SUGAR BEET PRODUCTION AFTER PREVIOUS CROPS OF CORN, WHEAT, AND SOYBEAN

Albert L. Sims (Associate Professor), University of Minnesota, Northwest Research and Outreach Center.

Sugar beet production has typically followed a small grains crop, such as hard red spring wheat (HRSW) in the Red River Valley (RRV) of Minnesota and North Dakota. However, in the southern part of the RRV and in the Southern Minnesota Beet Sugar Cooperative growing area, sugar beet production generally follows a previous crop of corn. Sims (2004) reported corn residue had a negative effect on sugar beet yield, but that effect appeared not to be related to nitrogen (N) availability. Following a typical HRSW crop, wheat residue had minimal or no effect on the following year's sugar beet root yield and quality. Corn production is expected to increase in sugar beet growing areas north of Fargo. Growers have raised concerns about the negative effects of the corn residue and have asked if managing the corn residue with a moldboard plow instead of a chisel plow would reduce this negative effect.

Another crop that has increased in acreage in sugar beet growing areas is soybean. Currently, it is not recommended that sugar beet be grown after a previous crop of soybean. Previous research in the RRV showed reductions in both sugar beet root yield and quality (recoverable sucrose per ton of beet) when grown after soybean compared to grown after a small grain crop (Smith and Dexter, 1988). However, Soine and Severson (1975) and Nordgaard et al., (1982) found no or, perhaps, a positive effect of a previous crop of soybean on sugar beet root yield and quality. Soybean production is expected to increase in the northern sugar beet growing area of Minnesota and North Dakota. Furthermore, this increased soybean production will likely displace small grains production. Thus the likelihood that sugar beet will be grown after a previous crop of soybean will increase in the future.

The current trial was established to examine the combined effects of previous crop, primary tillage of the previous crop, and N management of the following sugar beet crop. More specific objectives are:

Objectives

1. Determine if sugar beet root yield and quality are different when grown after previous crops of corn, wheat, or soybean.
2. Determine if sugar beet response to previous crops is altered by primary tillage (moldboard plowing or chisel plowing) after the previous crops were harvested.
3. Determine if sugar beet root yield and quality response to fertilizer N rates (and optimum N rate) varies with the previous crop or the primary tillage used on that previous crop.
4. Evaluate the effect of previous crop and fertilizer N rate on soil N availability to the sugar beet crop during the growing season.

Materials and Methods

A field experiment was initiated at the Northwest Research and Outreach Center near Crookston, Minnesota on a soil classified as Wheatville very fine sandy loam (Coarse-silty over clayey, mixed over smectitic, superactive, frigid aeric Calciaquoll). The experimental area was 360 ft wide by 520 ft long to accommodate 16 initial plots that were 44 or 48 ft wide and 240 ft long plus turnaround space for planters, sprayers, cultivators, and combines. Initial plots were grouped into four replications or blocks. In spring 2006, initial plots were planted to corn, wheat (hard red spring wheat) and two adjacent plots of soybean and will be referred to as previous crops in the remainder of this report. Wheat was planted with an 8-ft plot drill making a 48 ft wide plot necessary. Corn and soybean plots consisted of 24, 22-inch wide rows making each plot 44 ft wide. Previous crop plots were 240 ft long allowing extra length allowing enough space for chaff and straw to work through the combine and be uniformly distributed where the actual beet plots will be located. This distance also included a 30 ft center allowing turn-around space between primary tillage plots for tillage operations.

The experimental design was a split-split-plot randomized complete block design with whole plot treatments grown to the four previous crops; corn, soybean, soybean-RR, and wheat. Each previous crop plot was split in the fall after harvest and randomly assigned to one of two primary tillage operations, chisel plow with twisted spikes (CP) or moldboard plow (MP). In the spring of 2007, each tillage split-plot was split again into six split-split-plots each randomly assigned to one of six nitrogen (N) rates; 0, 25, 50, 75, 100, and 125 lbs. N A^{-1}.

Wheat was harvested in August 2006 with a commercial combine and primary tillage took place within a few days of harvest. When soybean leaves started to senesce in September 2005, most of the above ground biomass or residue was removed in one soybean plot (soybean-RR) by cutting with a swather and the residue removed from the plots using a forage chopper. A Carter small plot forage harvester was used to remove any excess residue leaving stubble of about 2 inches or less. The corn and remaining soybean plot was harvested at maturity with a commercial combine. After harvest, corn stalks were shredded and corn and soybean plots, including soybean-RR, were split and primary tillage treatments imposed. Primary tillage operations on the corn and soybean plots were done in early October. Secondary tillage with a chisel plow was done over the entire experimental area in late October as a last operation prior to winter.

In spring 2007, fertilizer N was hand applied to each split-split-plot using urea-N. A general broadcast of phosphorus (P) fertilizer (0-46-0) was also applied over the entire experimental area. To incorporate the fertilizer and prepare the seedbed for planting the experimental area was tilled with a tandem disk, which also cut the corn stalks, followed by a field cultivator with packing rolling baskets. Sugar beet (VanderHave 46519) was planted on April 28 with a 12 row Maxi Merge John Deere planter. Sugar beet rows were oriented perpendicular to the corn, soybean, and wheat rows and direction of the previous crop harvest to reduce potential differences among sugar beet plots due to deposition of chaff after the combine. Each split-split-plot was of 6, 22 inch rows wide and 30 ft long. Three gals 10-34-0 A^{-1} liquid starter fertilizer was seed applied at planting. Sugar beet was over-seeded and later hand thinned to 175 beets per 100 ft of row. Cultivation and applications of herbicides and fungicides were done as needed. In late September the middle two rows of each plot were harvested with a small plot beet lifter. The lifted beets were weighed and 10 randomly selected beets were sent the American Crystal Quality Laboratory in East Grand Forks to determine tare, sugar percentage, and percent impurities identified here as loss-to-molasses (LTM).

Soil samples were collected September 26 2006 from each previous crop plot. Each previous crop plot was represented by a composite of four soil cores (1.5 inch diameter and 4-ft deep) that were divided into 0-6, 6-12, 12-24, and 24-48 inch increments. These cores were analyzed for nitrate-N. Starting May 8th 2007, after sugar beet was planted, soil samples were collected every 2 wks from the selected split-split plots; those chisel plowed as primary tillage and receiving 0 and 75 lbs N A^{-1}. Individual split-split plots were represented by a composite of ten soil cores (.75 inch diameter and 1 foot deep) taken from between rows 1 and 2 and between rows 5 and 6 then divided into 0-6 and 6-12 inch increments. These soil samples were analyzed for nitrate- and ammonium-N. After five soil samplings the sugar beet canopy was nearly closed. At that point, sugar beet leaf petioles were collected in the same plots. Seven of the most recently matured petioles were collected each of rows 2 and 5 and combined into one sample (14 petioles). In the laboratory, the petioles were separated from the leaf blade and analyzed for nitrate-N. Just prior to sugar beet harvest, six feet from each of rows 2 and 5 in these same plots were hand harvested and the tops separated from the beet root. The tops were weighed, chopped, sub sampled, dried, and nitrate-N and total Kjeldahl nitrogen (TKN) determined. The roots were washed, weighed, split in two with one half brushed against a commercial sized cheese grater to obtain a beet sample from across the entire face of the split root. The shavings were sub sampled for moisture determination with the remainder freeze dried, ground, and analyzed for nitrate-N and TKN.

Data were analyzed using the Proc Mixed procedure in SAS 9.2. Specific analysis compares sugar beet root yield and yield parameters for previous crop, tillage, N rates and their interactions. Single degree of freedom orthogonal contrasts were used to separate meaningful comparisons. The nitrogen data (soils, petiole, and total plant) will be analyzed using SAS 9.2 comparing previous crop and N rates, but the analysis was not completed at the time of this report. Statistical significance was set at 0.05 or less.

Results

General Information

Soil moisture conditions prior to planting the sugar beet were considered adequate, but not excessive. As the growing season progressed the sugar beet experienced short periods of moisture stress, but this stress was considered moderate compared to that experienced in the 2006 growing season.

In the fall of 2006, residual soil NO_3-N in the top 4-ft of the soil profile within the experimental area ranged from 35 to 74 lbs. A^{-1}. Averaged across replications, residual NO_3-N was 52, 36, 42, and 62 lbs. A^{-1} following corn, soybean-RR, soybean, and wheat, respectively. Current University of Minnesota fertilizer N recommendations (Lamb et al., 2001) and allowing a 40 lb. N credit following soybean would indicate that about 80, 55, 50, and 70 lbs. fertilizer-N A^{-1} should be applied following the same respective crops for optimum sugar beet production.

In the third week of June, I spotted two sugar beet plants that appeared to be dying. Dead or dying sugar beet plants were counted in rows 2, 3, 4 and 5 of all plots and marked with swizzle sticks on June 27th, July 23rd, and September 3rd. Though not screened in the laboratory, it was presumed that the dead and dying plants were caused by Rhyzoctonia root rot disease. It was also presumed that the visual identification of the dead or dying plants did not identify all plants affected by the disease. After the sugar beet plots were detopped in preparation for harvest, but before the actual harvest, plant skips in these same rows exceeding 16 inches were measured and noted. These row skips were matched against plant stand counts taken in late May and dead plant counts in an attempt to estimate the area of those plots that might have been directly affected by the Rhyzoctonia root rot. Sugar beet root yields as affected Rhyzoctonia root rot were used in the analyses and comparisons of treatment effects. The impact of this disease on the sugar beet root yield is estimated in Fig 1. In Figure 1, the predicted root yield and measured root yield would be the same if root rot was not a factor (solid diagonal line). Data points below the 1:1 diagonal line indicate root rot reduced the actual root yield. Follow corn, there was little impact of root rot on sugar beet root yield. But following soybean (soybean and soybean-RR) and wheat, root rot had a more substantial effect on the measured sugar beet root yield.

Sugar Beet Root Yield:

Sugar beet root yield was significantly increased with the addition of fertilizer N, but significant interactions (Table 1) between the previous crop and N rates suggests this response varied with previous crop. The primary cause of the significant interaction was the relatively small increase in yield with applied N following wheat compared to following either corn or soybean (Fig 2a). Sugar beet root yields were least following corn and greatest following wheat at all N rates. Yields following soybean were nearly parallel those following corn, but elevated by about 3 ton A^{-1}. Following wheat, root yields tended to maximize near the 50 lbs. N A^{-1} rate, but more N was required to maximize root yield following corn or soybean. Figure 2a indicates differences in sugar beet root yield following corn or wheat are not caused by N availability. However, differences in sugar beet root yield follow soybean or wheat may be related to N availability. Sugar beet root yield following soybean or soybean-RR were only similar at the higher N rates with more N being necessary to achieve those yields following soybean (Fig 2b). Apparently, the soybean residue is reducing N availability, presumable by N immobilization during residue decomposition. Sugar beet root yield response to N rates was similar after a crop of wheat or soybean-RR (Fig 2a and b). In addition, overall root yields were similar between these two previous crops.

Sugar Beet Root Quality:

Sugar beet root quality is defined as the sugar percentage minus the loss to molasses (LTM) and adjusted to lbs. of recoverable sucrose per ton of beet. Interactions on sugar beet root quality between previous crop and N rates were significant (Table 1). Root quality tended to decline as N rates increased following wheat (Fig 3a), but there was a rise in root quality as lower N rates increased following both soybean and corn. In the latter situations, higher rates of N caused a decrease in sugar beet root quality primarily following soybean. The removal of soybean residue caused a sugar beet root quality response to N rates similar to that following wheat (Fig 3a and b).

Recoverable Sucrose:

Significant interaction affects on recoverable sucrose between previous crop and N rates were similar to those of root yield and root quality. Note that this parameter is really a calculation of root quality and root yield. Subsequently, Fig 4 a and b show that total recoverable sucrose was similar among all previous crops, but that it required more fertilizer N to do so following soybean and corn than following wheat (Fig 4a) and soybean-RR (Fig 4b).

Summary and Discussion

The data indicate that sugar beet production differs depending on the preceding crop that was grown. Root yields were greater following wheat than following corn regardless of the amount of fertilizer N that was applied. This is consistent with results reported by Sims (2007) for the 2006 growing season. When sugar beet is grown after a crop of soybean, root yields were still greater than when following corn but, less than following wheat. Interestingly, when the soybean residue was removed the sugar beet root yield and quality were not that different compared to those following wheat. In addition, sugar beet response to N rates was similar when following wheat and soybean-RR. Sugar beet root quality tended to start declining throughout the range of applied N rates when following wheat and soybean-RR. On the other hand, when following soybean or corn, some added N was necessary to maximize the sugar beet root quality.

These observations suggest that nitrogen availability varies between the previous crops. That is, nitrogen availability is greater following wheat and soybean-RR than following soybean or corn. Figure 5 shows the measured soil inorganic N in the surface 12 inches of the soil profile through the first 82 days of the growing season.

In the surface 6 inches (Fig 5a and b), inorganic N was greater in the soybean-RR treatment compared to the other previous crops up through the first 50+ days of the growing season. There was little difference among the other previous crops. In the 6 to 12 inch soil depth, greater inorganic was measured in the soybean-RR treatment than other previous crops, but there was greater separation among the other previous crops (Fig 5c and d). The lowest inorganic N tended to occur when corn was the previous crop. Total Plant DM and N accumulation in the sugar beet crop were not greatly different among previous crops when 75 lbs N A^{-1} was applied as fertilizer, but when no fertilizer N was applied, greater plant DM and N accumulation occurred following soybean-RR and wheat (Fig 6).

A nitrogen credit of 40 lbs. N A^{-1} is generally given for a previous crop of soybean when determining the fertilizer N recommendation for the following crop. Most of the research I have seen where this credit had been identified involves growing corn after soybean compared to corn after corn. The data reported in this report would suggest that a 40 lbs N credit for soybean to a sugar beet crop may be appropriate when compared to growing sugar beet after corn. However, it may not be appropriate when compared to growing sugar beet after wheat. This brings into question the current N credit and where it comes from. My data indicate that soybean residue immobilizes N based on the requirement for more fertilizer N where soybean residue was left on the field compared to where residue was removed to achieve similar sugar beet yields. Research reported by Sims (2004) indicated that this was not the case when comparing wheat residue to where wheat residue was removed. Future N recommendations for sugar beet may need more refinement with strong consideration given to the previous crop. This will require more detailed N calibration trials in the RRV. Nitrogen availability for sugar beet production apparently has different dynamics depending on the crop preceding sugar beet.

The findings of this research indicate that growing sugar beet after a wheat crop is consistently the better rotation of the three previous crops tested. Furthermore, this research indicates that negative issues of growing sugar beet after soybean are not great as growing sugar beet after corn. Following corn, there are sugar beet production issues that are not related to N and therefore cannot be corrected with additional fertilizer N.

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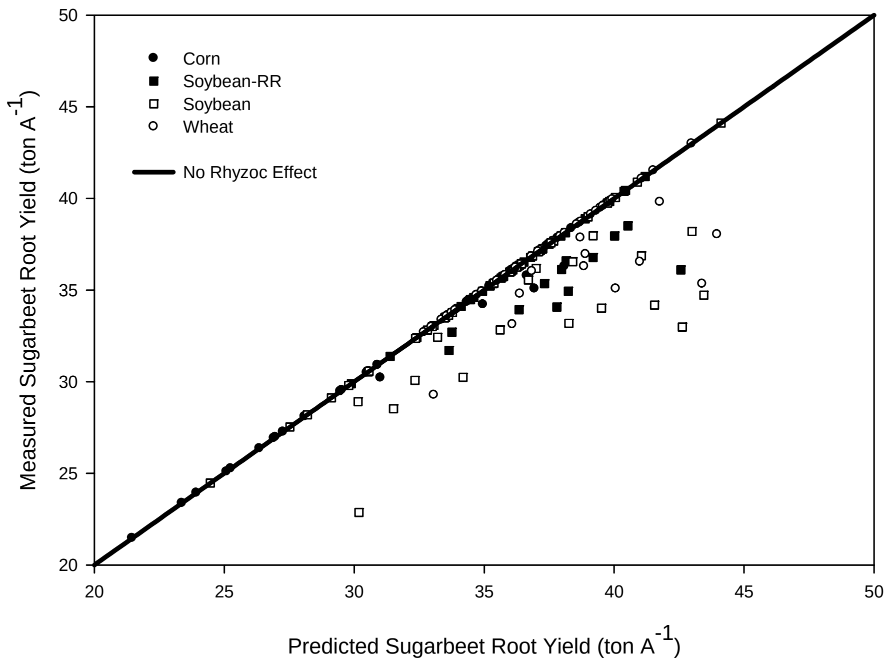

Figure 1. Potential sugar beet root yield effects caused by Rhyzoctonia Root Rot in the 2007 growing season

Table 1. Statistical Analysis with single degree of freedom Orthogonal Contrasts of primary sugar beet yield parameters in response to previous crop, primary tillage, and applied N rates in the 2007 growing season.

Source of Variation	Root Yield	Recoverable Sucrose	Root Quality	Loss to Molasses
Previous Crop	*	*	***	**
Legume vs Non-legume	ns	ns	ns	ns
Corn vs Wheat	**	**	***	***
Soybean (Residue vs No Residue)	ns	ns	**	*
Tillage (Plow vs Chisel)	ns	ns	ns	ns
Previous Crop vs Tillage	ns	ns	**	ns
Legume vs Non-legume by Tillage	ns	ns	*	*
Corn vs Wheat by Tillage	ns	ns	**	ns
Soybean (Residue vs No Residue) by Tillage	ns	ns	ns	ns
N rate	***	***	***	***
Linear	***	***	***	***
Quadratic	***	***	***	ns
Previous Crop by N rate	**	***	***	ns
Legume vs Non-legume by Linear	ns	*	***	**
Corn vs Wheat by Linear	***	***	***	ns
Soybean (Residue vs No Residue) by Linear	**	***	*	ns

Tillage by N rate	ns	ns	ns	ns
Previous Crop by Tillage by N rate	ns	ns	ns	ns

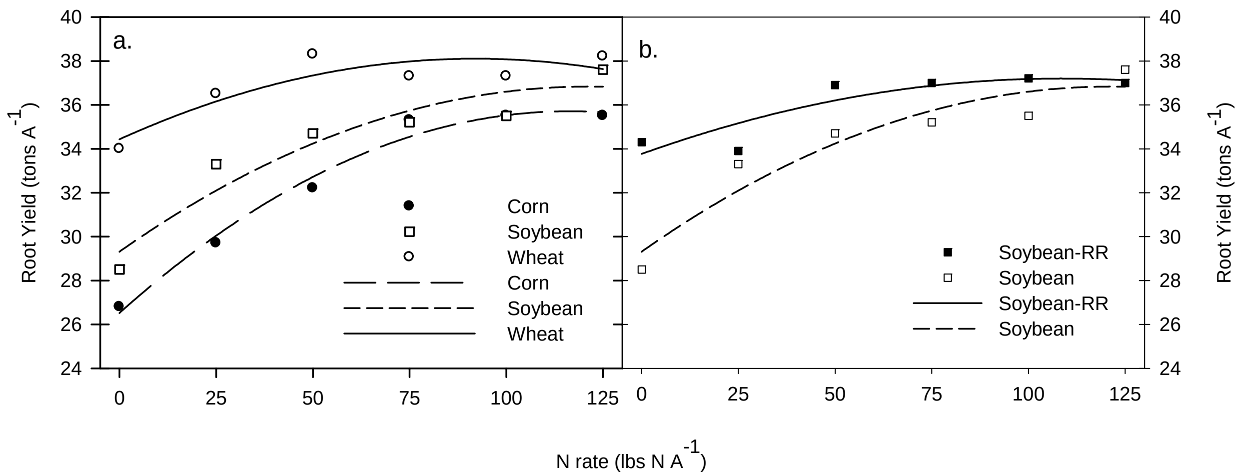

Figure 2. Response of sugar beet root yield to applied N rates in the 2007 growing season when grown after corn, soybean, and wheat.

a. Response when grown after corn, soybean, and wheat

b. Response when grown after soybean or soybean-RR (soybean with residue removed).

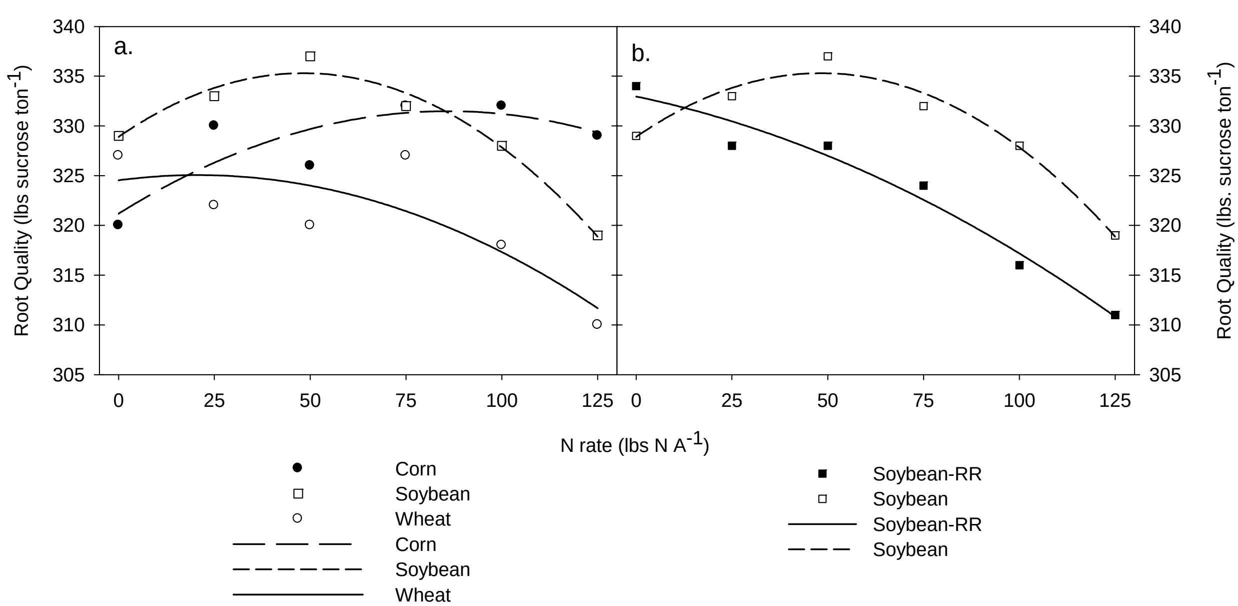

Figure 3. Response of sugar beet root quality to applied N rates in the 2007 growing season when grown after corn, soybean, and wheat.

a. Response when grown after corn, soybean, and wheat

b. Response when grown after soybean or soybean-RR (soybean with residue removed).

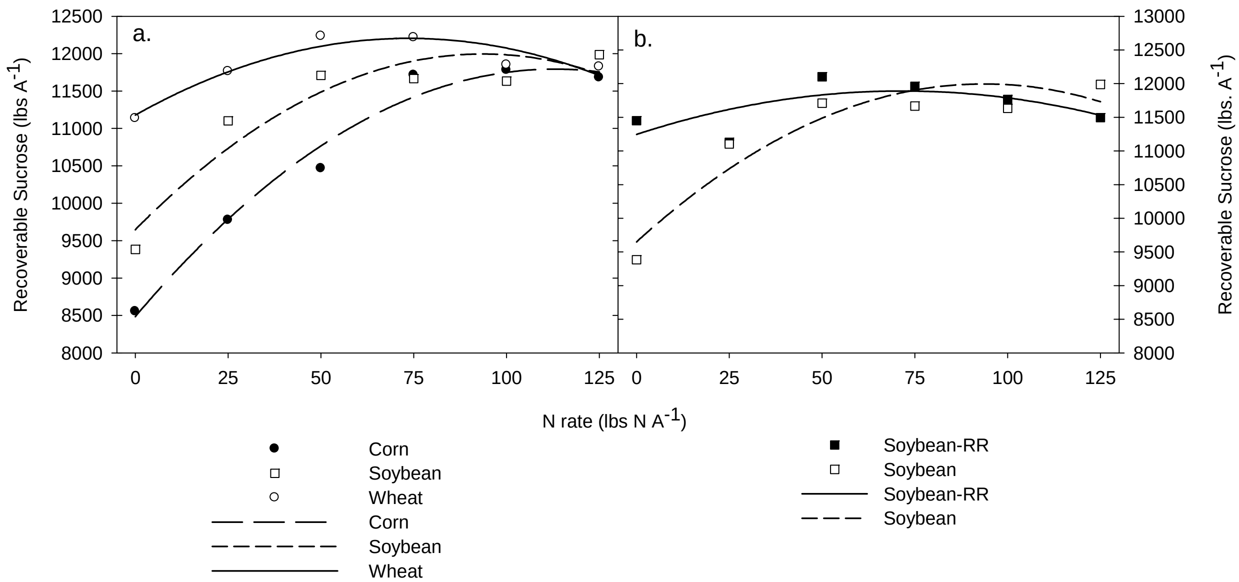

Figure 4. Response of sugar beet recoverable sucrose yield to applied N rates in the 2007 growing season when grown after corn, soybean, and wheat.
a. Response when grown after corn, soybean, and wheat
b. Response when grown after soybean or soybean-RR (Soybean with residue removed).

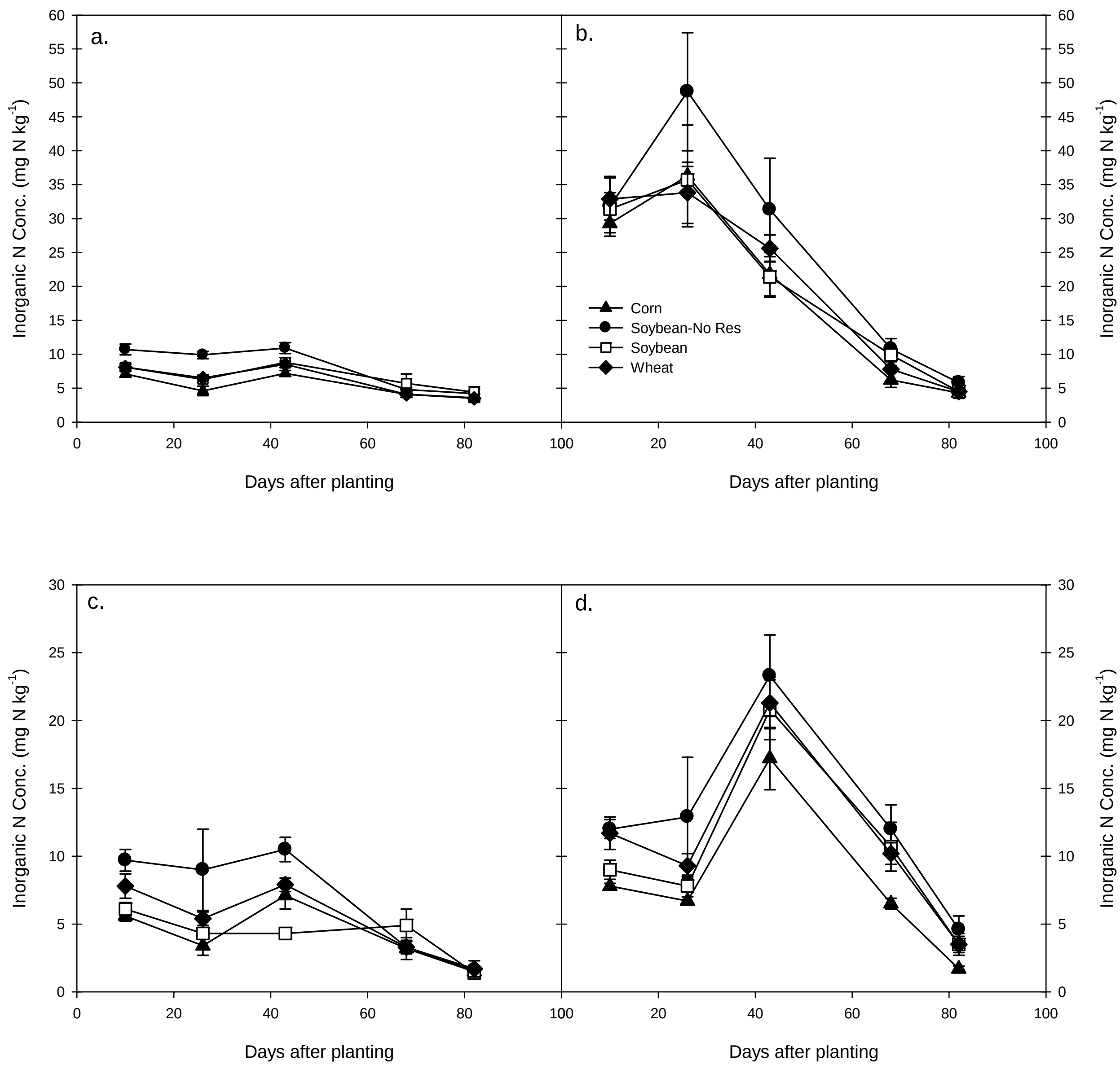

Figure 5. Soil inorganic N concentration (nitrate-N + ammonium-N) during the 2007 sugar beet growing season after previous crops of soybean, soybean-RR (residue removed), corn, and wheat. a. 0 – 6 inch soil depth, 0 N rate; b. 0 – 6 inch soil depth, 75 lbs. N A^{-1} rate; c. 6 – 12 inch soil depth, 0 N rate; b. 6 – 12 inch soil depth, 75 lbs N A^{-1} rate. Vertical bars associate with each mean value represents the standard error of that mean.

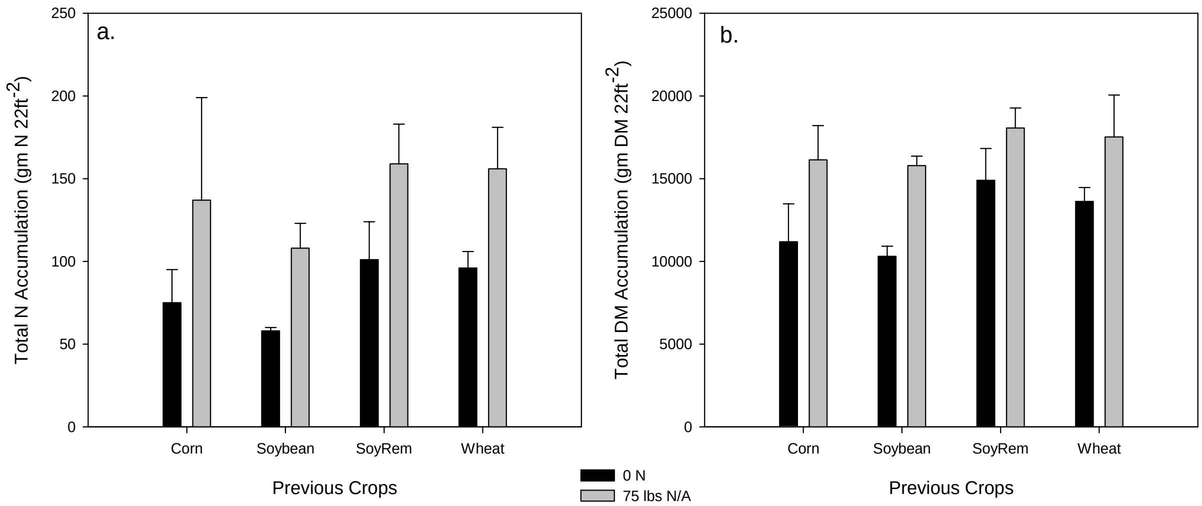

Figure 6. Total sugar beet nitrogen (a) and dry matter (b) accumulation in the 2007 growing season at two nitrogen fertilizer rates following four previously grown crops.