A typical sugar beet crop will accumulate from 180 to 220 lbs. N A^{-1} under non-N limiting conditions (Armstrong and Milford, 1985; Pocock et al., 1990; Duval, 2001). Nitrogen accumulation above this range can severely reduce sugar beet root quality (Armstrong and Milford, 1985; Pocock et al., 1990). However, N accumulation within this range is required for optimum sugar beet production. Root yield is determined by the biomass produced in actively functioning leaves and transported to and accumulated in the root. Nitrogen does not increase the conversion efficiency of intercepted light to biomass, but it does increase the size of the leaf canopy that intercepts more light (Armstrong et al., 1983). Light interception and dry matter production increases as the leaf canopy increases up a leaf area index of 3-4.

The sugar beet crop obtains its N from three major sources in the soil; residual inorganic N, N mineralized from the organic material, and applied fertilizer N. Researchers have used labeled non-radioactive N^{15} as a fertilizer source to trace of the fate of the fertilizer N. Sugar beet can acquire N down to a soil depth of at least 4 ft (Broeshart, 1983), but applied fertilizer N may contribute only 40% of the total N accumulated in the beet plant (Lindemann et al., 1983). Frequently the fertilizer uptake efficiency is 50% or slightly higher (Haunold, 1983; Lindemann et al., 1983). The inability of the sugar beet plant to acquire more than 50% of the applied fertilizer is consistent with what has been reported for other crops and reflects the complex dynamics of N in the soil environment. These findings also emphasize the contribution needed from the residual soil N and mineralized N to the sugar beet crop for optimum production. Residual soil N is estimated using soil testing to measure the amount of nitrate-N to either the 2-ft or 4- ft soil depth. The amount of residual soil N is a product of the overall N management strategy used in the entire cropping season as well as environmental factors affecting crop production. Mineralized N reflects several soil characteristics that include temperature, moisture, organic matter content and type, aeration, and microbial population, to name a few (Jansson and Persson, 1982; Myrold and Bottomley, 2008). This might suggest soil classification could be used to estimate fertilizer N requirements for sugar beet production, but after several investigations, the overwhelming conclusion was that soil classification based on soil texture and soil survey series was ineffective as a predictor of fertilizer N needs (Webster et al., 1977). Rather, estimates of residual soil N and the amount of N mineralized during the growing season were better predictors of fertilizer N needs. Soil N mineralization is almost impossible to predict ahead of time because of all the variables influencing mineralization.

Recently, the American Crystal grower data base from two production years were subjected to geostatistical analysis based on total N used (residual soil N plus fertilizer N) in sugar beet production (Sims, 2009). There was a clear geospatial relationship with total N used by the sugar beet producers. There were several areas where total N use was higher than current N recommendations (Lamb et al, 2001), but the largest single area started in northwest Polk County and ran along western Marshall and Kittson Counties in Minnesota. Though not subjected to geospatial analysis, this same area tends to have soils with heavier or finer textures than areas showing lower total N use. This same area also tends to have some of the lower sugar beet root yields, but higher sugar beet root quality than other American Crystal growing areas (Personal communications with Tyler Grove, American Crystal Fieldman). Why does this area seem to require greater total N use without the typical corresponding increase in root yield and reduction in root quality? Sims (2010) found that sugar beet root yields tended to increase only slightly, but continuously, over a range of 0 to 240 lbs. applied N A^{-1}. At the same time, sugar beet root quality increased up to about 90 lbs. applied N A^{-1} then leveled off at higher N rates (did not decline). Nitrate in the most recently mature leaf petiole collected in mid-July was low regardless of the fertilizer N rate (Sims, 2010) suggesting either the N was not available or the sugar beet plant was not able to gain access to it. The lack of N in the plant would also explain why root yields did not increase dramatically and quality did not decline. Visual observations suggests the dark soil layer, signifying organic matter, in these soils is not very deep. Combined with higher amounts of fine textured clay in these soils, is it possible that N mineralization is less in these soils? If that is the case, then higher rates of total N or fertilizer N would be required to meet sugar beet N demands. While this may explain why growers in the area use more N, it does not explain why the higher rates of applied N are either unavailable to the sugar beet plant or the sugar beet plant unable to gain access to it. In 2010, a follow up trial examined the possibility of increasing N available to the plant by sidedressing in a band near the plant row (Sims, unpublished data). Petiole samples taken about one week after the sidedress application revealed that plants sidedressed with 60 lbs. N A^{-1} (90 lbs. N applied preplant for a total of 150 lbs. N A^{-1}) had nitrate levels as higher or higher than that of 210 lbs. of fall applied N. This suggested the sidedress band of N near the seed row was accessed relatively quickly by the sugar beet plant. Ultimately, this sidedress treatment resulted in root yields similar to those of the high rate of fall applied N with no detrimental effects on root quality. These results suggest that a more intense N management strategy may improve fertilizer N utilization efficiency in sugar beets grown in these areas where higher N use is typical.

OBJECTIVES

1. Determine if fertilizer N placement and timing can improve fertilizer N availability and utilization in sugar beet production on finer textured soils in the RRV.

MATERIALS AND METHODS

Two trials were established in the fall of 2012. One trial was established 10 miles north and 1 miles west of Oslo, Minnesota, referred to as the North site, in a grower-cooperator field where excess N is required for optimum sugar beet production. A second trial was established on NWROC property, referred to as the NWROC site, near Crookston, Minnesota. Both trials contained the same treatments. The North site trial was on a Fargo sicl soil (fine, smectitic, frigid typic Epiaquert) and the NWROC site trial was on a Bearden-Colvin Complex (Bearden:fine-silty, mixed, superactive, frigid, Aeric Calciaquoll; Colvin: fine-silty, mixed, superactive, frigid, typic calciaquoll). The experimental design in both trials is a split-plot randomized complete block with four replications. Whole plot treatments were N rates. Nitrogen rates were 90, 120, 150, and 180 lbs. N A^{-1} plus soil residual N. Both experiments included two 0 N controls in each replication. Split-plot treatments consisted of fertilizer placement and timing:

1. Broadcast (Bdcst): Fall broadcast 100% of N fertilizer and incorporated.
2. Band: Fall band 100% of N fertilizer near where seed row will be placed in the spring.
3. Mixed: Combination Fall application with 50% N fertilizer broadcast and 50% N fertilizer banded.
4. Bdcst-Sidedress: Fall broadcast plus in-season sidedress of either 30 or 60 lbs. N Ac^{-1} depending on N rate.
5. Band-Sidedress: Fall Band plus in-season sidedress of either 30 or 60 lbs. N Ac^{-1} depending on N rate.

The broadcast fertilizer source was urea and the banded fertilizer source was liquid aqua ammonia. The sidedress nitrogen source was UAN (28% N). Sidedress N was applied in the center of the inter-row space when the sugar beets were in the 10 to 12 leaf growth stage.

All fall treatments were applied Nov 2, 2012 at the North site and Nov 9, 2012 at the NWROC site. Prior to any nitrogen being applied 60 lbs. P_2O_5 Ac^{-1} of 0-46-0 was broadcast applied. After the broadcast N was hand applied to the appropriate plots the entire plot area was tilled with a field cultivator that incorporated broadcast fertilizer and worked the soil prior to the application of the banded N. The banded N treatments were applied right after the tillage operations and no further tillage took place thereafter. Wheel tracks in the banded treatments were flagged at the time the fertilizer was applied to identify the placement of the tractor tires when the plots were planted this spring. At planting, every attempt was made to plant the seed row as close as possible to the fertilizer band. Sugar beet was planted on May 6 and 8 at the North and NWROC sites, respectively. Crystal 885RR was seeded at about 240 seed per 100 ft of row.

Due to the late fall preparation and the inclement weather that immediately followed, soil samples of the unpreped alley ways were not taken. They were taken in the spring immediately after the plots were planted. These soils samples were analyzed for residual soil nitrate-N. Every attempt was made to sample to a 4 ft soil depth, but the soil conditions at the lower depths made any sampling below 3+ ft difficult. Soil sample analysis was conducted in the NWROC soils analytical laboratory using KCl extraction procedures.

During the growing season weeds were controlled with Glyphosate, Rhizoctonia root rot was controlled with Quadris and seed treated Tachagaren and leaf diseases were controlled with other fungicides.
Twice during the latter half of the growing season, once in mid-July and again in mid-August, petiole samples were collected for nitrate analysis. Twelve most recently matured petioles from rows 3 and 4 of each 6-row plot were collected, placed in coolers for transport back to the NWROC soils laboratory and frozen. At a later date these petioles were heat dried and ground to a powder and nitrate was extracted using a KCl extraction procedure.

Final harvest occurred in the third week of September at the North site and the following week at the NWROC site. The middle four rows of the 6-row plot were detopped and the middle two rows harvested using a mechanical lifter. All the lifted beets were weighed and 10 random, but representative beets were sent to the American Crystal Sugar Company Quality Laboratory in East Grand Forks, Minnesota for tare, impurity, and sugar analysis.

For statistical analysis, the trials were divided into two experiments, one testing N rates and methods of application that included Broadcast, Band, and Mixed and the second testing N rates with Broadcast and Band pre-plant applications with or without in-season sidedress N applications. Analysis was conducted on each site separately. Tables 1 and 2 include significance to the 0.05 level.

RESULTS

General growing conditions were different between the two experimental sites. The North site experienced heavy rainfall soon after planting that resulted in flooding and standing water on some areas of the trial. It was easily apparent where the lower areas of the experimental area were located. During much of late May and early June this trial looked very tough and there was a question of whether the trial would have anything to harvest. This was a similar experience as occurred in 2010. In 2010, the experimental site west of Stephen, Minnesota looked extremely tough in mid-June and I questioned if it would be harvestable. One month later the beets in the trial had recovered and it turned into a good trial. I hoped this would happen again in 2013. And, it did! By mid-July the trial and the surrounding commercial sugar beet field looked like a very nice field of sugar beets. At the NWROC site, the beets looked quite good early in the growing season, but persistent drought conditions created difficult growing conditions throughout much of the latter half of the growing season. Interestingly, the NWROC site was starting to experience an increasing problem with Rhyzoctonia root rot by harvest while sugar beets harvested at the North site were quite clean.

Petiole Nitrate:

Nitrate-N can be stored in the sugar beet petiole and is an indication of the nitrogen availability to the sugar beet plant or reflects the ability of the plant to acquire soil N. Nitrate concentrations of 750 to 1000 ppm in the petiole of the most recently fully expanded leaf are considered sufficient. The ideal time for petiole sampling is thought to be between the hours of 10:00 a.m. and 2:00 p.m. After that time, the plant begins to reduce the nitrate stored in the petiole and incorporates it into amino-sugars and amino-acids for the production of proteins and enzymes. In this study, all samples were collected between the hours of 8:30 a.m. and 10:30 a.m.. I was more interested in measuring petiole nitrates near where I thought the peak accumulation might be and I wanted to make sure all samples were collected within a short amount of time so that direct comparisons among treatments would be valid. A difficulty in petiole sampling is determining the most recently fully expanded leaf blade. Usually it can be narrowed to two or three possibilities. Without destroying all the possible candidates and making a direct comparison of leaf size, a certain amount of subjectivity is necessary. I instructed my crews to narrow the possible candidates to a maximum of three and select the middle one. It is presumed that this systematic approach to the leaf-petiole selection process collected within a very short period of time for each sampling event will provide the best opportunity for comparisons across trials, treatments, and sampling times.

There was a substantial difference in petiole nitrates between the two experimental sites and between the two sampling times. NWROC had greater petiole nitrates than those from the North site. Petiole nitrates were also substantially greater in July than later in the August sampling. Statistical analysis was done by individual site and sampling time. Nevertheless, there were some consistent responses to treatments at both experimental sites and sampling dates.

Petiole nitrates were less when fertilizer N was banded compared to where it was broadcast. (Table 1 and 2). The contrast comparing fertilizer that was banded or broadcasted to where both methods were used (Mixed fertilizer application) was non-significant at both sites. This contrast combines the results of band and broadcast applications and compares it to the Mixed application. No difference indicates that the disadvantage of the band application also expressed itself in the band portion of the mixed application treatment.

Petiole nitrates responded to the N fertilizer rates used in this trial, it was a linear response meaning petiole nitrates increased consistently with each incremental increase in fertilizer N. However, the linear response was quite different depending on the method used to apply the fertilizer (N rate by Method interaction) (Table 1 and 2). Petiole nitrates increased more with each increment of broadcast N compared to the same increment of banded N (Fig 1). This occurred at both experimental sites and both sampling dates. The exception was the August sampling at the North site (Fig 1b). Petiole nitrates increased slightly from 90 to 150 lbs. N Ac^{-1} broadcast then increased rapidly between 150 and 180 lbs. N Ac^{-1}.

The data strongly suggest that broadcast N is much more available to the sugar beet plant than banded N. My first thought was that our banded N application was less than we thought it should be. We checked our calibrations of material delivery and we evaluated the total quantity of aqua ammonia that was used. Both checked out to be close to what we estimated it should be. Had our calibration or application rates of banded N been less than we thought, higher rates of banded N should be similar to some lower rates of broadcast N. Petiole nitrates with the highest rates of banded N were roughly similar the lowest rate of broadcast N suggesting the banded rates were half as effective as the broadcast N. Considering our calibration data and the total quantity of aqua ammonia used in these trials, I can say with certainty that were not in error that much. Banded N was simply not as available to the crop as the broadcast N.

Sidedressing N at the 10-12 leaf stage increased the July petiole nitrate levels. When preplant N was broadcast, sidedressing N increased petiole nitrates slightly, perhaps less than 10%. But, when pre-plant N was banded, sidedressing increased petiole nitrates in average of 800% at the North site and 400% at NWROC. This suggests plants in the banded N plots maintained their ability to acquire N, but were apparently unable to acquire the N placed in a band in the prior fall that was very near the seed row .

Quality Parameters:

Sugar beet quality, reported here as lbs. sucrose ton^{-1}, is determined by both sugar concentration and sugar loss to molasses (LTM). At both experimental sites, broadcast N increased sugar and LTM, but the difference was not always significant (Table 1 and 2). Sidedressing additional N at the 10-12 lead stage and increasing applied N rates had no effect on sugar, LTM or the subsequent root quality. This was surprising since excess N is late applied N has been shown to decrease root quality through one or both the sugar or LTM parameters.

Yield:

Sucrose yield response to treatments was similar that of the root yield response indicating that root yield response was the dominate variable in determining the sucrose yield. At the North site, root yield response to applied N was small, 26.5 ton Ac^{-1} for the 0 N control compared to 28.3 ton Ac^{-1} averaged over all applied N rates. Residual soil nitrate-N at this site was greater than expected with an experimental site average of 57 lbs. N Ac^{-1}. Combined with what might have been mineralization of soil N during the growing season the crop apparently had sufficient available N to optimize yields. Incremental increases in applied N rates had little effect on root yields. However, the method by which fertilizer was applied did impact the root yield (Table 1 and 2). Broadcast N resulted in about 1.5 ton Ac^{-1} more beets than banded N, 29.0 vs 27.5 tons Ac^{-1}, respectively. Sidedressing N during the growing season had not effect on root yield regardless of the preplant N application method.

At NWROC, N rates, methods of preplant N application and sidedress N all had a significant impact on root yield (Table 1 and 2). Root yields increased with each increment of applied N when banded. Root yield of the control treatment, 0 applied N, was 20.7 ton Ac^{-1}. When N was applied, root yields increased as N rates increased, but this increase varied depending on the method of fertilizer application (Table 1 and 2, Fig 2). Where N was applied, root yield increased about 6 ton Ac^{-1} over the entire range of applied N when that N was banded prior the fall before planting. Interestingly, the low rates of banded N did not yield any differently than the control. When applied N was broadcast, there was about a 4 ton Ac^{-1} yield increase over the range of applied N rates, but all the yields were greater than those of banded N. When applied N was mixed, that is half applied broadcast and half banded, the root yields at the lower N rates were greater than either of the applications methods. However there was little increase in root yield as N rates increased. Residual soil nitrate-N in the top 4 ft of the soil profile at NWROC was 50 lbs. N Ac^{-1} averaged over the entire experimental area.

Sidedressing N during the growing season did increase root yield at NWROC, but only when pre-plant N was banded. Sidedressing increased root yields from 22.9 ton Ac^{-1}, all N banded preplant, to 25.4 ton Ac^{-1} when averaged over all banded N rates. When pre-plant N was broadcast, root yields averaged 27.1 ton Ac^{-1} whether some of the N was sidedressed during the growing season or not.

SUMMARY

Banding N seemed to be detrimental to sugar beet production compared to broadcast applications. This occurred whether there was a yield response to N or not. Petiole nitrates suggest that banded N is not as readily available to the crop as broadcast N, at least when banded the previous fall near where the seed row will be. Banding N during the growing season away from the seed row, as is done in the sidedress treatments, increased N availability, but mainly where pre-plant N had been banded. This effect was manifested in root yield as well at NWROC, but not at the North site. When sufficient N was broadcast applied pre-plant, sidedress had no effect on N availability or root yield.

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Table 1. Statistical analysis comparing nitrogen rates and method of pre-plant application for several measured variables at the North site (a) and NWROC site (b).

a). North site

	Variable§						
	Rtyld	RtQual	RecSuc	Sugar	LTM	JulPetN	AugPetN
Source§§	------------ PR>F§§§ ------------						
N rate	ns	ns	ns	ns	ns	ns	**
Lin	ns	ns	ns	ns	ns	*	***
Quad	ns	ns	ns	ns	ns		
Method	ns	ns	*	ns	ns	***	**
Bdcst vs Band	*	ns	**	ns	ns	***	**
One vs Mixed	ns	ns	ns	ns	ns	ns	ns
N rate X Method	ns	ns	ns	ns	ns	ns	**
Lin by Bdcst vs Band	ns	ns	ns	ns	ns	**	***
Quad by Bdcst vs Band	ns	ns	ns	ns	ns	ns	*
Lin by One vs Mixed	ns	ns	ns	ns	ns	ns	ns
Quad by One vs Mixed	ns	ns	ns	ns	ns	ns	ns

b). NWROC site

	Variable§						
	Rtyld	RtQual	RecSuc	Sugar	LTM	JulPetN	AugPetN
Source§§	------------ PR>F§§§ ------------						
N rate	**	ns	*	ns	**	*	*
Lin	**	ns	**	ns	**	**	**
Quad	ns	ns	ns	ns	ns	ns	ns
Method	***	ns	***	ns	*	***	***
Bdcst vs Band	***	ns	***	ns	*	***	***
One vs Mixed	ns	ns	*	ns	ns	ns	ns
N rate X Method	ns	ns	*	ns	ns	ns	ns
Lin by Bdcst vs Band	ns	ns	*	ns	*	*	**
Quad by Bdcst vs Band	ns	ns	ns	ns	ns	ns	ns
Lin by One vs Mixed	*	ns	*	ns	ns	ns	ns
Quad by One vs Mixed	ns	ns	ns	ns	ns	ns	ns

§ Rtyld, RtQual, RecSuc, Sugar, LTM, JulPetN, and AugPetN represent root yield (ton Ac^{-1}) , root quality (lbs. sucrose ton^{-1}), recoverable sucrose (%), Sugar (%), Loss-to-molasses (%), July Petiole NO_3 (ppm), and August Petiole NO_3 (ppm), respectivefully.

§§ Lin=linear regression; Quad=quadratic regression; Bdcst=broadcast; Mixed=50% broadcast and 50% banded; One=broadcast and band applications tested together against both applications mixed.

§§§ ***,**,*, and ns represent significance at the 0.001, 0.01, 0.05 levels, and non-significant, respectfully.

Table 2. Statistical analysis comparing nitrogen rates and method of pre-plant application with and without sidedress nitrogen application for several measured variables at the North site (a) and NWROC site (b).

a). North site

	Variable[§]						
	Rtyld	RtQual	RecSuc	Sugar	LTM	JulPetN	AugPetN
Source[§§]	------------ PR>F[§§§] ------------						
N rate	ns	ns	ns	ns	ns	*	*
Lin	ns	ns	ns	ns	ns	**	***
Quad	ns	ns	ns	ns	ns	ns	*
Method	**	*	***	**	ns	***	***
N rate X Method	ns	ns	ns	ns	ns	**	***
Lin by Method	ns	ns	ns	ns	ns	***	***
Quad by Method	ns	ns	ns	ns	ns	ns	**
Sidedress	ns	ns	ns	ns	ns	*	ns
N rate X Sidedress	ns	ns	ns	ns	ns	ns	ns
Lin by Sidedress	ns	ns	ns	ns	ns	ns	*
Quad by Sidedress	ns	ns	ns	ns	ns	ns	ns
Method X Sidedress	ns	ns	ns	ns	ns	ns	ns
N rate X Method X Sidedress	ns	ns	ns	ns	ns	ns	ns
Lin by Method by Sidedress	ns	ns	ns	ns	ns	ns	**

a). NWROC site

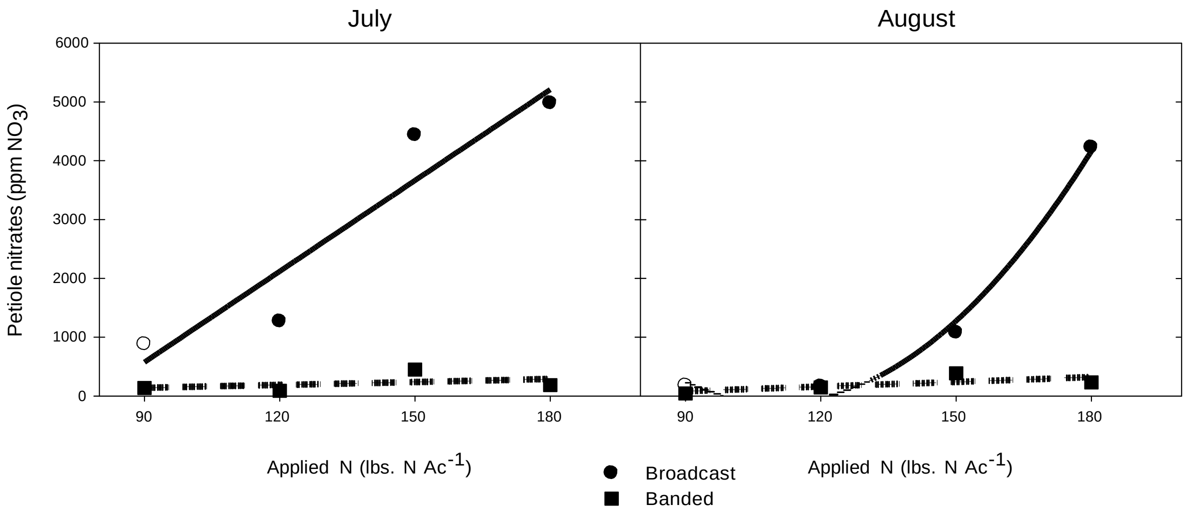
	Variable[§]						
	Rtyld	RtQual	RecSuc	Sugar	LTM	JulPetN	AugPetN
Source[§§]	------------ PR>F[§§§] ------------						
N rate	**	ns	*	ns	*	*	ns
Lin	***	ns	**	ns	**	**	*
Quad	ns	ns	ns	ns	ns	ns	ns
Method	***	ns	***	ns	***	***	***
N rate X Method	ns	ns	ns	ns	ns	*	*
Lin by Method	ns	ns	ns	ns	ns	*	***
Quad by Method	ns	ns	ns	ns	ns	ns	ns
Sidedress	**	ns	ns	ns	ns	***	ns
N rate X Sidedress	*	ns	*	ns	*	ns	ns
Lin by Sidedress	*	ns	*	ns	*	ns	ns
Quad by Sidedress	ns	ns	*	ns	ns	ns	ns
Method X Sidedress	**	ns	*	ns	ns	*	ns
N rate X Method X Sidedress	ns	ns	ns	ns	ns	ns	ns

§ Rtyld, RtQual, RecSuc, Sugar, LTM, JulPetN, and AugPetN represent root yield (ton Ac^{-1}) , root quality (lbs. sucrose ton^{-1}), recoverable sucrose (%), Sugar (%), Loss-to-molasses (%), July Petiole NO_3 (ppm), and August Petiole NO_3 (ppm), respectivefully.

§§ Lin=linear regression; Quad=quadratic regression; Bdcst=broadcast; Mixed=50% broadcast and 50% banded; One=broadcast and band applications tested together against both applications mixed.

§§§ ***,**,*, and ns represent significance at the 0.001, 0.01, 0.05 levels, and non-significant, respectfully.

a. North site



b. NWROC

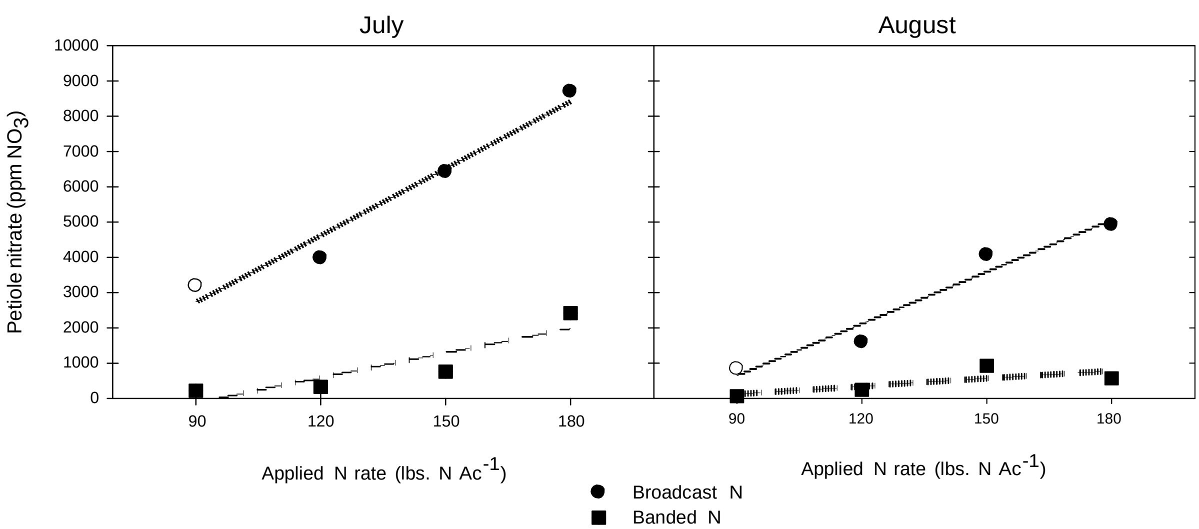


Figure 1. Petiole nitrates from most recently fully expanded leaf blade petiole at two sampling times and two experimental sites.

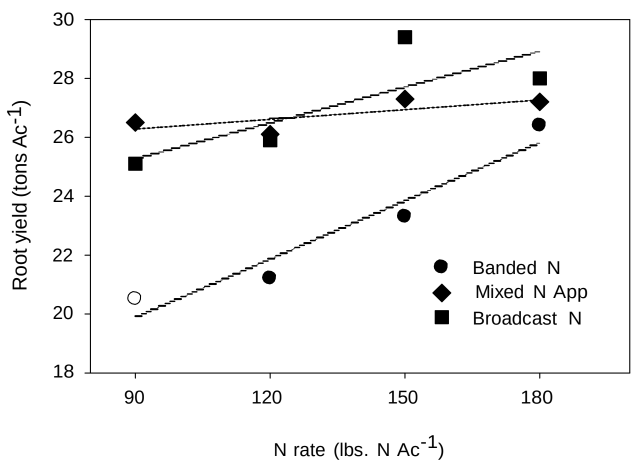


Figure 2. Root yield response to N rates and methods of pre-plant N applications at NWROC.