EVALUATION OF NITROGEN FERTILIZER TECHNOLOGIES AND FERTILIZER TIMING FOR SUGAR BEET PRODUCTION

Daniel Kaiser[1], Mark Bloomquist[2], and David Mettler[2]

[1]/University of Minnesota Department of Soil, Water, and Climate, St Paul, MN
[2]/Southern Minnesota Beet Sugar Cooperative, Renville, MN

Justification: Research on biostimulant use in sugar beet production is not widespread. Limited work has been conducted looking at the benefits of chitosans. Eweiss et al. (2005) studied the effect of chitosans on mycelial growth, sporulation, and germination of conidia or sclerotial of *Rhizoctonia solani*, *Sclerotium rolfsii* Sacc., and *Fusarium solani* and noted a limited impact on *R. solani*. More research has been conducted with sugar beet treated with beneficial microbes. Mrkovacki et al. (1995) found increased dry mass of sugar beet treated with Azotobacter chroococcum. Cakmakc et al. (2001) found increased root yield and sugar content for sugar beet seed inoculated with Bacillus and Pseudomonas bacterial strains. Mahmoud et al. (2014) indicated that 60-80 kg N applied with Azobacter and Asospirillum sp produced similar root yield as 100 kg N without treatment. The majority of research has been conducted outside of the U.S. on soils which do not have the same microbial activity as Minnesota soils. A recurring issue with microbial treatments is the ability for the microbe to establish itself when it is not native to the soil and the ability to establish in the presence of high rates of nitrogen. Free living N fixers typically are less active when high rates of N are applied. Some native strains of bacteria are currently being engineered to allow for colonization on plant roots when near optimal rates of N are applied. These bacteria will not likely supply the majority of the N requirement by a crop but may help supplement N to the crop potentially reducing the need for supplemental N application.

Objectives:

1. Evaluate nitrogen fertilizer requirement for sugar beet.

2. Determine whether a biostimulant such as chitosans or beneficial N fixing bacteria can increase sugar beet yield and reduce the amount of N required to maximize root yield and recoverable sugar per acre.

Materials and Methods: Two field locations were established in spring 2020 in Minnesota one located at the Northwest Research and Outreach Center at Crookston and the second on a farmer field near Wood Lake (Table 1). Trials laid out using a strip plot design. Main blocks consisted of six rates of N (0, 40, 80, 120, 160, and 200 lbs of N) at Crookston and eight rates of N (0, 30, 60, 90, 120, 150, 180, 210 lbs of N) at Wood lake. All fertilizer was applied as spring urea (46-0-0) applied to the soil and incorporated prior to planting.

The biostimulant treatment were applied in-furrow across the N rates as strips randomized within each replication. Biostimulant treatments included none, High Tide [chitosan additive manufactured by Tidal Vision and applied at 75 mL/ac (30 mL/gallon of starter)], and a mixture of 60 oz/ac of Bio Red plus 22.5 oz/ac of Bio Mate. Bio Red and Bio Mate contain Azotobacter, Clostridium, and Lactobacillus bacteria which are nitrogen fixing bacteria, plus sugar which acts as a food source for the bacteria. Bio Red and Bio Mate were sourced locally through a Biovante distributor at Grand Meadow, MN and High Tide was sourced through Amazon.com. All biostimulant treatments were mixed with deionized water and the mix was combined 1:1 v/v with 3 gallons per acre of 6-24-6. The combined solution starter/biostimulant mixture was applied at a rate of 6 GPA. The no biostimulant control included 6-24-6 and deionized water only.

Soil samples will be collected from each replication at 0-6, 6-24, and 24-48" as a single composite sample from each trial area. Initial soil test information is summarized in Table 2. Leaf blade and petiole samples were collected in early July (Table 1) by sampling the uppermost fully developed leaf. Extractable nitrate-N was determined following extraction with 2% acetic acid. Petiole and leaf blade samples was analyzed for total N dry combustion.

Plots were harvested at the end of the growing season and root samples will be analyzed for quality parameters. The variety planted at each location was Crystal 796RR at Crookston and SV 863 at Wood Lake. All practices, weed and disease control, planting, and tillage were consistent with common practices for the growing regions. All statistical analysis was conducted using SAS 9.4 assuming fixed effects of Site, N rate, biostimulant treatment and their interaction and random blocking effects. Treatments are considered significant at the $P \leq 0.10$ probability level.

Results

A summary of main effect significant is given in Table 3. Figures 1 through 5 summarize sugar beet response to N at the two trial locations. Data are summarized across all biostimulant treatments when the statistical analysis indicated no N rate by biostimulant interaction for a given locations. The summary of the main effect of the biostimulant treatments are given in Table 4.

Sugar beet emergence was significantly impacted by N rate at both locations and by the biostimulant treatment only at Crookston (Table 3 and Figure 1). In both cases, sugar beet emergence was less as the rate of N applied as spring urea increased. The decrease was quadratic at both locations where the difference in emergence was generally non-significant between no nitrogen and the lowest rate applied at both locations and the effect increased with increasing N application rate. The effect to of the biostimulant treatment at Crookston occurred when emergences was reduced more when the biostimulant products were used but only at higher rates of applied N. When 120 lbs of N or less was applied there was no difference among the biostimulant treatments at Crookston and the greatest different was between the no-biostimulant treatment and the BioRed/BioMate treatment when 200 lbs of N were applied. Overall, the impact of the biostimulant treatment was relatively minor compared to the impact that spring urea had on emergence.

Sugar beet root yield as impacted by N application rate at both locations and was not affected by use of biostimulant (Table 3). The amount of N applied with starter (2 lbs/ac) was combined with the amount of residual nitrate in the top four feet of the soil (Table 2) and related to root yield. Root yield responded to 81 lbs of total N at Crookston. At Wood Lake two models were fit to the data. First, root yield appeared to increase up to the highest total N rate, 242 lbs, fitting a quadratic model. A linear plateau model could also be fit where root yield maximized at 177 lbs total N. In either case sugar beet root yield was more responsive to nitrogen than expected at the Wood Lake location.

The decrease in plant population did not impact sugar beet root yield at either location. The loss of population was compensated by the sugar beet plants which increased the mass of roots per plant (not shown). While higher rates of N as spring urea could reduce yield the effect on root yield should be minimal if the variety planted can compensate by growing larger roots. In fact, at Wood Lake the highest rate of N applied, 210 lbs/ac, reduced emergence by 20% and increased root yield by 40%. This speaks to the ability for sugar beet to compensate for reduced stands by increasing root size.

Nitrogen rate effects on extractable sucrose are summarized in Figures 3 and 4. Nitrogen rate effected extractable sucrose per ton at Crookston but not at Wood Lake (Table 3). At Crookston, extractable sucrose per ton was greatest for 80 lbs total N, similar to the total N which maximized root yield, and decreased as total N increased past 80 lbs. A decrease in extractable sucrose with increasing total N is expected. Extractable sucrose generally increase as total N increased but the effect was more variable, and a statistical model could not be fit to the data. Since root yield was not maximized at the highest amount of total N an increase then decrease in extractable sucrose per ton would not be expected at Wood Lake as the peak would be beyond the greatest rate of N applied. Biostimulant treatments impacted extractable sucrose per ton at Wood Lake. However, neither biostimulant source differed from the no-biostimulant control at Wood Lake. The only difference at Wood Lake was between the High Tide treatment which produced greater, on average, extractable sucrose compared to BioRed/BioMate.

Extractable sucrose per acre followed similar trends as root yield maximizing close to 80 lbs of total N at Crookston while increasing up to the highest total N rate at Wood Lake (Figure 4). No decrease in extractable sucrose on a per acre bases was found at Crookston where extractable sucrose per ton decreased as N was applied beyond the optimal N rate.

Petiole nitrate concentrations were determined following sampling in early to mid-July. Leaf blade nitrate was also analyzed but the data were more variable and are not included in this report. Nitrogen application rate significantly impacted petiole nitrate concentration at both locations while the biostimulant treatments only impacted petiole nitrate at the Wood Lake location (Table 3). The effect of biostimulant at Wood Lake was a reduction in petiole nitrate concentration when BioRed/BioMate was applied. In fact, there was a significant interaction between N rate and biostimulant treatment at Wood Lake where difference in petiole nitrate concentration between the BioRed/BioMate treatment compared to the no biostimulant control or High Tide treatment only occurred at the highest rates of N applied. This difference among the biostimulant sources was not reflected in differences in root yield.

In all cases the effect of N rate on petiole N concentration were curvilinear where petiole nitrate concentrations increased slowly at first then rapidly as total N reached or exceeded the amount of N needed to maximize root yield (Figure 5). Data from Crookston and Wood Lake were combined with data from a separate N rate trial established near Lake Lillian, MN also in 2020 (yield data for the Lake Lillian trial are not included in this report). Yield data were converted at each location to a relative basis (deviation from maximum site yield) by dividing root yield for each plot in all locations by the maximum yield produced for a given location. For Crookston and Wood Lake the maximum yield was assumed to be the yield produced at the plateau as identified by the quadratic- or linear plateau models.

Petiole nitrate concentration was regressed with relative yield and the data are given in Figure 6. Data indicate that 100% of maximum root yield was achieved with a petiole nitrate concentration near 850 ppm. However, relative root yield for plots ranged from 50-110% for petiole nitrate concentration less than 850 ppm. The high range in relative yield levels for petiole nitrate concentration does present some issues for using petiole nitrate concentration to assess nitrate sufficiency to direct supplemental application of N for sugar beet. The range in relative yield values is similar to what is seen with other tests such as the corn basal stalk N test. While we could say that 850 ppm would be a sufficient petiole nitrate concentration for sugar beet what to do if you concentration is below that level is more difficult to determine. As we continue the nitrogen work, we will add more data to the dataset. One item of note is that root yield at Lake Lillian did not respond to nitrogen and yield levels were 40+ tons similar to Wood Lake, yet many of the petiole nitrate concentration were less than 850 ppm. Past research has also not been able to calibrate the petiole nitrate test. The petiole nitrate test may work to help manage nitrogen at specific locations, but it may not be possible to determine which locations it may work until yield data is available at a given location.

Conclusions

Based on the 2020 data the biostimulant products did not provide any nitrogen or enhance yield for sugar beet. It should be noted that research was conducted at only two locations and it cannot be determined whether a response might occur given a specific circumstance. However, the amount of data available does not indicate widespread benefits for the use of biostimulant for sugar beet production. Sugar beet response to N was greater than expected at one location but the data at that location does not mean the amount of N applied to all sugar beet fields in the southern growing region need to be adjusted. The data will be added to additional current data on sugar beet response to nitrogen. The current suggested rates of N to achieve optimal extractable sucrose per acre is 123 lbs of N in the southern growing region and 130 lbs of N in the northern growing region (applied N plus nitrate-N in a two-foot soil sample). Petiole nitrate concentration did respond to the addition of nitrogen fertilizer but could not be accurately calibrated to determine how much fertilizer to apply if petiole nitrate concentration is less than 850 ppm.

Acknowledgments

The authors would like to thank the research crews at the Southern Minnesota Beet Sugar Cooperative, the Department of Soil, Water, and Climate Field Crew, and the research staff at the Northwest Research and Outreach Center for their work with this study. I would also like to thank both Southern Minnesota Beet Sugar Cooperative and American Crystal Sugar Co. for providing the quality analysis for this research, and the Sugar beet Research and Education Board of Minnesota and North Dakota for providing funding for this project.

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Table 1. Location, planting and sampling information and dominant soil series for each location.

	Date of				Soil		
Location	Urea Application	Planting	Tissue Sampling	Harvest	Series	Texture†	Classification‡
Crookston	18-May	18-May	14-Jul.	15-Sept.	Wheatville	FSL	Ae. Calciaquoll
Wood Lake	22-Apr.	22-Apr.	9-Jul.	5-Oct.	Canisteo	CL	T. Endoaquoll

† CL, clay loam; FSL, fine sandy loam.
‡Ae, aeric; T, typic

Table 2. Summary of soil test results for 2020 locations.

	0-6” Soil Test				Soil Test Nitrate-N	
Location	Olsen P	Ammonium Acetate K	pH	SOM	0-2’	2-4’
	----------ppm----------			----%----	--------------------lb/ac--------------------	
Crookston	75	185	8.1	4.1	15	12
Wood Lake	69	274	7.5	4.5	22	8

Table 3. Summary of analysis of variance for main effects of nitrogen application rate (N rate) and biostimulant (Bio.) and their interaction at Crookston (CRX) and Wood Lake (WL), MN in 2020.

	Emergence		Petiole N		Yield		Recoverable Sugar (ton)	
Effect	CRX	WL	CRX	WL	CRX	WL	CRX	WL
	--*P*>F--							
N rate	***	***	***	***	*	***	**	0.32
Bio.	0.88	0.44	0.48	**	0.40	0.16	0.13	0.08
N rate x Bio.	*	0.71	0.75	*	0.46	0.37	0.13	0.51

†Asterisks represent significance at P<0.05,*; 0.01, **; and 0.001, ***.

Table 4. Summary of the main effect of in-furrow biostimulant source for selected variable at Crookston (CRX) and Wood Lake (WL), MN in 2020. Letters indicating least significant difference are only listed in the table when the main effect of biostimulant was significant.

	Emergence		Petiole N		Yield		Rec. Sugar (ton)		Rec Sugar (acre)	
Biostimulant	CRX	WL	CRX	WL	CRX	WL	CRX	WL	CRX	WL
	------%------		----ppm----		--tons/ac--		---lb/ton---		----lb/ac----	
None	71	72	2766	905a	23.9	35.9	306	299ab	7314	10670
BioRed/Mate	69	75	3058	621b	22.9	34.6	308	295b	7093	10227
High Tide	71	72	2745	852a	25.3	34.7	304	301a	7701	10474

†Numbers followed by the same letter are not significantly different at the $P \leq 0.10$ probability level.

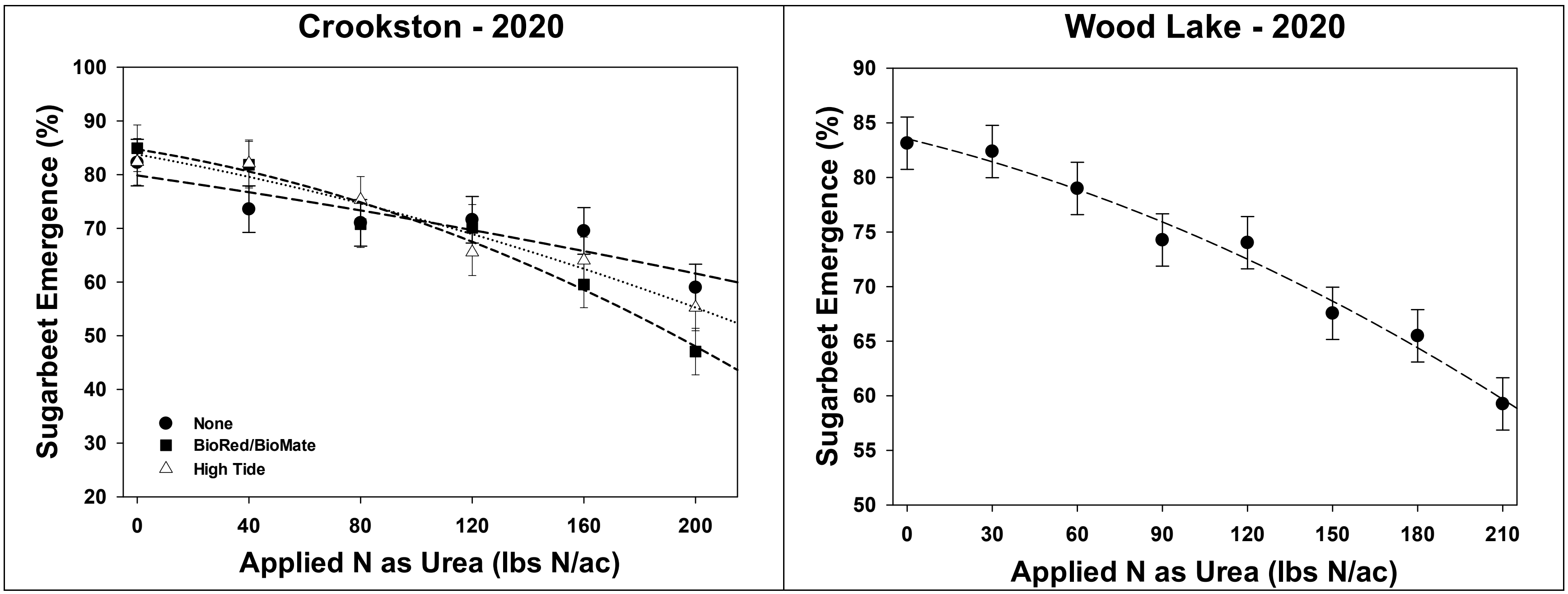

Figure 1. Effect of nitrogen applied as spring urea on sugar beet emergence at two Minnesota locations during the 2020 growing season.

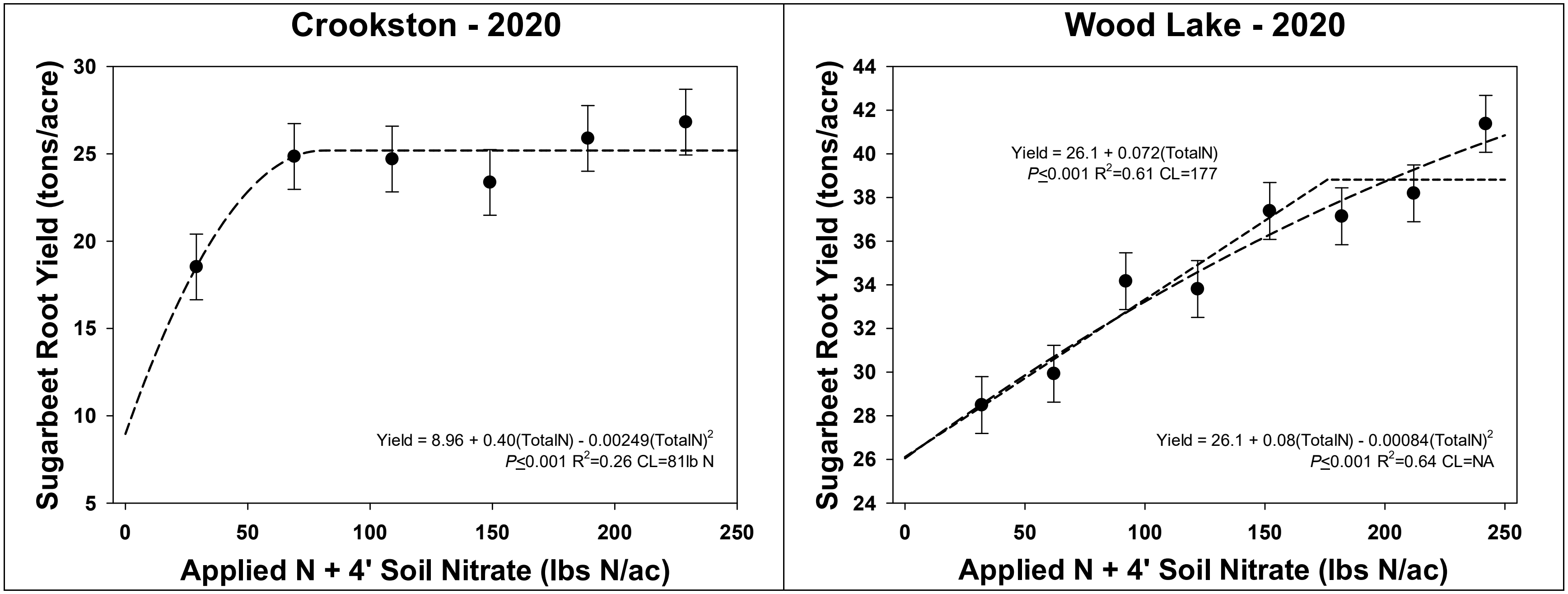

Figure 2. Effect of nitrogen applied as spring urea plus the nitrate in a four-foot on sugar beet root yield at two Minnesota locations during the 2020 growing season.

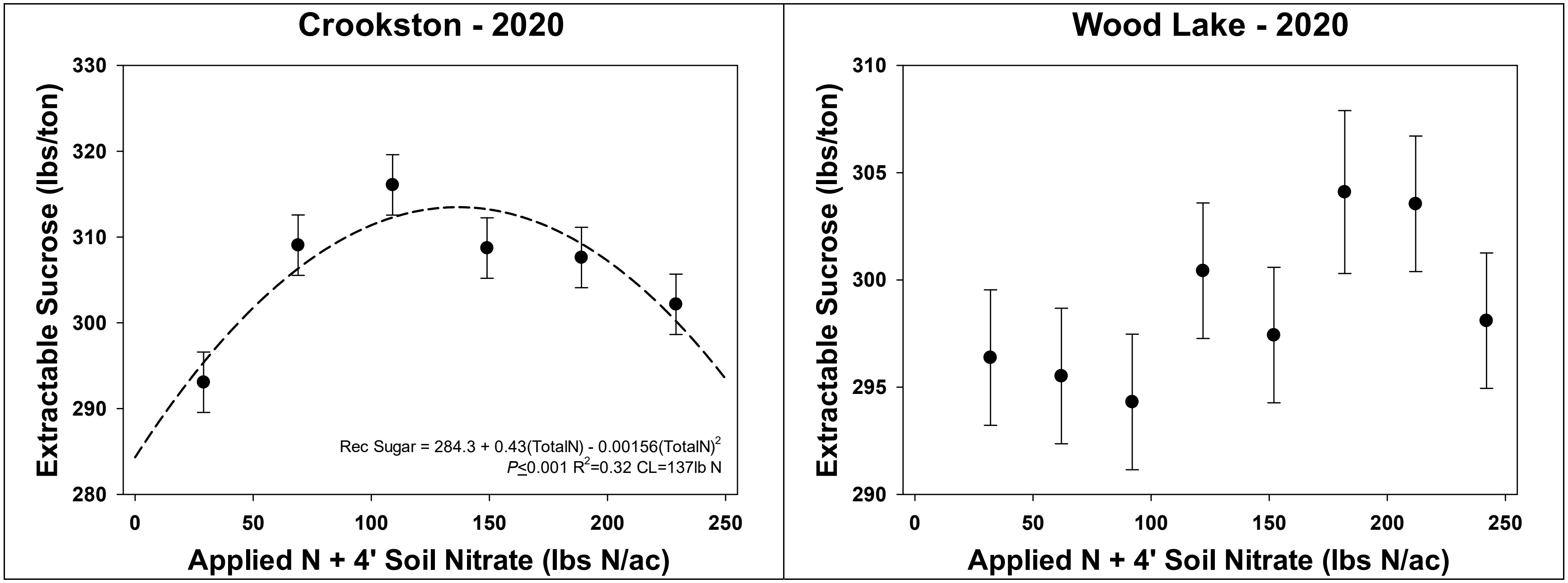

Figure 3. Effect of nitrogen applied as spring urea plus the nitrate in a four-foot on sugar beet extractable sucrose per ton at two Minnesota locations during the 2020 growing season.

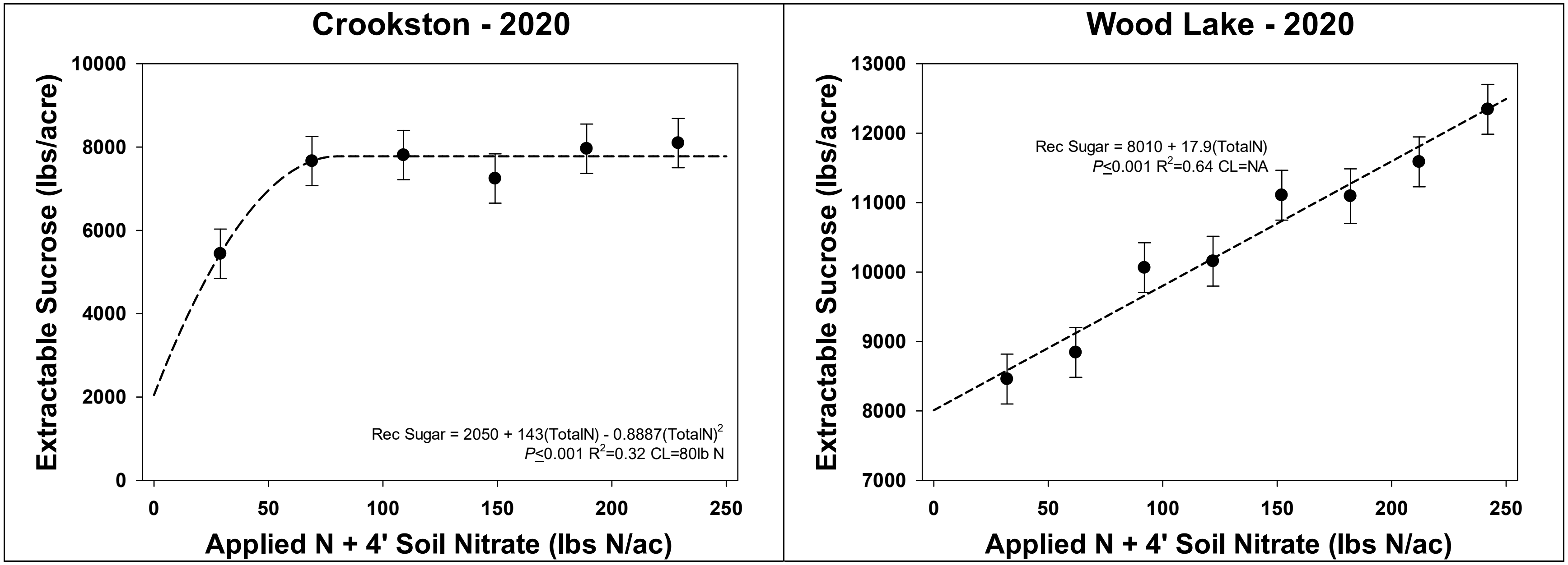

Figure 4. Effect of nitrogen applied as spring urea plus the nitrate in a four-foot on sugar beet total extractable sucrose per acre at two Minnesota locations during the 2020 growing season.

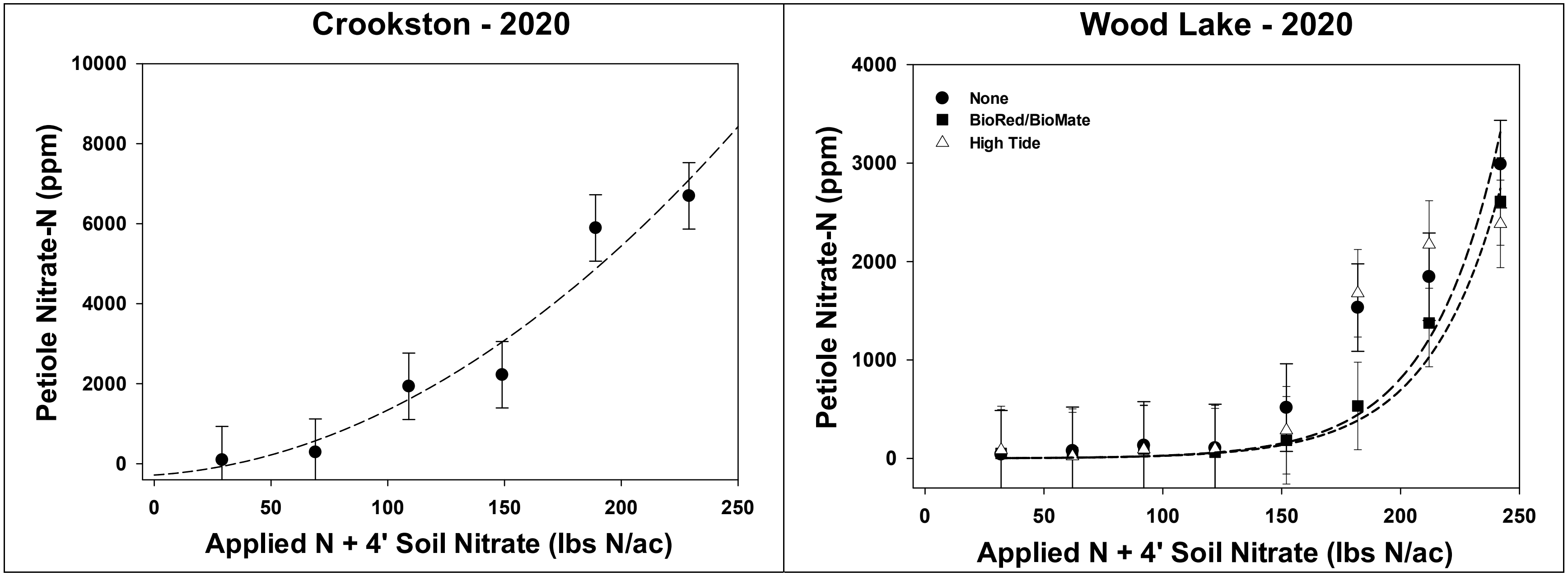

Figure 5. Effect of nitrogen applied as spring urea plus the nitrate in a four-foot on sugar beet early to mid-July petiole nitrate measured from the newest fully developed leaf at two Minnesota locations during the 2020 growing season.

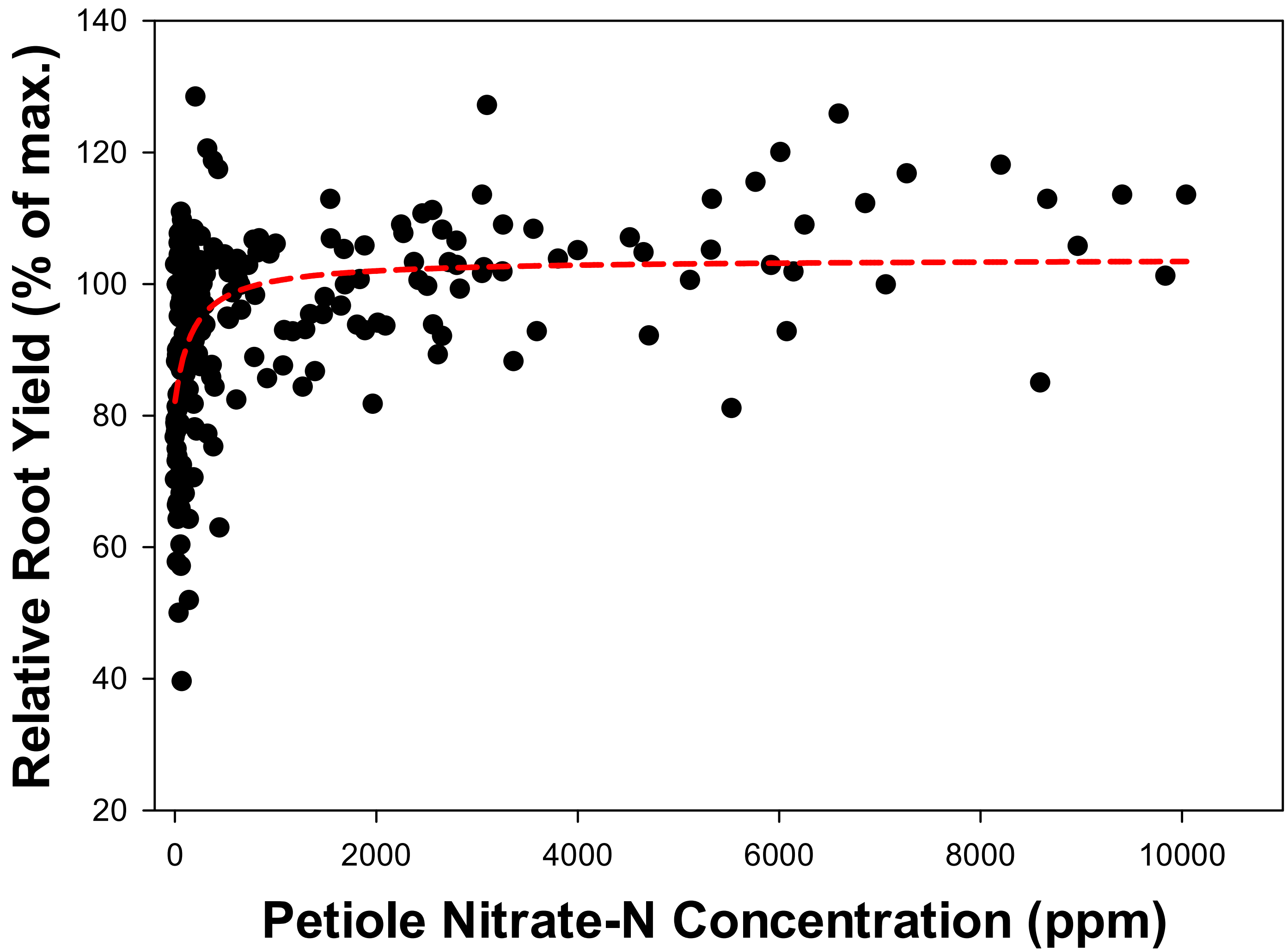

Figure 6. Relationship between relative sugar beet root yield (% of site maximum yield) and nitrate concentration in the uppermost fully developed petiole sampled in early- to mid-July.