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

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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 2011. One trial was established 10 miles north and 3 miles west of Alvarado, Minnesota in a grower-cooperator field where excess N is required for optimum sugar beet production. A second trial was established on NWROC property 2miles north and 2 miles west of Crookston, Minnesota. Both trials contained the same treatments, but the N rates were different.

The experimental design in both trials is a split-plot randomized complete block with four replications. Whole plot treatments were N rates. Nitrogen rates at the North site were 90, 120, 150, and 180 lbs. N A^{-1} plus soil residual N. At the NWROC site the N rates were 60, 90, 120, and150 lbs. N A^{-1}. Both experiments included two 0 N controls in each replication. Split-plot treatments consisted of fertilizer placement and timing:

1. Broadcast (Bdcst): 100% of N fertilizer fall broadcast and incorporated.
2. Band: 100% of N fertilizer fall banded 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 and banded fertilizer source was urea. The sidedress nitrogen source was UAN (28% N). Sidedress N was applied in the center of the interrow space when the sugar beets were in the 10 to 12 leaf growth stage.

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 April 23, 2012 at the NWROC site and April 24, 2012 at the North Site. Crystal 985RR was seeded at about 240 seed per 100 ft of row.

Immediately after the experimental plots were established last fall soil cores to a 4 ft depth. were taken from each alley between replications and analyzed for residual nitrate-N . Soil samples were again taken in the spring following planting and analyzed for residual nitrate-N. During the growing season weeds were controlled with Glyphosate, Rhizoctonia root rot was controlled with Quadris, and other fungicides were used to control leaf diseases. Twice during the latter half of the growing season petiole samples were collected for nitrate analysis.

Twelve most recently matured petioles from rows 2 and 5 of each 6-row plot were collected and frozen. Later in the fall these petioles were heat dried and ground and nitrate was extracted using a KCl extraction procedure.

In the third week of September (North Site) and the following week (NWROC Site) the middle four rows of the 6-row plot was 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.

The trials were divided into two experiments, one testing N rates and methods of application that included Broadcast, Band, and Mixed, the second testing N rates with Broadcast and Band pre-plant applications with or without in-season sidedress N applications. Tables 1 and 2 include significance to the 0.10 level for future reference, but most interpretations here were limited to the 0.05 level.

Results:

At the time of this writing the results of the petiole nitrate-N were not available for interpretation and report. That analysis is currently under way. Residual soil nitrate at the two sites were slightly higher than typical for this type of trial. At the NWROC Site the average residual nitrate-N in the top four feet of soil was 43 lbs. Ac^{-1} and at the North Site 62 lbs. Ac^{-1}. The results of 2012 were more variable than I typically report. I believe much of this was caused by the extreme dry conditions throughout the growing season. The North Site received more timely rainfall early in the growing season than the NWROC Site, but neither site had sufficient rainfall throughout the growing season. However, the yields of both sites were quite good and are consistent with what the grower commercial fields were yielding.

<u>Nrate by Pre-plant Method</u>

Root yields increased as N rates increased at both locations (Table 1, Fig 1). However, the increase was greater when fertilizer N was banded near the seed row. At the North Site this interaction was significant at the 0.05 level and 0.10 level at the NWROC Site. Generally, the Mixed method produced yields similar to Broadcast and Banded when the two were not greatly different. When they were different Banded had higher root yields than Broadcast and Mixed was somewhere between the two.

Root quality tended to decrease as N rates increased at both sites, but to a lesser extent at the NWROC Site (Table 1, Fig 2). Only at the North Site does the statistics suggest method of N fertilizer application affect root quality. Generally Mixed applications had greater root quality than either Broadcast or Banded, which were not greatly different.

Loss-to-molasses increased as N rates increased at both sites (Table 1, Fig 4). At the North Site the increase in loss-to-molasses was quite substantially increased from about 1.2% to 1.5-1.7% at the higher N rates. Banded N had greater loss-to-molasses than Mixed or Broadcast. At the NWROC Site the overall loss-to-molasses was greater than at the North Site. Though loss-to-molasses increased with increasing N rates at the NWROC Site, the increase was only slight (significant at the 0.10 level) and pre-plant application method had not differential effect.

<u>N rate by Pre-plant Method with and without in-season sidedress</u>

As previously described, Banded N produced greater root yields as N rates increased than Broadcast N (Table 2, Fig 5). However, there was no difference of whether some of the N was sidedressed in the growing season or all the N was applied pre-plant. This was the case at both experimental sites.

At the NWROC Site root quality was not affected by pre-plant N method or whether some of the N was sidedressed or all applied pre-plant (Table 2, Fig 6). At the North Site root quality was reduced more with the Banded N than Broadcast N (Table 2, Fig6). However, sidedressing some of the N tended to have a lesser reducing effect on root quality compared to all N applied pre-plant, this was surprising.

As previously described Loss-to-molasses at the NWROC Site increased only slightly as N rates increased with no differential effect of fertilizer application method (Table 2, Fig 8). Whether some or none of the fertilizer N was sidedressed also had no effect. AT the North Site, however, Banding N increased loss-to-molasses more as the N rates increased more so than when N was Broadcast. Sidedressing some of the fertilizer during the growing season increased loss-to-molasses less than when all the N was applied pre-plant.

Summary

The first year of this study was hindered by the dry weather conditions through yields and productivity were quite good. It is presumed the sugar beet roots grew deeper into the soil profile than what would normally be the case to access soil water and possibly deep nitrogen. The surface soils tended to be dry most of the growing season. The variability observed in the data is response to the experimental factors may been caused by the dry surface soil conditions. All the N, whether pre-plant applied or sidedressed, is applied in the surface soils.

This one year of data suggest Banding N near the seed row may be the more efficient method of application in producing root yield than Broadcast applications. However, the Banded N also increased impurities leading to increased loss-to-molasses. The data further suggest that sidedressing some of the N during the growing season will have little effect on root yield, but could reduce the loss-to-molasses. Again, caution is prudent with this conclusion because the sidedressed N may have not been fully accessible by the plant because the soil in the application zone may have been too dry for root activity.

This trial was established in two locations in late October and early November 2012. The basic experimental design remained the same as described in this report. There were two differences, however. First, for the Banded treatments I used liquid ammonium hydroxide this time instead of urea. Second, the NWROC Site is also a very fine textured soil, which was not the case in this report.

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Table 1. Statistical analysis results of various sugar beet variables response to nitrogen (N) rates and methods of pre-plant applications in trials at two locations.

	North Site§					NWROC Site§			
Source§§	RtYld	RtQual	RecSuc	LTM		RtYld	RtQual	RecSuc	LTM
	------- significance level§§§ -------					-------- significance level§§§ -------			
Nrate	+	ns	ns	***		+	ns	ns	ns
Lin	**	*	*	***		*	ns	+	+
Quad	ns	ns	ns	**		ns	+	ns	ns
Method	ns	+	ns	ns		ns	ns	ns	ns
Bdcst vs Band	+	ns	ns	ns		ns	ns	ns	ns
Single vs Mixed	ns	*	ns	+		ns	ns	ns	ns
Nrate X Method	ns	ns	ns	*		ns	ns	ns	ns
Lin by Bdcst vs Band	**	ns	**	ns		+	ns	*	ns
Quad by Bdcst vs Band	ns	*	ns	**		+	ns	*	ns
Lin by Single vs Mixed	ns	ns	ns	*		ns	ns	ns	ns
Quad by Single vs Mixed	ns	ns	ns	ns		ns	ns	ns	ns

§ Tested variables are root yield (RtYld), Root quality as recoverable sucrose per ton (RtQual), Recoverable sucrose per acre (RecSuc) and loss-to-molasses (LTM)..

§§ Source of variation are Nrate (nitrogen rates used in the trials), Lin (linear regression contrast for N rates), Quad (quadratic regression contrasts for N rates), Method (method of fertilizer application), Bdcst (broadcast fertilizer application followed by incorporation with tillage), Band (banded fertilizer near the seed row application), Mixed (50% of N is broadcast and 50% of N is banded).

§§§ ***, **, *, +, and ns represent significance levels of 0.001, 0.01, 0.05, 0.10 and non-significant, respectively.

Table 2. Statistical analysis results of various sugar beet variables response to nitrogen (N) rates and methods of pre-plant applications with or without in-season sidedress application of N in trials at two locations.

	North Site§					NWROC Site§			
Source§§	RtYld	RtQual	RecSuc	LTM		RtYld	RtQual	Rec Suc	LTM
	-------- significance level§§§ -------					-------- significance level§§§ -------			
Nrate	*	*	+	***		*	ns	+	ns
Lin	**	**	*	***		**	ns	*	+
Quad	ns	ns	ns	ns		ns	ns	ns	ns
Method (Bdcst vs Band)	ns	ns	ns	ns		ns	ns	ns	ns
Nrate * Method	*	ns	+	**		ns	ns	ns	ns
Lin by Method	**	ns	*	ns		ns	ns	ns	ns
Quad by Method	ns	*	ns	***		ns	ns	ns	ns
Sidedress	ns	+	ns	**		ns	ns	ns	ns
Nrate * Sidedress	ns	*	ns	+		ns	ns	ns	ns
Lin by Sidedress	ns	ns	ns	+		ns	ns	ns	ns
Quad by Sidedress	ns	**	ns	+		ns	ns	ns	ns
Method by Sidedress	+	ns	ns	ns		ns	ns	ns	ns
Nrate * Method * Sidedress	ns	ns	ns	ns		ns	ns	ns	ns
Lin by Method by Sidedress	+	ns	+	ns		ns	ns	ns	ns
Quad by Method by Sidedress	ns	ns	ns	ns		+	ns	+	ns

§ Tested variables are root yield (RtYld), Root quality as recoverable sucrose per ton (RtQual), Recoverable sucrose per acre (RecSuc) and loss-to-molasses (LTM)..

§§ Source of variation are Nrate (nitrogen rates used in the trials), Lin (linear regression contrast for N rates), Quad (quadratic regression contrasts for N rates), Method (method of fertilizer application), Bdcst (broadcast fertilizer application followed by incorporation with tillage), Band (banded fertilizer near the seed row application), Mixed (50% of N is broadcast and 50% of N is banded).

§§§ ***, **, *, +, and ns represent significance levels of 0.001, 0.01, 0.05, 0.10 and non-significant, respectively.

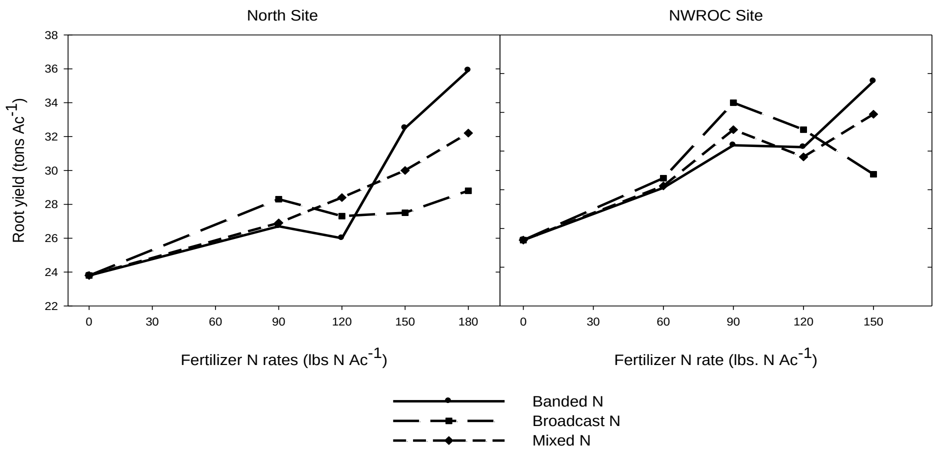

Figure 1. Root yield response to N rates and methods of pre-plant applications of fertilizer.

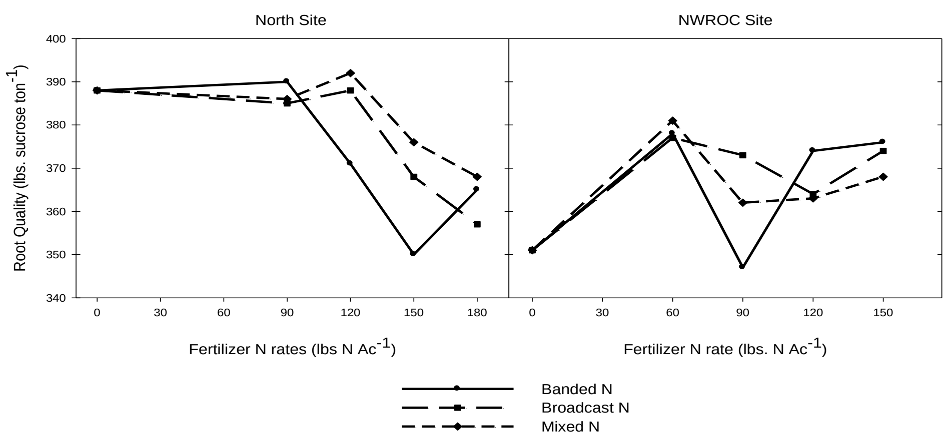

Figure 2. Root Quality response to N rates and methods of pre-plant applications of fertilizer.

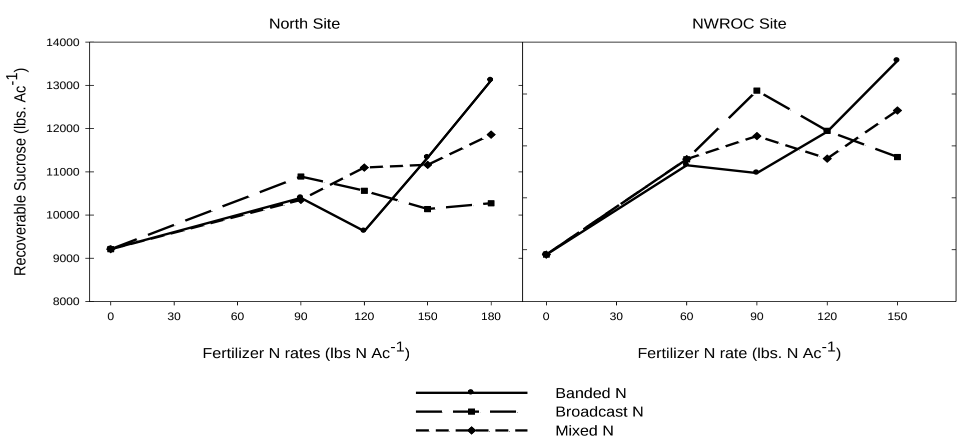

Figure 3. Total recoverable sucrose response to N rates and methods of pre-plant applications of fertilizer.

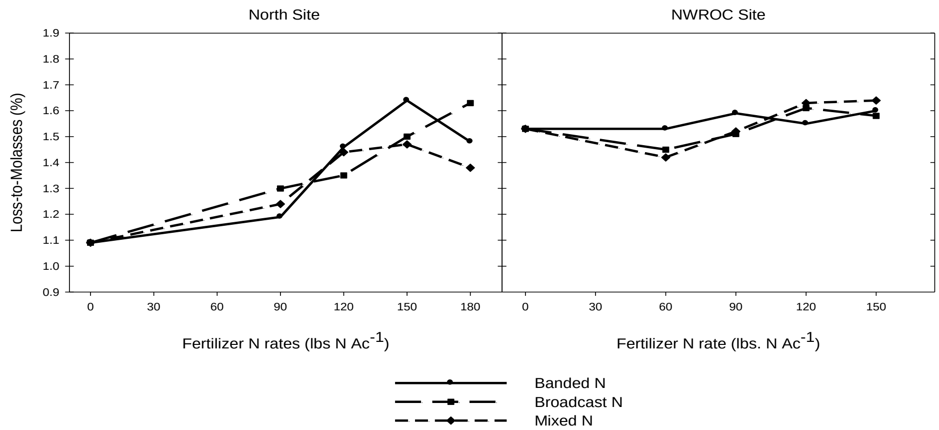

Figure 4. Loss-to-molasses response to N rates and methods of pre-plant applications of fertilizer.

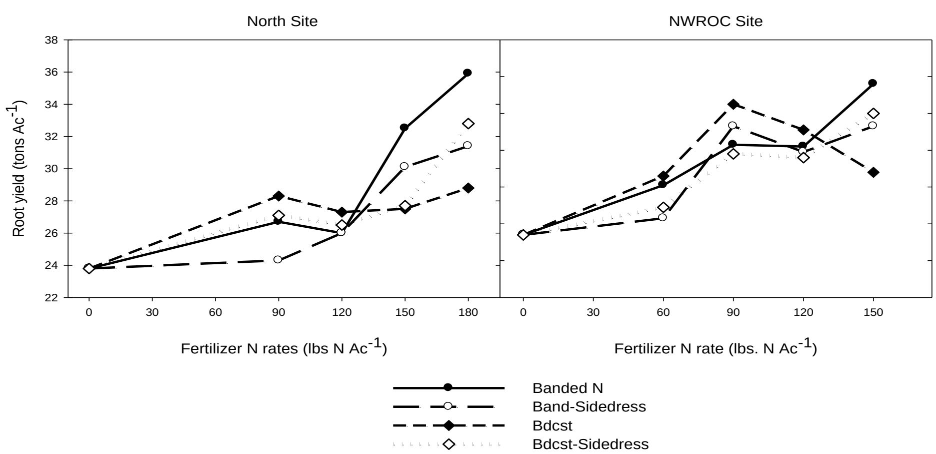

Figure 5. Root yield response to N rates and methods of pre-plant applications of fertilizer with or without additional N as in-season sidedress applications.

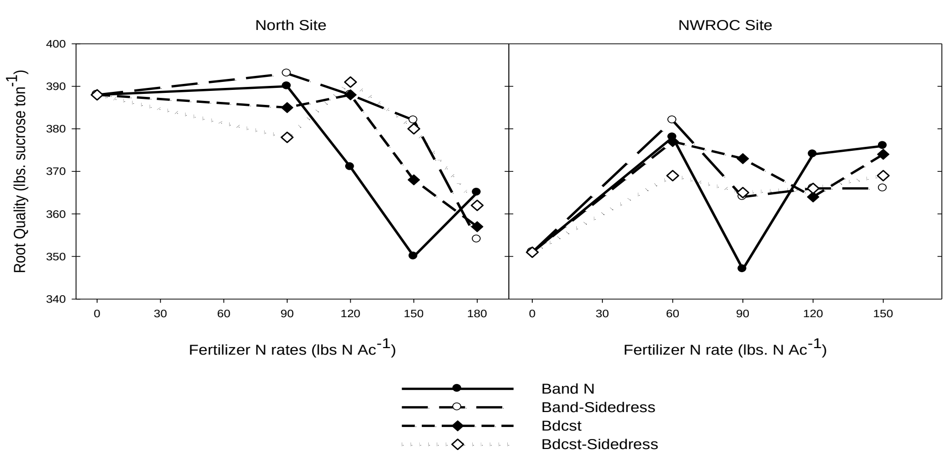

Figure 6. Root Quality response to N rates and methods of pre-plant applications of fertilizer with or without additional N as in-season sidedress applications.

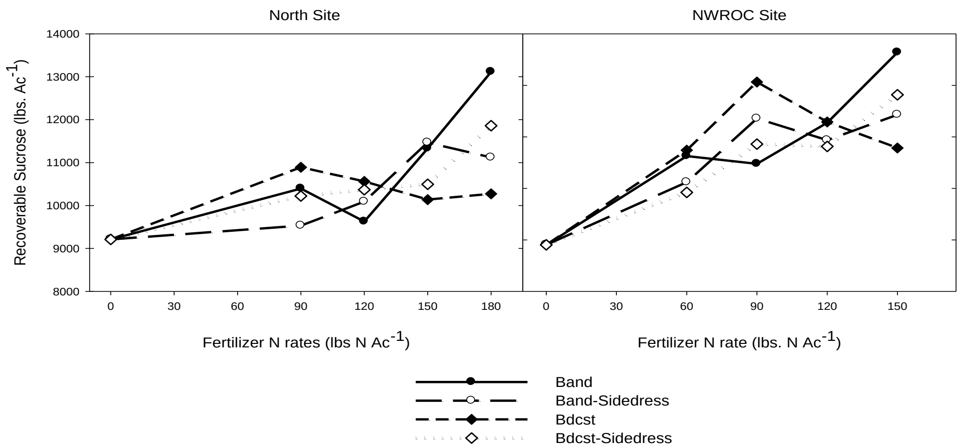

Figure 7. Total recoverable sucrose response to N rates and methods of pre-plant applications of fertilizer with or without additional N as in-season sidedress applications.

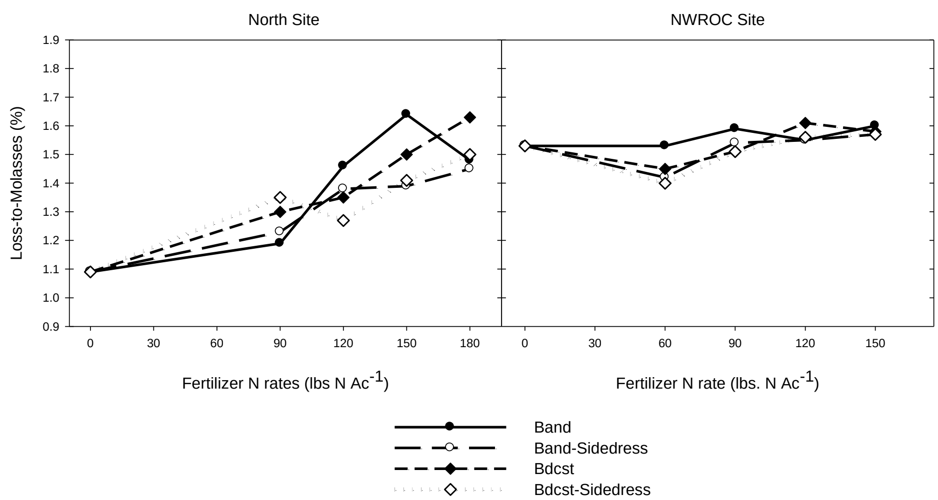

Figure 8. Loss-to-molasses response to N rates and methods of pre-plant applications of fertilizer with or without additional N as in-season sidedress applications.