CHALLENGING CURRENT NITROGEN RECOMMENDATIONS: SUGAR BEET RESPONSE TO NITROGEN IN DIFFERENT RRV LOCATIONS AND SOILS-REPORT 1

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Nitrogen (N) is the most managed nutrient, and probably always will be, in crop production in general and sugar beet production specifically. Unlike many crops, there is an agronomic penalty for over application of N in sugar beet production. Too little available N and sugar beet root yield is reduced; too much available N and sugar beet root quality is reduced. In recent decades, the amount of fertilizer N applied to the sugar beet crop has declined significantly. In France, fertilizer N use decreased from about 180 kg N ha^{-1} (160 lbs N A^{-1}) in 1977 to about 120 kg N ha^{-1} (107 lbs. N A^{-1}) in 2003 while at the same time sugar beet sugar yields increased from 7 to 11 metric tons ha^{-1} (Cariolle and Duval, 2006). Draycot and Martindale (2000) reported that fertilizer N applications in the UK declined from 6 kg N $tonne^{-1}$ (12 lbs N ton^{-1}) of beet produced at 16% sugar to 1.7 kg N $tonne^{-1}$ (3.4 lbs N ton^{-1}) in 2000. Similar reduction in fertilizer N application has occurred in Minnesota and North Dakota in the past 25 years. In 2001, Nitrogen (N) recommendations for sugar beet production in Minnesota and Eastern North Dakota were modified and generally called for reduced fertilizer N application compared to the previous recommendation.

The new recommendations proposed by Lamb et al. (2001) included a couple of significant changes from the previous recommendations. The most notable change was the elimination of sugar beet root yield goal to determine target N availability levels. Instead, the new recommendation set the target N availability level at 130 lbs. N A^{-1} regardless of yield goal, which includes residual soil NO_3-N in the 4-ft soil depth plus applied fertilizer N. This rate was derived as the most economical rate of available N based on field research trial data from the Northwest Research and Outreach Center and the Southern Minnesota Beet Sugar Cooperative (So. Minn.) grower area combined with various payment structures of the three sugar beet cooperatives.

In recent years, sugar beet root yields have substantially increased with record or near record yields in several of the past six years. While some of this can be attributed to different management strategies including the application of growth regulators, better producing varieties, and better best nutrient and pest management practices, the full explanation of this phenomenon is elusive. However, the question must now be asked if current N recommendations are adequate to sustain this elevated sugar beet yield potential? Draycot and Christensen (2003) showed a graph that clearly indicated that 100% relative sugar yield was achieved with the accumulation of or slightly higher than 200 kg N ha^{-1} in the total sugar beet plant. Combined with the decline in available N and greater sugar beet production reported by Draycot and Martindale (2000) and Cariolle and Duval (2006), this suggests that new varieties, while capable of substantially higher yield potential, may also be more efficient in recovering and utilizing the N that is available. Thus, greater amounts of N may not be needed.

When the new N recommendations were presented in 2001 (Lamb et al., 2001), they were met with a combination of acceptance, reluctance, and outright rejection. Some argued the new recommendations are too liberal while others argued they are too conservative. Critical evaluation of many of the comments revealed some common concerns. One concern is that field research from the northern Red River Valley area that contributed to the new recommendations was too limited in scope and may not represent the valley at large. While, the field trial locations in the northern valley may have been limited, it is worth noting that similar results were found from field research trials in the So. Minn. growing area. Many of the field research trials contributing to the new recommendations used sugar beet varieties no longer available and as growers switch to newer Rhyzomania resistance and glyphosate resistant (RoundUp Ready) varieties, will they require a different N recommendation than old varieties? And of course the higher sugar beet yield averages in recent years raises questions about adequacy of current N recommendations. These questions are all legitimate questions and are the result of the necessary and important critical evaluation of our highly educated and progressive growers, ag professionals, and research personnel. Therefore, it behooves the sugar beet industry and the University of Minnesota to continually reevaluate, and update when necessary, the current N recommendations for sugar beet production.

Objectives:

1. Conduct nitrogen rate response trials at multiple locations in the northern Red River Valley region and evaluate response curves for optimum N rate.
2. Compare and contrast response to N availability of two modern sugar beet varieties, RoundUp Ready varieties and where possible non-RoundUp Ready varieties.
3. Expand the area in which field research trials are conducted that will eventually contribute to updated sugar beet N management guidelines.

Materials and Methods:

Potential sites to conduct N rate response trials in commercial sugar beet fields in the 2008 growing season were limited because many growers had applied N fertilizer the previous fall. Nevertheless, three sites were located across an area ranging from Euclid to NW of Argyle to NW of Alvarado. Two of these fields were to be planted to RoundUp Ready (RR) sugar beet thus allow this trial to include two RR sugar beet varieties. The third site was to be planted to conventional sugar beet allowing this trial to include one conventional sugar beet variety and one RR sugar beet variety. However, due to a contract complication between the university and seed/companies, we were unable to use RR sugar beet varieties in any of these trials. A mad scramble ensued to find two additional sites where conventional sugar beet varieties would be planted to replace the two RR sites already selected. Two sites were located providing three experimental sites across a range from west of Crookston (Site T) to west of Alvarado (Site N) and NW of Alvarado (Site H).

Each experimental site was designed as a factorial randomized complete block with four blocks (replications). One factor included two conventional sugar beet varieties, Van der Have H46519 and Hillshog 3035. These two varieties were selected because they typically are somewhat different in root yield and root quality characteristics and were used at all three experimental sites. The second factor was increasing N fertilizer rates in 30 lbs. N A^{-1} increments. Site T included seven N rates (0 to 180 lbs. N A^{-1}), Site N included eight N rates (0 to 210 lbs. N A^{-1}) and Site H included nine N rates (0 to 240 lbs. N A^{-1}). Individual plots were 11-ft wide (six rows) and 30-ft long.

On May 5, N fertilizer treatments were imposed by hand broadcast applications of urea to appropriately designated plots. Phosphorus (P) fertilizer (60 lbs. P_2O_5 A^{-1} as 0-46-0) was broadcast applied across individual replications at Sites T and N using a ground driven fertilizer feeder and PTO driven airflow system. Soil test P levels at Site H indicated sufficient P availability. All fertilizer was immediately incorporated with a field cultivator. The following day, May 6, all experiments were planted. In-furrow with the seed was applied 3-gallons of 10-34-0 mixed with 3 gallons of water as a starter. On June 6, Site H was replanted due to poor stand, but this time only Van der Have H46519 was used and no starter was applied. Plots were overseeded and later hand thinned to an approximate 41,500 plants per acre (175 plants per 100-ft of row). Cultivation and application of herbicides were used to control weeds followed by hand weeding when necessary. Appropriate fungicides were applied at appropriate rates and times. Final harvest took place September 29 where the middle four rows of each plot were defoliated and beets in the middle two rows of each plot were lifted using a 2-row lifter. Harvested beets from each plot were weighed and 10 randomly selected beets were collected and transported to the American Crystal Sugar Quality Laboratory in East Grand Forks for quality analysis.

Several data variables were collected throughout the growing season. After plots were hand thinned, sugar beet plant stands in the entire middle four rows or each plot were evaluated and any stand gap greater than 16 inches was measured and recorded. At harvest after defoliation, but before the beets were lifted, beet density in the entire middle four rows of each plot was evaluated and any gap greater than 16 inches was measured and recorded. Harvested root yields were determined using weights of the lifted beets from the middle two rows of each plot, an adjustment made to account for gaps in the middle four rows, then extrapolated and yield expressed as tons A^{-1}. Root quality was determined form the laboratory analysis of sugar concentration minus loss to molasses concentration and expressed as lbs. sucrose ton^{-1}. Total recoverable sucrose is simply the product of root yield and root quality expressed as lbs. sucrose A^{-1}.

Statistical analysis was done using Proc Mixed procedures in SAS 9.1 (SAS, 2002; Littell et al., 2006). Regression characteristics of N rate response curves were determined using single degree of freedom contrasts.

Results:

General Comments

Soil conditions at planting were less than ideal at all three experimental sites. The already limited soil moisture began declining immediately after the initial tillage operation. As a result a substantial amount of sugar beet seed was placed in dry or drying soil. Sugar beet seedling emergence was extremely uneven across the entire experiment at all sites. Subsequent rainfall promoted additional seedling emergence filling in most, but not all, apparent seedling gaps. Across the experimental sites and within individual plots, sugar beet plants varied from the 3 to 4 leaf stage to recently emerged cotyledon stage plants. Even then substantial stand gaps remained and hand thinning was a drawn out and complicated process. The exception was site H that did not receive many of these subsequent rain events that occurred at Sites N and T. On June 5th, less than a third of the plots at Site H had sufficient plant stand to collect any data. The search for seed or seedlings in the stand gaps turned up mostly dead or dying pre-emerged seedlings. I made the decision to replant, which was done the next day, June 6th.

After hand thinning operations were completed, established plant stand was evaluated in the entire middle four rows of each plot. Any stand gap greater than 16 inches was measured and recorded. At Sites N and T, stand gaps were minimal or non-existent until N rates of 90 lbs. A^{-1} or greater were applied. As N rates increased, the number and size of the stand gaps increased. Presumably this was caused by the relatively high rates of urea applied to the dry seed bed creating ammonia toxicity in the seed bed inhibiting seed germination and seedling survival. This did not occur at Site H, but Site H was replanted a month after urea had been applied. In addition, Site H received a significant rainfall within hours of replanting, thus diminishing the urea toxicity potential.

In late September, after the beets were defoliated, but before the beets were lifted, beet density was evaluated in the entire middle four rows of each plot. Again, any gap greater than 16 inches was measured and recorded. At Site N, gaps at harvest followed similar patterns as gaps earlier in the season where increasing N rates increased incidents and size of gaps. However, harvest gaps at Site H and T followed no treatment pattern. Both sites had isolated areas of what appeared to be Rhyzoctonia Root Rot, though the disease was not confirmed.

Residual Soil N

The three experimental sites were selected based on the following criteria: 1) grower-cooperator's willingness to work with us; 2) experimental site location within the general field was easily accessible for our crew and equipment without being an undue inconvenience to the grower; and 3) residual soil N was relatively low. Initial field selection and zone within a field is based off the grower's consultant soil test N levels. Subsequent soil sampling of the experimental site area provides specific residual soil N values for the exact site of the experiment. Soil samples were not collected at the three experimental sites until after planting. After planting, soil cores to 4-ft were collected from within the alleys between each replication at each site. At site H, the average residual soil nitrate-N was 56 lbs. A^{-1} with a range of 41 to 67 lbs N. Site N was more variable with an average of 70 lbs. N A^{-1} and a range of 32 to 101 lbs. N. Site T however, was quite variable with a range of 54 to 936 lbs N A^{-1} and an average of 384 lbs. N. It was apparent that a sugar beet response to N rates at Site T would not occur, at least on a consistent basis, and which was confirmed by visual observations throughout the growing season. Statistical analysis of the sugar beet root yield response to N rates was not significant though there was a response of root quality and recoverable sucrose (Table 1). The latter two variables declined as N rates increased over the entire range of applied N rates. Site T will not be discussed further in this report.

Sugar Beet Root Yield

Root yields at Site H and N differed by 8 or more tons A^{-1} (Fig 1). The lesser yields at Site H are probably mostly caused by the late replanting at Site H. The yield response to N rates was significantly quadratic at both sites and there was no difference between the sugar beet varieties (Table 1). Maximum root yield appeared to have occurred with the application of 30 and 90 lbs N A^{-1} at Site N and between 60 and 90 lbs. N A^{-1} at Site H (Fig 1).

Sugar Beet Root Quality

Root quality, recoverable sucrose per ton of beet, was nearly 25 pounds greater at Site N than Site H, again probably due to the late replanting at Site H. At both sites, root quality response was fairly constant at N rates less than 90 lbs N A^{-1}. At higher N rates the root quality declined (Fig 2). Root quality response characteristic to N rates was significantly quadratic and there was no effect of sugar beet variety (Table 1).

Sugar Beet Recoverable Sucrose

Recoverable sucrose response to N rates was significantly quadratic in nature with no differential effects due to sugar beet variety (Table 1). Most of the increase in recoverable sucrose at the lower N rates (Fig 3) can be attributed to increasing root yield (Fig 1) followed by an offset in slight root yield increases as root quality begins to decline in the middle N rate ranges (Fig 1 and 2). At higher N rates, the decline in recoverable sucrose can be attributed to a rapidly declining root quality (Fig 2). Nevertheless, maximum recoverable sucrose appeared to have occurred with the application of 30 to 90 lbs. N A^{-1} at Site N and 60 to 90 lbs N A^{-1} at Site H.

Summary

The nature of the growing season in 2008 caused variability in seedling emergence, replanting of one site in June, stand gaps related to both higher rates of N and root diseases, and the generally dry conditions. Obviously, this will cause skepticism in the extrapolation of the data to a broader application. Of course, this is exactly why these types or experiments are conducted at multiple locations and years. he extremely dry conditions might very well have resulted in N loss through volatilization as urea had sufficient moisture to hydrolyze, but not enough to hydrogenate the ammonia being formed. Ammonia toxicity is presumed to have been a factor causing reduced stand emergence early in the growing season. Greater soil moisture would probably have reduced this effect. Secondly, optimum economic N rate is generally somewhat less than maximum yield N rate, but that differential varies with the ratio of product value and fertilizer costs, which are not determined in this report.

The two sugar beet varieties selected for this trial did not differ significantly in any of the variables measured and both responded to N rates similarly. Though these sets of trials are not definitive, they will be used in a larger data set collected over the coming years to challenge the current N recommendations.

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Table 1. Statistical analysis for the sugar beet root yield and quality and total recoverable sucrose at three experimental sites in the 2008 growing season.

		Site H			Site N			Site T		
Source of Variation	df	RtYld	RtQual	RecSuc	RtYld	RtQual	RecSuc	RtYld	RtQual	RecSuc
		---------------- PR>F$^{\delta}$ ---------------								
Variety	1	-	-	-	ns	*	ns	ns	ns	ns
N rate	6-8	***	***	***	***	***	***	ns	ns	*
Linear	1	***	ns	***	***	*	***	ns	*	ns
Quad	1	*	*	**	ns	*	***	ns	ns	**
Variety by N rate		-	-	-	ns	ns	ns	ns	ns	ns

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

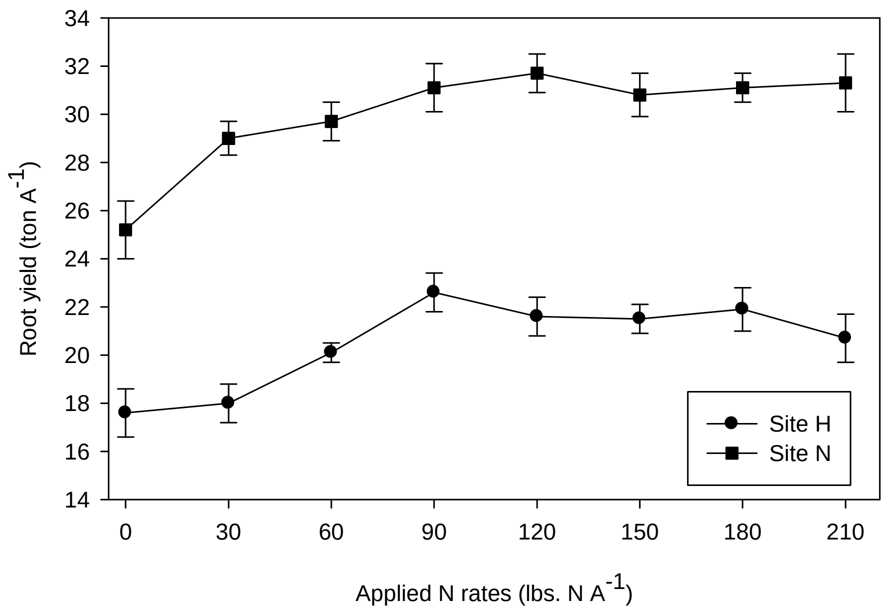

Figure 1: Sugar beet root yield response to applied N rates at two experimental sites in the 2008 growing season. Error bars represent standard error of that mean.

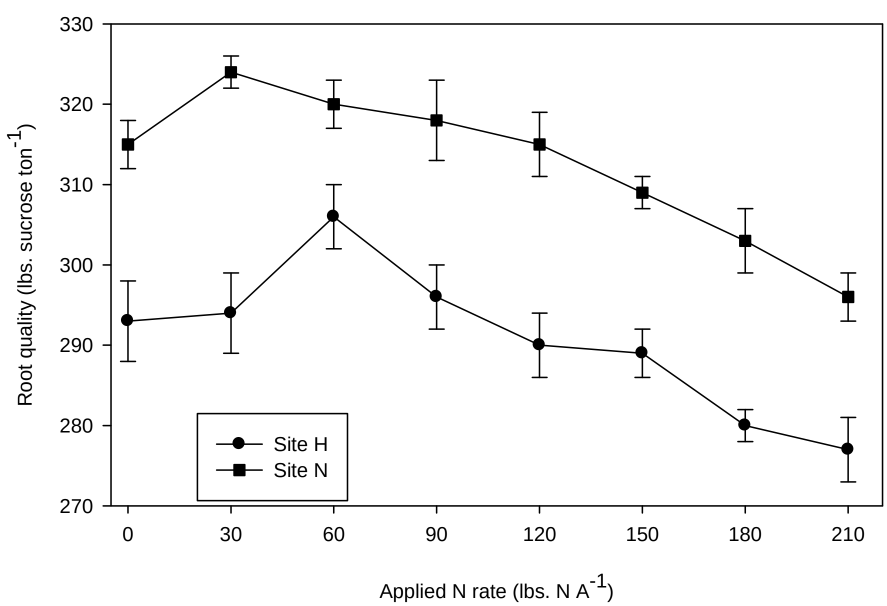

Figure 2: Sugar beet root quality response to applied N rates at two experimental sites in the 2008 growing season. Error bars represent standard error of that mean.

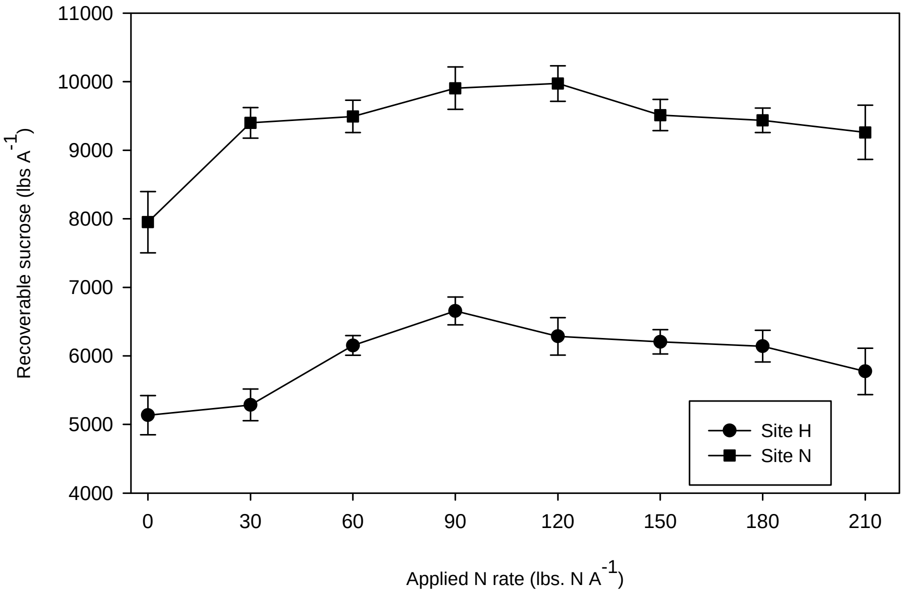

Figure 3: Sugar beet recoverable sucrose response to applied N rates at two experimental sites in the 2008 growing season. Error bars represent standard error of that mean.

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