CHALLENGING CURRENT NITROGEN RECOMMENDATIONS: SUGAR BEET RESPONSE TO NITROGEN IN DIFFERENT RRV LOCATIONS AND SOILS-REPORT 2

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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:

Three experimental sites were selected for this experiment in the 2009 growing season. Site identification throughout this report is as follows:

Site 1: about 9 miles southeast of NWROC

Site 2: about 10 miles northeast of Alvarado

Site 3: about 5 miles west of Argyle

The experimental design at each site was a Randomized Complete Block with four replications and the treatment design was a 2 by 10 factorial. Factor one was two sugar beet varieties. Site 1 was located within a commercial sugar beet production field where a conventional non-RoundUp Ready variety was used. So, the two sugar beet varieties used in the experiment at this site was Beta 88RR66 and Hillshog 3035. Sites 2 and 3 were located within commercial production fields planted to RR varieties. Experiments at these sites were Beta 88RR66 and Hillshog 4012. The second factor in each experiment was 10 N rates/source combinations. Eight N rates of 0 to 210 lbs N A^{-1} in 30 lb. increments using urea plus two N rates (60 and 90 lbs N A^{-1}) as a polycoated urea (Environmentally Safe Nitrogen, ESN, produced by Agrium Inc.). Both rates of polycoated urea were supplied entirely by the polycoated urea at Sites 1 and 2. At Site 3, 50% of the N was polycoated urea and 50% as urea. The mixture of N sources was used for these two N treatments because Site 3 was not initiated until the spring 2009.

Sites 1 and 2 were established in the fall 2008. Phosphate fertilizer and N treatments were applied and incorporated after October 31st 2008. Site 1 was established and fertilizer applied and incorporated on May 21, 2009. Site 1 was tilled with a field cultivator and planted on May 18 and Sites 2 and 3 were tilled and planted on May 22. Prior to planting at Sites 1 and 2 and before fertilizer was applied at Site 3, the field cultivator was used to remove from the plots as much surface wheat residue as possible. The cultivator was lowered so that the shovels just scratched the soil surface. After the residue was removed the cultivator was lowered to till to deeper soil depth. At Site 3, the last cultivation incorporated the fertilizer that was applied. Weed control at Site 1 was by conventional micro-rate herbicide application. At Sites 2 and 3, weed control was by applications of glyphosate. Hand weeding was done as necessary at all sites.

All plots were 11 ft wide, accommodating 6 sugar beet rows spaced 22 inches apart, and 30 ft long. All plots were overseeded and hand thinned to spacing consistent with a plant population of 175 plants per 100 ft of row. Just prior to thinning, emerged sugar beet seedlings from the middle 4 rows of each plot were counted and totaled. On July 21nd to the 23rd fourteen petioles from the most recently expanded leaves were collected from rows 2 and 5 of each plot. Petioles were diced, dried, and analyzed for nitrate-N. Final harvest consisted of mechanically harvesting the entire middle two rows of each plot. Harvested beets were weighed and 10 randomly selected beets were collected and transported to the American Crystal Quality Laboratory in East Grand Forks, Minnesota for quality analysis. The laboratory provided tare, sugar, and loss-to-molasses (LTM) data from each sample. Root yield was determined by the weight of the harvested root and subtracting off the tare percentage obtained from the quality lab. Root Quality was determined by the sugar percentage minus LTM from the quality lab and adjusted to a ton of beets.

Statistical analysis of the 2009 data was more complicated than usual. Spring flooding affected both Sites 1 and 2 with flood waters standing on Site 2 for several weeks. When the water sub-sided a thick, hard layer of residue was left along the edges of the experiment. At Site 1 the residue was on the west side of the experimental plots. At Site 2, the residue layer was on both the east and west side of the experimental plots. Since, both experiments were established the previous fall I could not block out variation due to this residue. Even though every attempt was made to remove as much of this residue layer as possible, its effects on sugar beet growth were evident throughout much of the growing season. This was not an issue at Site 3 where heavy residue resided over the entire plot area prior to removal. Several statistical covariance models using Proc Mixed Procedures (SAS 9.2, 2007) were tested for all three sites (Littell et al., 2006). The fit statistics indicated root yield statistical analysis of Sites 1 and 2 was better using a spherical covariance model to account for spatial variation within the plot. Essentially, spatial variation was used instead using replication effects. For root quality and LTM analysis at Sites 1 and 2 and all variables at Site 3, the covariance model used the randomized complete block model assigning replications as the random effect.

Graphical illustration of seedling emergence and petiole nitrates used line graphs with standard error of the mean bars for each treatment mean. Graphic illustration of root yield used the regression, linear or quadratic, relationships to N rates for each sugar beet variety that was indicated through contrasts tested in the statistical analysis. Root quality illustrations were done using line graphs except for Site 2 where the two varieties were not different and the quality response to N rates was clearly quadratic.

Results:

General Comments

Sites 1 and 2 were established in late October 2008 and were flooded during the spring 2009 snow melt. Site 1 was under water for several days as waters drained off the field, but site 2 was under water for several weeks. In both cases, but especially at Site 2, the question of N loss must be considered.

Fertilizer at both sites 1 and 2 were applied to the soil on or after October 31 when soil temperatures at the 4 inch depth was 43^{o} F at NWROC. This indicates that most of the applied N, which was supplied as urea, should have remained in the ammonium-N form going into soil freeze up, which occurred about November 30 at NWROC. Granted a month at above freezing temperatures may have allowed more ammonium-N to be nitrified to nitrate-N than if the soil had frozen with days of fertilizer application. What N was in the nitrate-N form may have been subject to loss through denitrification or possibly leaching during the flooding the following spring. However, when the flooding started, the soils were mostly frozen. Continuous flooding may have thawed the soil, but soil temperatures were still quite cold and should have reduced microbial denitrification potential. Chemical denitrification is possible. In addition, soils at both sites are fine textured with depth so leaching was probably not the issue it might have been had the soils been loam or sandy. So the question of whether N was lost during the flooding is still debatable.

At both Sites 1 and 2, two rates of a polycoated urea were applied at two N rates, 60 and 90 lbs. N A^{-1}, to each sugar beet variety. This polycoated urea slows N release by forcing water to diffuse through the coating, solublizing the urea, and the liquid N diffusing back through the coating. Diffusion rate is dependent on several factors, but one of the most important factors is temperature. As temperature declines the rate of diffusion slows. The presumption is that N in the polycoated urea applied on October 31 or later 2008 was still mostly enclosed within the coating and not subject to nitrification and nitrate-N losses associated with N directly in the soil. If the polycoated N was preserved and urea N lost during the flooding, then yields from the polycoated urea should have been greater than the same N rate as urea.

Soil residual nitrate-N at all experimental sites was determined within a few days after the plots were planted. Soil samples were taken from the alleys between the blocks or replications and nitrate-N determined in the lab providing five sets of samples for each site. Averaged over the five sets of samples, Site 1 contained 47 lbs.

nitrate-N A^{-1} in the top 4 ft of soil and Site 3 averaged 36 lbs. nitrate-N A^{-1}. Site 2 was more troubling with an average of 134 lbs. nitrate-N A^{-1}. Relatively large amounts of nitrate-N were in the 12 to 48 inch soil depths. Only Site 2 was sampled in the fall of 2008 when soil residual nitrate-N averaged 123 lbs. nitrate-N A^{-1}. Site 2 was selected in conference with the grower and his consultant using satellite photos of previous crops were also used to identify the location. The field zone where the experiment was located had 41 lbs. nitrate-N A^{-1} in the top four feet of the soil profile. There was no reason to suspect such a high residual nitrate-N level at Site 2. As will be discussed later in this report, the high soil residual nitrate-N makes the response to fertilizer N more puzzling.

Stand Emergence

Stand emergence, though variable, was not affected by N rates at either Site 1 or Site 2 (Fig 1). Fertilizer at both sites was applied the previous fall. At Site 1, there was no difference overall between the two sugar beet varieties. At Site 2, seedling emergence appeared to be slightly lower for Beta 88RR66 than Hillshog 4012, but neither was detrimentally affected by N rates. At Site 3, differences between varieties were quite apparent (Fig 1). Beta 88RR66 had lower seedling emergence than Hillshog 4012 at the O N rate. Emergence decreased as N rates increased above 60 lbs. N A^{-1} with the Beta variety and above 150 lbs. N A^{-1} with the Hillshog variety. Supplying all or some of the N as polycoated urea had no effect on seedling emergence at Sites 1 and 2. There might have been a benefit at Site 3 for the Beta variety.

Root Yield

Root yield was significantly affected by applied fertilizer N rates at all three sites (Table 1). Sugar beet variety differences were significant at Sites 1 and 3, but not at Site 2. At Sites 1 and 3, root yield response to fertilizer N rates was best described using a quadratic model (Fig 2). Generally, root yields were near maximum levels between 120 and 150 lbs. applied N at both sites. There were slight differences in sugar beet varieties response to N rates at both sites, but the variety by N rate interaction effect was not significant. At Site 2, however, root yield response to fertilizer N rates was best described using a linear model. Root yield increased as N rates increased. There was no difference between the two sugar beet varieties.

There was a difference in root yields among the sites. Site 1 root yields ranged from 23 ton A^{-1} at 0 applied N to about 32 ton A^{-1}. Root yields at Site 3 ranged from 15 to about 25 ton A^{-1}. At Site 2, root yields were about 21 ton A^{-1} at 0 applied N and 28 ton A^{-1} at 210 lbs. applied N.

Root Quality

Root quality was significantly affected by both applied fertilizer N rates and sugar beet variety at Sites 1 and 3 and only by applied fertilizer N rate at Site 2 (Table 1). There was no significant N rate by variety interaction at any of the sites. Statistically, root quality response to applied N rates could be described by regression models, however, I thought the results were better illustrated using simple line graphs (Fig 3). At Site 1, root quality generally was consistent or possibly increased slightly as N rates increased up to 90 lbs. applied N A^{-1}. At higher rates of N, the quality declined. The response was similar at Site 3 except quality declined at N rates greater than 60 lbs. applied N A^{-1}. At both sites, Beta variety had lower root quality than the Hillshog variety. At site 2, root quality increased with increasing N rates up to about 90 lbs. applied N A^{-1} then tended to level off at higher applied N rates (Fig 3). There was no difference between the Beta and Hillshog variety.

LTM

Loss-to molasses increased as applied N rates increased at all sites. This response was best described by a quadratic model (Table 1). Generally as N rates increased above 90 to 120 lbs. applied N LTM increased. The Beta variety tended to be .1 to .2 percentage points higher LTM than the Hillshog variety at all sites. The Beta variety was more difficult to detop in these experiments because the root tended to be setting lower in the soil. As a result, making the correct adjustment on the detopper was difficult. Adjusting it low enough to thoroughly clean the Beta variety was too low for the Hillshog variety. Adjusting for the Hillshog variety tended to be too high for the Beta variety. A grower would normally have planted the entire field or section of field to one or the other variety and should have been able to appropriately adjust the detopper for that variety. In these experiments, after the first pass with the detopper, the detopper was adjusted lower and a second pass through the plots focused only on the Beta variety.

Table 1. Statistical analysis results from three experimental sites in the 2009 growing season.

	Site 1			Site 2			Site 3		
	Rtyld	RtQual	LTM	Rtyld	RtQual	LTM	Rtyld	RtQual	LTM
Source	-------------------- PR>F[§] --------------------								
N rate	***	**	***	***	***	ns	***	*	***
Linear	***	***	***	***	***	ns	***	ns	***
Quadratic	**	*	**	ns	***	**	***	**	*
Variety	*	***	***	ns	ns	***	**	ns	***
N rate X Variety	ns	ns	ns	ns	ns	ns	ns	ns	ns

§ ***, **, *, and ns represent significance at 0.001, 0.01, 0.05, and not significant, respectively.

Summary

The 2009 growing season was quite unusual. It can only be speculated on what impact the prolonged spring flooding followed by a cold summer had on the research results. Maximum root yields occurred at applied N rates somewhat higher at Sites 1 and 3 than expected in a more “normal” year. It was hypothesized that early season N mineralization was slowed due to the cold temperature. At Site 3, the 60 and 90 lbs. N A^{-1} rate was applied as both all urea and as 50% urea plus 50% polycoated urea. As the growing season progressed it was apparent the sugar beets from 60 lbs N A^{-1} as a 50:50 mixture (urea:polycoated urea) were visually more vigorous than 30 lbs N A^{-1} all urea, but not as vigorous at 60 lbs N all urea. Likewise, 90 lbs N as a 50:50 mixture looked better than 60 lbs all urea, but not as good as 90 lbs. N all urea. At an experimental walk-through on August 25th, there was little visual difference between the urea and urea:polycoated urea mixtures at the same N rates. If N release from polycoated urea was hindered by cooler than normal soil temperatures there might have been N deficiencies until temperatures warmed in mid-August and September. Could this have also been the situation for soil N mineralization.?

Of special interest are the results at Site 2. This site apparently had high residual soil nitrate-N levels, especially below the 12inch soil depth, yet there was a linear sugar beet root yield response over the entire range of applied fertilizer N. At the same time root quality did not decline, rather, it remained at consistent levels at the higher applied N rates. How can this be?

On August 23rd and 24th , petioles were collected from 14 of the most recently expanded leaves in each plot at each site. Petiole nitrate response to applied N rates and sugar beet variety are plotted along with standard error of the mean bars in Figure 4. Petiole nitrates increased as applied fertilizer N increased at Sites 1 and 3. At this point in time, petiole nitrates at Sites 1 and 3 were 6000 to 10,000 ppm at applied N rates where root yields were maximized and 3000 to 4000 ppm nitrate at N rates beyond which root quality began to decline. At Site 2, however, petiole nitrate levels were low throughout the entire range of applied N rates. This might explain why root yield increased over the entire applied N rate range without a decrease on root quality. Drawing conclusions from this data is difficult as the variability in the data was substantial. However, it appears the sugar beets at Site 2 are not gaining accessing or unable to absorb the excessive N that should have been available.

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References:

Cariolle, M. R. Duval. 2006. Nutrition-Nitrogen. *In* A.P. Draycot (ed), Sugar Beet, Blackwell Publishing Ltd., 9600 Garsington Rd., Oxford, OX4 @DQ, UK.

Draycot, A.P., and D.R. Christenson. 2003. Nutrients for Sugar Beet Production Soil-Plant Relationships. p 7-33. CABI Publishing, 44 Brattle St., 4th Floor, Cambridge, MA, 02138.

Draycot, A.P., and W. Martindale. 2000. Effective use of nitrogen fertilizer. British Sugar Beet Review 68:18-21.

Lamb, J. A., A.L. Sims, L.J. Smith, and G.W. Rehm. 2001. Fertilizing sugar beet in Minnesota and North Dakota. University of Minnesota Extension Service, College of Ag., Food, and Enviorn. Sci., St. Paul, Minnesota. FO-07715-C.

Littell, R.C., G.A. Milliken, W.W. Stroup, R.D. Wolfinger, and O. Schabenberger. 2006. SAS for Mixed Models, 2nd Ed. SAS Instititute, Cary, NC.

SAS. 2002. Statistical Analysis System 9.1, SAS Institute, Cary, NC.

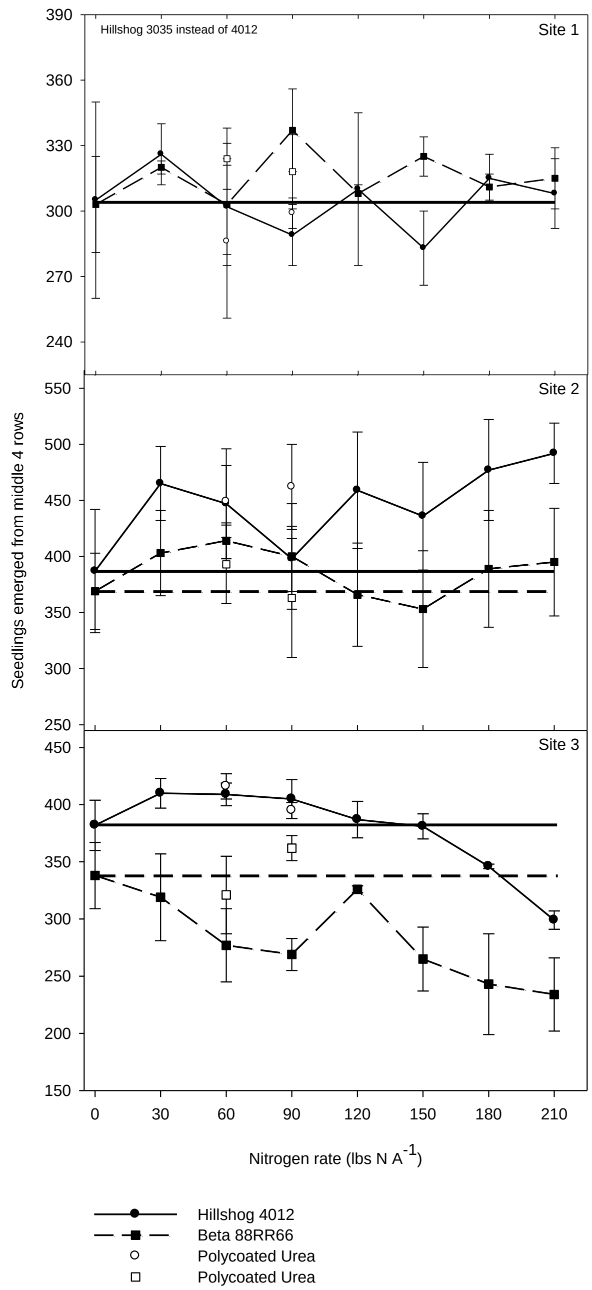

Figure 1. Sugar beet seedling emergence response to applied N rates and sugar beet varieties at three experimental sites in 2009. Solid and dashed horizontal lines mark seedling emergence with 0 applied N. Vertical bars represent the standard error of the mean.

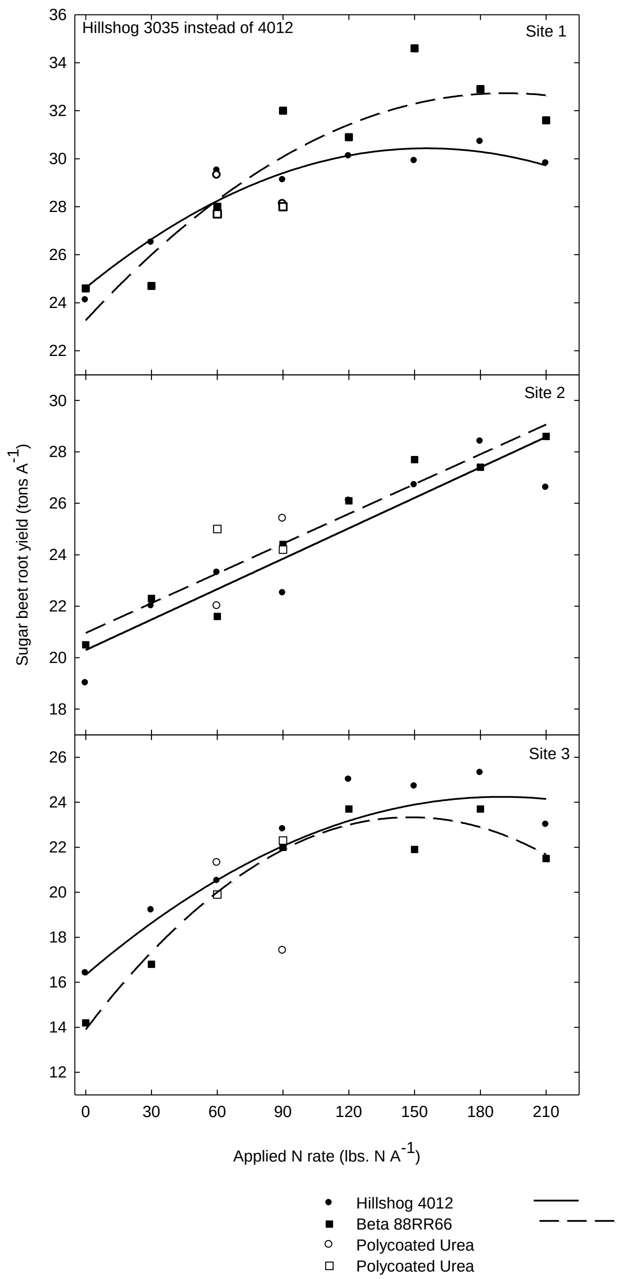

Figure 2. Sugar beet root yield response to applied N rates and sugar beet varieties at three experimental sites in 2009. Solid and dashed represent regression models as indicated by regression contrasts in the statistical analysis.

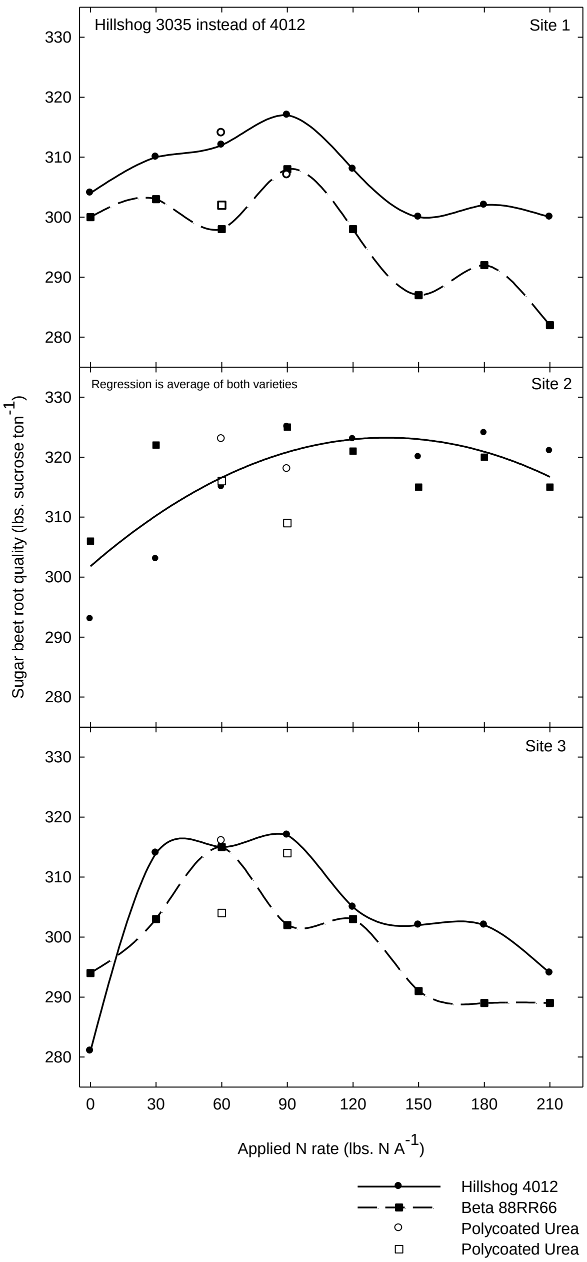

Figure 3. Sugar beet root quality (lbs. sucrose ton^{-1}) response to applied N rates and sugar beet varieties at three experimental sites in 2009.

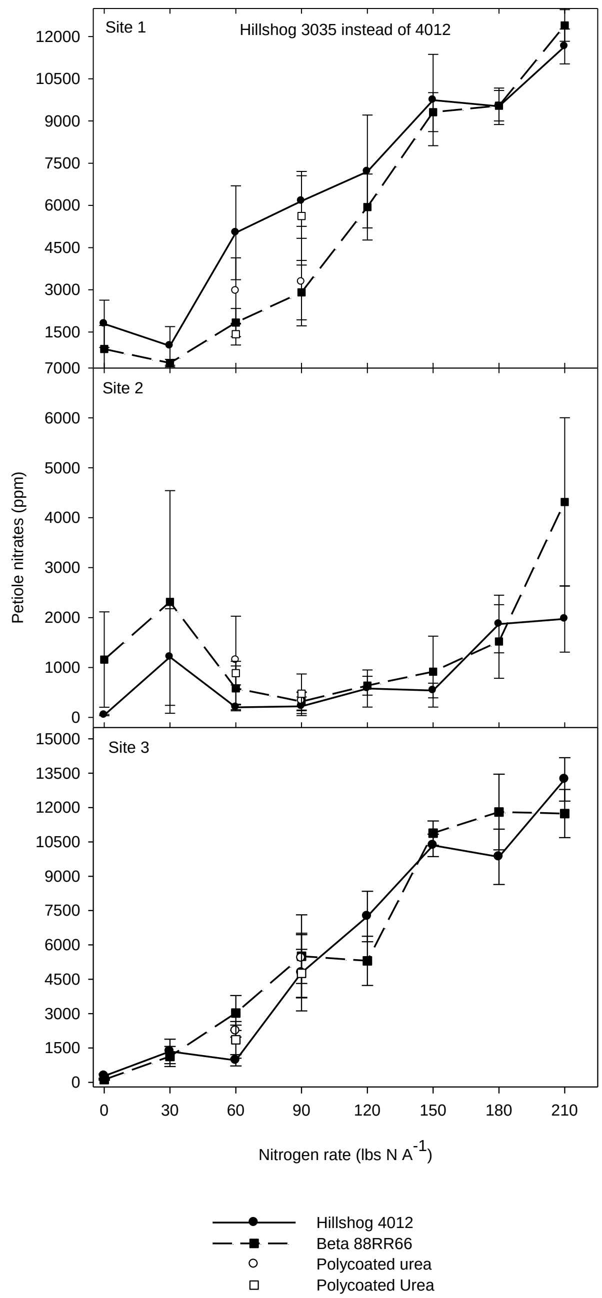

Figure 4. Sugar beet petiole nitrates response to applied N rates and sugar beet varieties at three experimental sites on August 23/24 in 2009. Vertical bars for each mean represents the standard error of the mean.