

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

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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 aeris Calciaquoll), but transitioned into a Gunclub silty clay loam (fine-silty, mixed, superactive, frigid aeris Caciaquoll). The experimental area was 360 ft wide by 460 long to accommodate 16 initial plots that were 44 or

48 ft wide and 210 ft long plus turnaround space for planters, sprayers, cultivators, and combines. Initial plots were grouped into four replications or blocks. In spring 2005, one plot each of corn and wheat (hard red spring wheat) and two adjacent plots of soybean were grown. Wheat was planted with an 8-ft plot drill making a 48 ft wide plot necessary. Corn and soybean plots were 24, 22-inch wide rows making each plot 44 ft wide. Previous crop plots were 210 ft long to allow for a 30 ft turn around area in the center of each plot for the primary tillage operations and to allow space for straw and chaff to work their way through the combine during harvest so that the actual sugar beet plots had a uniform application of previous crop residue.

The experimental design was a split-split-plot randomized complete block design with whole plot treatments grown to four previous crops; corn, soybean, soybean-NR, 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 2006, each tillage split-plot was split again into six split-split-plots each randomly assigned to one of six nitrogen (N) rates; 0, 30, 60, 90, 120, or 150 lbs. N A⁻¹.

Wheat was harvested in August 2005 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 was removed in one soybean plot (soybean-NR) 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 a stubble of about 2 inches or less. The corn and remaining soybean plot was harvested at maturity with a commercial combine. After harvesting, all corn and soybean plots, including soybean-NR, was divided into split-plots and primary tillage was done. 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 2006, 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. The experimental area was tilled with a field cultivator to incorporate the fertilizer then planted to sugar beet (VanderHave 46519) on May 8 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 previous crop harvest to reduce potential differences among sugar beet plots due to deposition of chaf after the combine. Sugar beet was over-seeded in split-split-plots that were 6 rows wide (22 inch wide rows) and 30 ft long. Three gals 10-34-0 A⁻¹ liquid starter fertilizer was seed applied at planting. Sugar beet seedlings were hand thinned to 150 beets per 100 ft of row and were cultivated and sprayed with herbicides and fungicides as needed. In late September the middle two rows of each plot were harvested with a small plot beet lifter, 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 in October 2005 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 30th 2006, after sugar beet was planted, soil samples were collected every 2 wks from the split-split plots receiving 0 and 90 lbs N A⁻¹ and were chisel plowed as the primary tillage in the fall of 2005. 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 four soil samplings the sugar beet canopy was nearly closed in plots receiving fertilizer N. At that point, sugar beet leaf petioles were collected in the same plots. Seven of the most recently matured petioles were collected from both the 2nd and 5th rows of the plots 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, subsampled, dried, and nitrate-N and total Kjeldhal 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 subsampled 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

Initial Conditions:

Soil moisture prior to planting sugar beet in the spring 2006 was not measured, but was considered sufficient to sustain the sugar beet crop through any short term drought period. That fact that 2006 was an extremely dry growing season and that sugar beet yields were greater than expected or record levels suggests spring soil moisture reserves were quite good. This may not be the situation going into the 2007 growing season.

Soil samples collected from all previous crop plots on Oct 10, 2005 were analyzed for residual soil nitrate-N. Over the entire four foot soil depth, soil nitrate-N was similar following corn and soybean with 27 and 26 lbs. N A⁻¹, respectively. Soil nitrate-N was similar following soybean-NR and wheat with 42 and 44 lbs. N A⁻¹, respectively. All previous crops had similar nitrate-N in the 24-48 inch soil depth increment with nitrate-N ranges of 10 to 13 lbs. N A⁻¹. Differences among the previous crops were primarily in the 0 to 24 inch soil depth increment with nitrate-N levels of 15, 16, 29 and 33 lbs. N A⁻¹ following corn, soybean, soybean-NR, and wheat, respectively. Following current N fertilizer recommendations (Lamb et al., 2001), maximum sugar beet yields should have required additional N fertilizer amounts of about 100 lbs. N A⁻¹ following corn and soybean (minus a 40 lbs N A⁻¹ credit) and 85 to 90 lbs. N A⁻¹ following soybean-NR and wheat.

During the growing season, sugar beet seedlings developed quickly and progressively early in the season. However, as air temperatures increased, drought conditions developed, and soil moisture reserves were used, slow sugar beet top growth and development in July compared to previous years was apparent. Sugar beet tops were visually more stressed following corn than other previous crops. Low N fertilizer treatments following corn did not close the canopy between the sugar beet rows at anytime during the growing season. Sugar beet canopy following soybean, soybean-NR, and wheat did close the row in July.

Sugar Beet Root Yield:

Sugar beet root yield ranged from 15 to 42 tons A⁻¹ in individual plots. Statistical analysis indicated significant interactions between primary tillage treatments and soybean verses

non-soybean and with corn versus wheat were significant (Table 1). The primary cause of the significant interaction was a 3 ton A⁻¹ yield increase with MP over CP on the previous wheat ground (Fig 1a). There was little difference between primary tillage methods in the other previous crops. The yield enhancement in MP treatments following wheat was caused by two high yielding individual plots that yielded 38 and 42 tons A⁻¹. All other plot yields in MP treated plots were similar to those of CP treated plots. This suggests that the observed difference between MP and CP may be an artifact of the data and not a real treatment effect. Averaged across the two primary tillage operations and N rates, sugar beet yields were least following corn and greatest following soybean-NR (Fig 1b). Root yields following soybean and wheat were similar.

Sugar beet root yield response to N rates varied among the previous crops (Table 1). In most cases the interaction suggested a linear response to N rates even though the slope of the response (root yield increase per increment of N) varied among previous crops. Sugar beet root yield response to N rates was similar following corn and wheat (no significant interaction) (Table 1; Fig 2b). Growing sugar beet after corn, however, resulted in nearly a 5 ton A⁻¹ decline in root yield compared to following wheat.

Root yields following soybean were similar to those following wheat, but there was less response to the N rates (Fig 2b). The difference in response was not great, but at the highest N rates there was a 1 to 2 ton A⁻¹ less roots following soybean than following wheat.

In Fig 2a, root yield response to N rates follow soybean and soybean-NR are compared. The interaction between N rates and previous crops is significant (Table 1). Maximum sugar beet root yield was similar between the two previous crops, but it appears less N was needed to obtain that yield when beets followed soybean-NR than when grown after soybean.

Recoverable Sucrose:

Net recoverable sucrose followed response trends similar to those described for root yield. There was a significant interaction between primary tillage and corn versus wheat as previous crops (Table 1). As with the root yield, this was caused by greater recoverable sucrose in MP than CP following wheat and little difference following corn (Fig 3a). Again the primary cause of the interaction was substantially greater root yields in two individual plots in MP following wheat. Averaged across both primary tillage treatments and N rates, recoverable sucrose was least when sugar beet followed corn, greatest following soybean-NR, and there was little difference between previous crops of soybean and wheat (Fig 3b).

Interactions between N rates and previous crops were significant (Table 1). Recoverable sucrose response to N rates was somewhat similar between previous crops of corn and wheat (Fig 4b) though the interaction was significant (Table 1). The response curves to N rates in these two previous crops appear quite similar, but there was more variability in the response to N rates following wheat than following corn. This variability was probably the cause of the statistical significant interaction. Where soybean was the previous crop, recoverable sucrose was less than following wheat at the higher N rates (Fig 4b). Recoverable sucrose was least when sugar beet followed corn at all N rates.

The impact of removing soybean residue is apparent in recoverable sucrose (Table 1; Fig 4a). Following soybean-NR, maximum sugar beet recoverable sucrose occurred at a lower N rate than when following soybean.

Root Quality:

Sugar beet root quality is defined here as the net recoverable sucrose per ton of beet harvested. Root quality takes into account sugar concentration minus loss-to-molasses impurities. Previous crop and N rate had significant effects on root quality, but tillage had no effect (Table 1). There was little difference in root quality response to N rates when sugar beets followed either corn or wheat (Fig 5b). In both previous crops the root quality declined from 330 to 315 lbs sucrose ton⁻¹ as N rates increased. Where soybean was the previous crop, low N rates resulted in similar root quality as either wheat or corn, but the quality declined sharply as N rates increased above 90 lbs. N A⁻¹ (Fig 5b). In Fig 5a, sugar beet following soybean-NR tended to have less root quality than when following soybean, but the difference was not significant (Table 1). Root quality of beets grown after soybean regardless of how the residue was managed declined sharply at higher N rates.

Loss-to-Molasses (LTM):

As with root quality, there was no difference in LTM when sugar beets followed either soybean-NR or soybean (Table 1). Nor was there any effect of primary tillage operations. Loss-to-molasses increased as N rates increased regardless of the previous crop (Fig 6). However, the increase with increasing N rates was greater following either soybean crop than with either corn or wheat, which were not different from each other.

Nitrogen Availability:

Total plant N accumulation in sugar beet plants at harvest will be determined by the dry matter accumulation and N concentration in both the beet tops and the roots. At the time of writing this report that chemical analysis has not yet been completed. Shaved root samples are currently being freeze dried and will be ground and analyzed for TKN in January or so. At the same time, sugar beet tops will also be analyzed for TKN.

Soil nitrate- and ammonium-N were combined to determine a total inorganic N concentration through the first 58 days of the growing season. Soils from the 0 and 90 lbs N A⁻¹ rate were sampled and divided into the 0 to 6 and 6 to 12 inch soil depth increments. Figure 7 is divided into 0 N, 0-6 inch depth (a), 90 lbs. N, 0-6 inch depth (b), 0 N, 6-12 inch depth (c), and 90 lbs. N, 6-12 inch depth (d). Evaluation of Fig 7, clearly suggests considerable variability in the data means and greater inorganic N in the surface 6 inches of soil compared to the 6 to 12 inch depth increment. There is also substantially more inorganic N where 90 lbs. N A⁻¹ fertilizer was applied compared to the 0 N rate. In almost all cases inorganic N was greater where the previous crop was soybean or soybean-NR than with either wheat or corn until the last sampling date 58 DAP. Soybean-NR as a previous crop tended to have greater inorganic N than soybean, at least during the early part of the growing season. Inorganic N was less in previous crops of wheat and corn than either soybean previous crops, but the differences between the two varied with soil depth and N rate. By the last sampling date in July, inorganic N concentrations tended to decrease from previous samplings and there was little difference among the previous crops.

Sugar beet petiole nitrate-N was quite different between the 0 and 90 lbs N A⁻¹ rates (Fig 8). Between the first and second sampling date there was little change in petiole nitrate in the 0 N rate. Where 90 lbs. N A⁻¹ had been applied, petiole nitrates tended to decline between the first and second sampling date when previous crops were either wheat or soybean-NR. There was little change in petiole nitrate between the first two samplings when previous crops were either soybean or corn. At the last sampling, petiole nitrates increased substantially from previous samplings in all previous crops except corn, which did not change. During the first two petiole

samplings (in July) we attempted to identify the most recently matured leaf for sampling. It was apparent at the July 28th sampling that the sugar beet canopy had developed very little from the previous sampling on July 7th, though there were a few exceptions. Less sugar beet canopy development occurred following a corn crop. The third petiole sampling occurred on Aug 21, eight days after a two inch rain. The development of the sugar beet canopy after the rain was obvious. The rainfall apparently increased N availability because not only was there a visual increase in canopy biomass, petiole nitrates also increased. This suggests that the rainfall increased the sugar beet access to the available N in the soil wetting zone.

Summary

The negative impact on sugar beet grown after a previous crop of soybean has been attributed to a potential allelopathic effect of the soybean. Earlier observations revealed a decrease in both sugar beet root yield and quality after sugar beet compared to after a small grain crop (Smith and Dexter, 1988). In the trial reported here, there was not a large reduction in sugar beet root yield or recoverable sucrose when sugar beet followed soybean compared to HRSW in the rotation. The lowest sugar beet root and recoverable sucrose yield occurred when sugar beet was grown after corn. Growing sugar beet after soybean did decrease the root quality to a greater extent than when grown after either corn or HRSW. The soils data clearly indicate greater N availability in the upper 12 inches of the soil profile throughout the growing season following soybean than following either corn or wheat. The extra N availability following soybean is probably the main reason sugar beet root quality decreased (Draycott and Christenson, 2003).

Of particular interest is the difference, primarily in sugar beet root yield, between soybean and soybean-NR. Soil test results from October 2005 indicate that soybean-NR had 16 lbs. N A⁻¹ residual soil nitrate-N more than the soybean previous crop. However, Fig 1a indicates the reduce N to maximize sugar beet yields following soybean-NR compared to following soybean is substantially less than 16 lbs N A⁻¹. This suggests an impact of the soybean residue itself. Frequently, crops following soybean, primarily corn, in the rotation requires less N than monoculture or non-legume rotations. This has been attributed to increased soil N availability from the fragile soybean residue and N₂ fixation aspects of the soybean. Recent studies have found evidence that the N credit often given for soybean may be not necessarily be an increased availability of N, but rather less N is immobilized during soybean residue decomposition relative to that of other residues such as corn (Green and Blackmer, 1995; Gentry et al., 2001). Our data seem to support these findings and indicate that soybean residue does immobilize N or otherwise reduce soil N availability. The difference between N availability following soybean verses following non-legume crops such as corn or wheat may be caused by less N immobilization by soybean residues.

References

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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.

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