CHALLENGING CURRENT NITROGEN RECOMMENDATIONS: SUGAR BEET RESPONSE TO NITROGEN IN DIFFERENT RRV LOCATIONS AND SOILS-REPORT 3

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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 recommendation. 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) show 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 in 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 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.

In previous years of this trial, sugar beet varieties often varied in their root yield and root quality variables, but there was no interaction between variety and their response to N rates (Sims, 2010). This indicates that though sugar beet varieties may vary in their root yield and quality potential, they tend to respond to N similarly. It was also found that petiole nitrates were very low and did not respond to N rates at the site northeast of Alvarado. The opposite occurred at the other two locations. I hypothesized that N rate may not be the issue in those areas where growers use higher N rates. Rather, it may be N management that is the issue. In 2010, the objectives of this trial were altered in an attempt to address this hypothesis.

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. Evaluate the effectiveness of sidedress N and spring verses fall applications of N fertilizer.
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 in the fall of 2009. Site identification throughout this report is as follows:

Site 1: 8.5 miles north and 3 miles west of Alvarado, Minnesota
Site 2: 3.5 miles north and 5 miles west of Stephen, Minnesota
Site 3: 4.0 miles east and 1 mile north of Climax, Minnesota

Soil at Site 1 was a Colven sicl (Fine-silty, mixed, superactive, frigid Typic Calciaquoll). Soil at Site 3 was also a Colvin sicl with sufficient Fargo (Fine, smetitic, frigid, Typic Epiaquert) intermixed to make the soil series a Colvin-Fargo Complex. At Site 2, the soil was an Eaglepoint-Northcote Complex (very-fine, smetitic, frigid, Aeric Calciaquoll and very-fine, smetitic, frigid, Typic Epiaquert, respectively). Sites 1 and 2 were located within an area identified as a higher N use zone for sugar beet production in a GIS project (Sims, 2009). Site 3 was located just outside a high N use zone, but the grower-cooperator does tend to use higher than currently recommended N rates in this geographic region.

The treatment and experimental design was an incomplete factorial Randomized Complete Block with four blocks or replications at each site. Plots were 6-rows wide (11 ft) and 30 ft long. Eight treatments consisted of fall applied N fertilizer rates ranging from 0 to 210 lbs. N A^{-1} in 30 lbs. increments. Plot establishment and fall fertilizer application and incorporation occurred during the last week of October and first week of November in 2009. Four additional treatments were added in the spring 2010. Two treatments were 120 and 150 lbs. N A^{-1} broadcast and incorporated just prior to sugar beet planting. Two treatments were 90 lbs. N A^{-1} broadcast and incorporated pre-plant plus 30 or 60 lbs. N A^{-1} sidedressed during the growing season. Phosphorus fertilizer was also broadcast over the entire experimental areas in the spring. All fertilizer was incorporated (fall and spring) with a field cultivator. All broadcast N was supplied as urea and sidedress N was liquid UAN. Phosphorus was supplied as TSP (0-46-0). At planting, 3 gal A^{-1} of 10-34-0 was banded with the seed.

At each experimental site, Round Up Ready sugar beet variety Hillshog 4094 was over seeded then hand thinned to 175 plants per 100 ft of row. Hand thinning took place when the sugar beet plants were between the 2nd and 4th true leaf growth stage. Seedling emergence was determined by counting all emerged plants in the middle four rows of each plot prior to thinning. Cultural practices during the growing season were typical of the area and included herbicide and fungicide treatments as needed. Because glyphosate was used to control weeds, no in-season cultivation was done at any of the sites.

Sidedress treatments were difficult to apply due to heavy rainfall and very wet conditions within the experimental areas. Site 3 was sidedressed on June 21st and Site 1 on June 24th. Site 2 was sidedressed July 1st.

While there was some variability in growth stage among the experimental sites, for the most part the sugar beets were in the 10 to 12 leaf stage at the time of sidedressing. A shallow trench was dug 4 to 6 inches from the sugar beet row and 100 mls of a water and UAN solution was evenly dribbled into the trench. The amount of UAN in the solution varied depending whether the sidedress rate was 30 or 60 lbs. N A^{-1}. The trench was then recovered.

Initiating one week after the sidedress treatments were applied, petioles from each plot was collected and later analyzed for nitrate. At Site 1, petioles were collected on July 1, July 12, July 26, and August 10. At Site 2, petioles were collected July 12, July 26, and August 10. At Site 3, petioles were collected June 30, July 13, July 27, and August 12. In each sampling, 12 petioles from one of the last three fully expanded sugar beet leaves was collected from each of rows 2 and 5 of each plot. The 24 petioles were placed in a cooler, transported back to the laboratory at NWROC and placed in the freezer. Over subsequent weeks the petiole samples were freeze dried, ground, and analyzed for nitrate.

In early October, the two center rows of each plot were mechanically harvested and the lifted beet roots weighed. Ten randomly, but representative, beet roots from each plot were selected, bagged, and transported to the American Crystal Quality Laboratory in East Grand Forks, Minnesota. Beet roots were analyzed for tare, sugar, and potassium, sodium and amino N that contribute to loss-to-molasses.

Statistically analysis was done using Proc Mixed procedures in SAS 9.2 (2008). Analysis was done on each experimental site separately. Petiole nitrates were analyzed by individual site and individual sampling time. Where appropriate, single degree contrasts are used to separate meaningful treatment comparisons. Contrasts comparisons included linear and quadratic response to the increasing fall applied N rates, 120 and 150 lbs. N A^{-1} compared across fall, spring, and split applications, 120 and 150 lbs. N A^{-1} compared across spring split applied verse all spring preplant applied. Harvested root weights are used to calculate sugar beet root yield and are reported as tons roots per acre. Root quality is reported as pounds of recoverable sucrose per ton of beets, which accounts for both sugar and loss-to-molasses percentages. Recoverable sucrose is the product of root yield and root quality and reported as pounds of recoverable sucrose per acre.

Results:

General Comments

Experimental plots and fall fertilizer applications were done when soil temperatures at the 4 inch depth was less than 50^{o} F at all sites. While this will not prevent the conversion of urea-N to nitrate, these temperatures at the time of application and decreasing temperatures thereafter should have greatly reduced the rate and amount of N converted to nitrate. The following spring (2010), Site 1 was flooded and under water for several days from the spring snow melt. The exact impact of this flooding on potential N loss is not known. Site 3 was flooded by an early season heavy rainfall event just as the sugar beet plants were emerging. This flooding was only for a short period of time, but it did cause substantial movement of the previous crops wheat straw. The straw was heavily matted in certain areas of the plots and was interfering with sugar beet seedling emergence. We manually removed wheat straw from over the sugar beet rows. Soil conditions at all three experimental sites were wet during much of the first couple of months of the growing season.

Seedling Emergence

Comparisons of spring verses fall applied urea on sugar beet seedling emergence can be made at the 90, 120, and 150 lbs. N A^{-1} rates where both application times are represented. At all experimental sites spring applied urea reduced seedling emergence. At Site 1, seedling emergence was reduced 9, 24, and 31% with 90, 120, and 150 lbs. N A^{-1}, respectively. At Site 2, emergence was reduced 5, 17, and 22 %, respectively. Seedling emergence was generally less at Site 3 than Sites 1 and 2. Spring applied urea reduced emergence at Site 3 by 2, 14, and 12% at the same respective N rates.

Sugar Beet Root Yield

There was a large root yield response to fall applied N rates at all three experimental sites with approximately a 12 ton A^{-1} increase over the control. At Sites 1 and 3, root yield response to fall applied N was significantly linear (Table 1) and root yield increased over the entire range of fall applied N (Fig 1). At Site 2, root yield response to fall applied N rates was curvilinear with a significant quadratic response (Fig 1, Table 1). Maximum root yield occurred with 150 lbs. N A^{-1} at Site 2. Maximum root yield was 32, 28, and 34 ton A^{-1} at Sites 1, 2, and 3, respectively.

At Sites 1 and 3, there was a significant increase in root yield with spring applied N compared to fall applied N (Table 1, Fig 1). The increase with spring applied N tended to be 2 to 4 tons A^{-1}. As with fall applied N, spring applied 150 lbs. N produced greater root yield than spring applied 120 lbs. N. However, there was no difference between split applications of these N rates compared to all applied pre-plant. At Site 2, there was no difference between fall and spring applied N or between split and all pre-plant applied N. This was probably due maximum root yield potential being already reached at the 120 to 150 lbs. N A^{-1}.

Sugar Beet Root Quality

Sugar beet root quality was quite good at all three experimental sites ranging from 320 to 345 lbs. sucrose ton^{-1}. Root quality response to fall applied N rates was curvilinear (Fig 2), significantly quadratic (Table 1) at all three sites. Root quality increased as N rates increased up to about 60 lbs. N at Site 2 and 90 lbs. N at Sites 1 and 3. Root quality tended to decrease at the very highest applied N rates, but the decrease was most pronounced only at Site 2. Applying N in the spring had little effect on root quality compared to fall applied N at Sites 1 and 2. At Site 3, spring applied N reduced root quality compared to similar amounts of fall N. There were no differential effects on root quality between spring N split applied or all applied pre-plant.

Recoverable Sucrose

Total recoverable sucrose, which is the product of root yield and root quality, ranged from 6500 to 11,000 lbs. A^{-1}, 5000 to 9500 lbs. A^{-1}, and 7500 to 11,500 lbs. A^{-1} at Sites 1, 2, and 3, respectively. Recoverable sucrose response to fall applied N rates was similar to that of root yield. Significant linear response at Sites 1 and 3 (Table 1) resulted from increasing recoverable sucrose over the entire range of fall applied N rates (Fig 3). At Site 2, maximum recoverable sucrose occurred with about 150 lbs. fall applied N A^{-1} (Table 1, Fig 3). Spring applied N increased recoverable sucrose compared to fall applied N at Sites 1 and 3 only. There were no differential effects of split applied N compared to all pre-plant applied N at any of the experimental sites.

Table 1. Statistical analysis results from three experimental sites in the 2010 growing season.

	Site 1			Site 2			Site 3		
	Rtyld	RtQual	RecSuc	Rtyld	RtQual	RecSuc	Rtyld	RtQual	RecSuc
Source	-------------------- PR>F§ --------------------								
Fall N Linear	***	**	***	***	ns*	***	***	***	***
Fall N Quadratic	ns	*	ns	***	***	***	ns	***	ns
120 vs 150	**	ns	**	ns	ns	ns	*	*	ns
Fall vs Spring	+	ns	+	ns	ns	ns	***	*	***
Split vs Once (sprg)	ns	ns	ns	ns	ns	ns	ns	ns	ns
Split 30 vs 60	*	ns	*	ns	ns	ns	*	*	ns

§ ***, **, *, + and ns represent significance at 0.001, 0.01, 0.05, 0.10 and not significant, respectively.

Summary

In 2009, petiole nitrates from sugar beet plots at the Alvarado Site, very near the 2010 Site 1, were very low and showed little response to increasing N rates (Sims, 2010). Petiole nitrates at the other two 2009 experimental sites were much greater and showed a very strong response to increasing N rates. I hypothesized that the issue at the Alvarado Site may not be an N rate issue; rather it may be an N management issue. Therefore, in 2010, I adjusted the treatments to include spring applied N and split applied N with some N applied as a sidedress in an attempt to increase N availability to the sugar beet crop compared to fall applied N.

In the 2010 growing season, the three experimental sites were in growing zones where growers tend to use greater N rates than would normally be recommended. At two, Sites 1 and 3, of the three experimental sites, response to fall applied N suggests maximum yield is yet to be attained even with 210 lbs. N A^{-1}. Yet at both sites 150 lbs. N A^{-1} applied in the spring produced the same root yield and recoverable sucrose as 210 lbs N in the fall. This suggests that approximately 60 lbs. of fall applied N is not available to the sugar beet crop. Reduced root quality with 150 lbs. spring applied N compared to the highest rate of fall applied N also suggests potential N loss from fall applied N. At Site 2, there was little difference between spring and fall applied N where maximum root and recoverable sucrose yield occurred at the 120 to 150 lbs N rate. Little difference between the spring and fall applied N suggests little N loss from fall applied N or similar N loss from both spring and fall applied N.

Petiole nitrates 7 to 9 days (Sites 1 and 3) and 12 days (Site 2) after sidedress N was applied is shown in Figure 4. Similar to 2009, Site 1, near the Alvarado site of 2009, had low petiole nitrate levels and a response only to the higher N rates. At Sites 2 and 3, there was a petiole nitrate response over the range of fall applied N. Spring applied N increased petiole nitrate compared to similar rates of fall applied N at all experimental sites. When sidedress N was compared to all spring pre-plant applied N, petiole nitrate was increased only at the 150 lbs. N rate at Sites 1 and 3. There was no advantage over the fall applied N at Site 2. Petiole nitrates from petioles collected later in the growing season showed mixed results in terms of response to fall applied N. My interpretation of these mixed results is tempered because I question our handling of the petioles after sampling; they may have gotten too warm and biased the nitrate measurements. However, in almost every case, applying all the spring N as pre-plant tended to have higher petiole nitrates than sidedress N.

The results of 2010 indicate the potential of substantial N loss over the winter and through the growing season. Soil conditions were frequently very wet and may have promoted N loss through denitrification of fall applied N. Spring applied N increased the availability of N, split applying N with a sidedress strategy did not improve N availability. The results suggest spring applied N is a better fertilizer management strategy than fall applied N, but it must be remembered that these plots were over seeded and hand thinned to a uniform plant stand. High rates of spring broadcast applied urea-N tended to reduce stand emergence by 25-30%. So, a grower planting to stand and losing 25% of their stand to spring applied N will probably not realized the yield increase with spring applied N I did. However, the trend does suggest further work in N management strategy is warranted. For those growers using anhydrous ammonia, the results may be different from using broadcast urea. Future work will probably need to address differences in anhydrous and urea, fall and spring placement of urea-N, and some of the enhanced efficiency N sources that are now available on the market.

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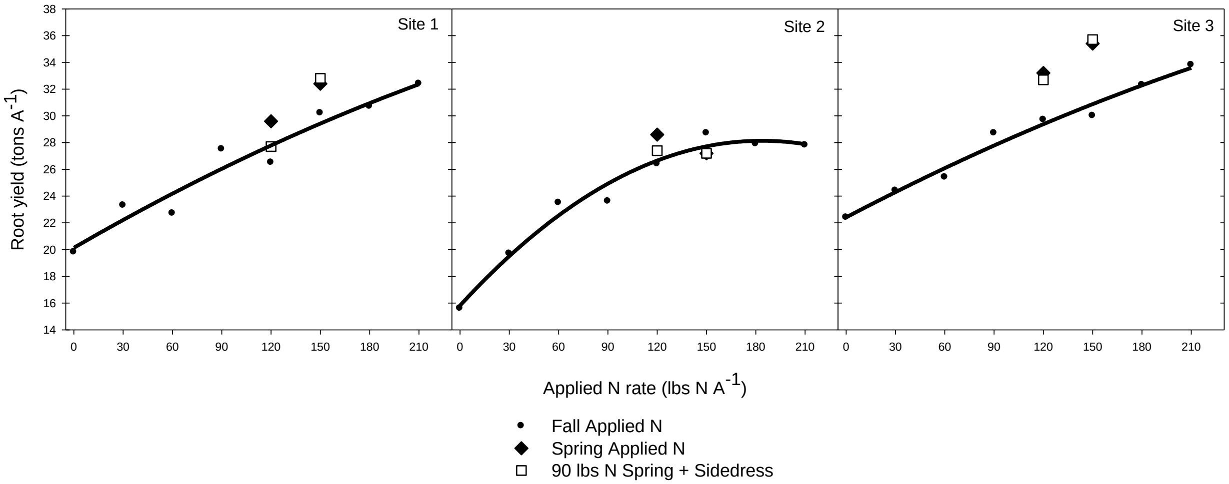

Figure 1. Sugar beet root yield response to fall applied N rates, spring applied N, and split applied N at three experimental sites in 2010.

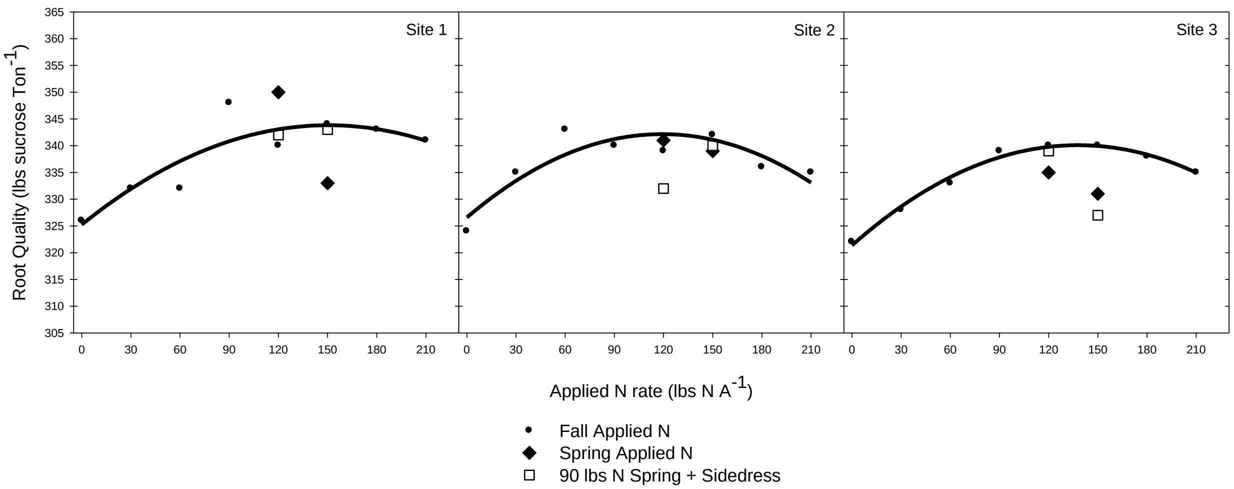

Figure 2. Sugar beet root quality response to fall applied N rates, spring applied N, and split applied N at three experimental sites in 2010.

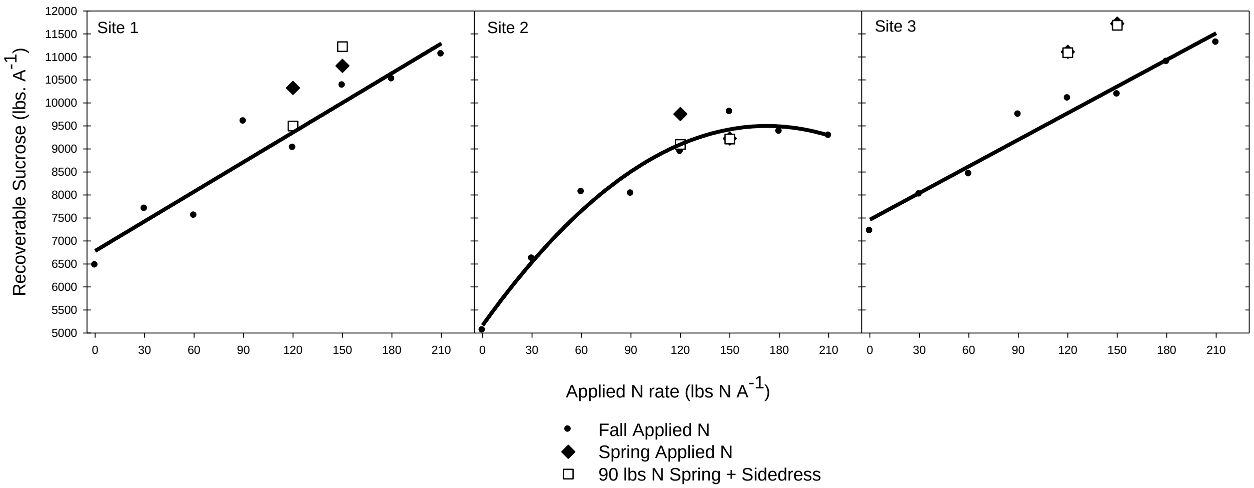

Figure 3. Total recoverable sucrose response to fall applied N rates, spring applied N, and split applied N at three experimental sites in 2010.

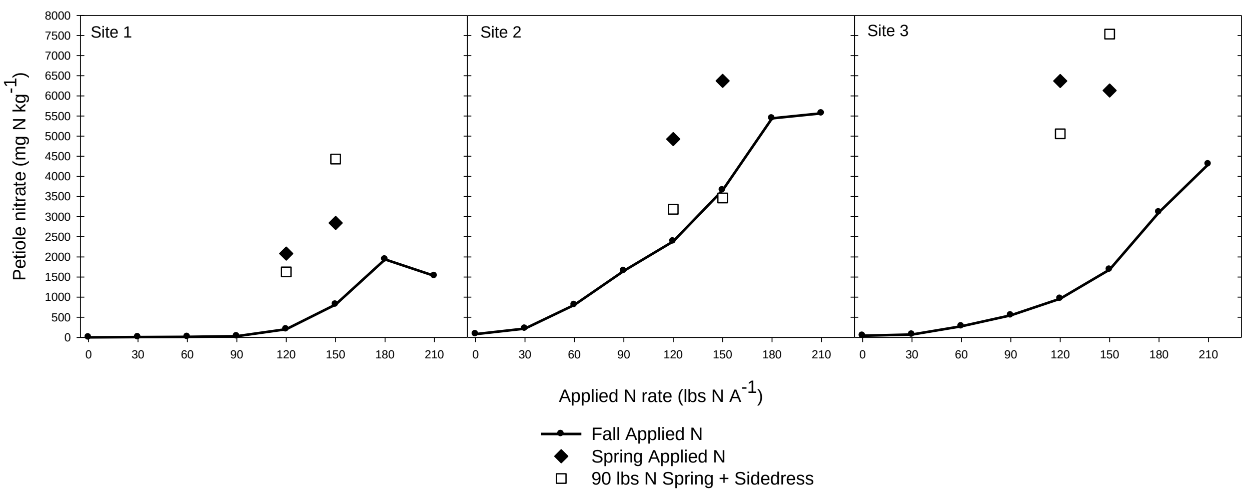

Figure 4. Sugar beet petiole nitrate-N 7 to 9 days (Sites 1 and 3) and 12 days (Site 2) after sidedress N applications in 2010.