NITROGEN MANAGEMENT IN SUGAR BEET GROWN IN SPRING WHEAT AND CORN RESIDUE.

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Crop residue is a major component of most agricultural production systems. How this residue is managed impacts many soil characteristics such as water infiltration, percolation, and evaporation, soil organic matter content, soil erosion susceptibility, and nutrient cycling. Residue management has been divided into four categories: 1) residue left at or above the soil surface; 2) residue mixed in the surface 2-4 inches of the soil; 3) residue completely incorporated into the soil, usually below the 4 inch soil depth; and 4) residue completely removed from the soil (Van Doren and Allmaras, 1978). In most sugarbeet fields the management of the previous crops residue fit into either category 2 or 3 where most, if not all, of the residue is incorporated into the soil.

Part of the natural fertility of any soil is derived from the mineral makeup of the soil parent material and the nutrient composition of the soil organic matter. The type or chemical composition of the residue is important in determining its decomposition rate and contribution to the stable soil organic matter content. During the decomposition process, 55-70% of the carbon (C) in the residue is released to the atmosphere as CO_2, 5-15% of the C is incorporated into the soil microbial biomass, and the remaining 15-40% of C is partially stabilized as new soil humus (Jenkinson, 1971; Stott and Marten, 1989). Crop residues contain lignin, which is resistant to decomposition and becomes a substrate for soil humus formation. The more lignin in a residue type the slower the decomposition and the larger its contribution to the soil humus formation. Older, mature residues will tend to have more lignin content than young, non-mature residue from the same crop. The simple sugars, amino acids, polysaccharides, proteins, and lipids decompose first in the decomposition process.

Nitrogen (N) is necessary for the decomposition process. The less N the residue contains relative to the C, the slower the decomposition rate. If the residue N content is low, or the C:N ratio high, the decomposition process will require the input of N from either available soil inorganic N or fertilizer. Generally, residues with N concentrations less than 1.5% or C:N ratios greater than 30 will require N from sources outside the residue itself; it will immobilize soil N (Schomberg et al., 1994). Residues with greater N concentration or lower C:N ratios, as is frequently the case with legume residues or non-mature residues, tend to decompose at a more rapid rate and will release or mineralize N. The actual decomposition rate will depend on N content and chemical composition of the residue and the environmental conditions such as soil moisture and temperature. Crop residues such as corn and wheat residue have large C:N ratios and soil N will be immobilized during the decomposition process. However, mineralization of N will generally start to occur after 50-60% of the residue has been decomposed (Douglas et al., 1980) when enough C has been volatilized as CO_2 and N immobilized such that the remaining residue C:N ratio is below 30. This would suggest that N immobilization would occur during the early part of the sugarbeet growing season where the previous crop residue was from corn or wheat and the residue was incorporated into the soil. However, the decomposition process may proceed sufficiently that N mineralization could occur later in the growing season. Nitrogen immobilization reduces N availability to the growing crop and N mineralization increases N availability.

The total amount of nutrients contained in crop residues is often overlooked because fertilizer recommendations were developed under crop residue situations similar to those that exist in the current fields. That is, the crop residue contribution to nutrient management is integrated into the fertilizer recommendation. However, as fertilizer management is continually fined tuned in crops such as sugarbeet production, crop residue nutrient content and cycling needs to be considered. From 58 million acres of corn, 7.5 million acres of barley, and 53 million acres of wheat grown in the United States in 1990, it is estimated that residues from these crops contained 3.9 billion, 14.4 million, and 945 million pounds of N, respectively (Schomberg et al., 1994). All three of these residues have high C:N ratios so N immobilization is expected early in the decomposition period followed by mineralization of a portion of this total N at some point. Wagger et al. (1985) found that 12-15% of wheat and 12-33% of grain sorghum residue N was mineralized after one cropping season under field conditions in Kansas. Though mineralization was low, the recovery of this N by the subsequent crop was quite high at 79-82%. This indicates that residue N mineralization later in the growing season may coincide with rapid N uptake by the subsequent growing crop increasing the N uptake and utilization by that crop.

Sugarbeet production is very sensitive to N management. Too little N during the early half of the growing season will reduce root yields. But, too much N during the latter quarter of the growing season will reduce sucrose concentration and root quality. Moraghan et al. (2003) found that 40 lbs N A^{-1} applied as urea fertilizer over came reduced sugar beet production caused by 3000 lbs A^{-1} mature spring wheat straw, but was not enough to over come the effects of 6000 lbs A^{-1}. They concluded that N fertilizer requirements of the sugarbeet crop could be reduced if the majority of the previous wheat crops residue was removed. Recommended N fertilizer rates have been steadily declining in the Minnesota and North Dakota sugarbeet growing areas in a successful attempt to increase root quality without detrimental effects on root yield. The most recent recommendation is for a total of 130 lbs N A^{-1}, which includes soil NO_3-N in the top 4 feet of soil plus N fertilizer (Lamb et al., 2001). Data that led to these recommendations were obtained from field experiments in the American Crystal Sugar Company growing area where the previous crop residue was spring wheat and Southern Minn Cooperative growing area where the previous crop residue was corn. While there was consistency in the optimal N rate in both situations, questions still persist about the need for higher total N recommendations for sugarbeet production, especially when the previous crop residue was corn.

The objectives of this experiment were to examine the effects of corn and spring wheat residue on the N management in sugarbeet production. No attempt was made to differentiate or remove below ground residues such as roots from the corn and wheat crop. The residue being examined was that residue that resided on or above the soil surface after the corn or wheat was harvested and then incorporated with tillage in the fall prior to sugarbeet production. Specfically, my objectives were:

1. Evaluate the effects of residues from corn and spring wheat on the sugarbeet response to N fertilizer
2. Estimate N immobilization/mineralization during the growing year as it is affected by corn and spring wheat residues.

Materials and Methods

A field was selected at the Northwest Research and Outreach Center near Crookston, Minnesota in the fall of 2002 because of its low residual soil NO_3-N levels in the top four feet of the soil profile. The soil was a Wheatville loam. In the spring of 2003, 100 lbs N A^{-1} as urea and 60 lbs P_2O_5 A^{-1} as 0-44-0 were broadcast over the entire field. The field was then divided into two 88 ft strips and corn and spring wheat was each planted into one of the strips. Prior to harvest (August for the wheat and September for the corn) 10 quadrants were randomly selected within each crop. The wheat quadrant was 2 ft X 3 ft and the corn quadrants were 3.7 ft X 6ft. Crop plants within these quadrants were hand cut about 2 inches above the soil surface, grain was removed and the residue was dried, weighed, ground, and analyzed for N in the laboratory. This provided an estimate of the dry matter accumulation and N concentration in each crops residue that would be left on the field after harvest. Each crop was harvested with a commercial combine.

After harvest, four replications of two whole plots were marked in each crop residue strip. One plot in each replication was randomly assigned whole plot treatments of residue removed (RR) or residue left (RL). Residue in the RR treated plots was removed by two passes with a Carter Forage Harvester followed by hand raking to remove as much residue as possible. This usually left about a 2-inch stubble in each crop. In the RL treated plots, the residue was evenly distributed over the plot area by hand to ensure as uniform a distribution as possible. Wheat residue was removed on Aug 19, 2003 and corn residue was removed Oct 1, 2003. Remaining wheat residue was shredded then a chisel plow with twisted shanks was used for the primary tillage on August 21, 2003. After corn residue removal the remaining residue was shredded and a tandom disk used as the initial tillage, first with the rows then in the opposite direction. During the last pass of the disk, the wheat plots were also disked because of the large clods created during the August chisel plowing and the dry soil conditions. A chisel plow with twisted shanks was used over the entire field area, both corn and wheat plots, as a final tillage in preparation for winter. This means the corn area was chiseled once and the wheat was chiseled a total of two times.

In the spring (April 27) of 2004, each whole plot was subdivided into six subplots. Each subplot was assigned one of 6 N rate treatments (0, 30, 60, 90, 120, 150 lbs N A^{-1}). Thus the experimental design was a split plot randomized complete block with four replications. The whole plot treatment was RR or RL and the split plot treatments were the six N rates. Appropriate rates of urea fertilizer were hand distributed over each plot and 60 lbs P_2O_5 A^{-1} as 0-44-0 was broadcast over the entire field area with a pneumatic fertilizer applicator.

Sixty pounds of P_2O_5 as 0-44-0 were broadcast over the entire plot area on April 28, 2004. Afterwards, a field cultivator was used to till the plot area and incorporate the fertilizer. Due the large quantity of residue produced in the 2003 growing season the plot seedbed was packed with a Melroe grain drill going at a 90 degree angle to the sugar beet rows. The plots were planted with sugar beet variety Beta 3820 on April 30, 2004. The plots were over seeded and hand thinned later to a population of 35,641 plants A^{-1}. All plots were 11 ft wide (6 rows 22 inches wide) and 35 ft long. All rows ran perpendicular to the direction of the combine that harvested the previous crop in the fall of 2003. Appropriate herbicides, insecticides, and fungicides were applied throughout the growing season as needed to control pests. On September 29, 2004 the center two rows of each plot were machined harvested. Beets were weighed and 10 randomly selected beets were placed in tare bags and sent to the American Crystal Company Quality Laboratory in East Grand Forks, Minnesota for analysis.

Soil cores to a depth of 4 ft and segmented into 0-6, 6-12, 12-24, and 24-48 inches were taken in the wheat plots on August 19th, immediately after residue removal. Six cores were taken from each replication (three where residue was left and three where residue was removed) and composited. On October the same procedure was done on the corn residue site after corn residue removal. At this time we also resampled the wheat residue site using the same procedure as before. All soil samples were analyzed for NO_3-N.

Soil NO_3-N was monitored by two methods during the growing season. The first method of monitoring soil NO_3-N is by soil sampling all the 0 and 90 lb N A^{-1} treated plots in both previous crop residues and all replications. Ten cores 0.75 inches in diameter and 12 inches deep were randomly taken from the each plot, split into 0-6 inch and 6-12 inch deep sections and a composite sample of each depth was made. Each soil core was taken about 4 inches from the sugarbeet row. This was supposed to be done at 2 wk intervals starting soon after the sugar beet was planted and continued until the canopy was closed; there was to be a total of four sampling events. The soil was dried at 25^{o} C for 48 hrs, ground, extracted with 1 M KCl, and analyzed for NO_3-N. (NOTE: Due to wet conditions it was impossible to keep the 2 week schedule for soil sampling). The second method involved the use of clear plastic sleeves (2.38 inches in diameter X 12 inches long) and nylon bags containing a 20 gm mixture of anion/cation exchange resin. The plastic sleeve was inserted into a specially made soil sampling tube and pushed into the soil to a depth of approximately 10 inches with a Giddings hydraulic driven soil probe. When the tube is inserted into the soil, the soil is forced inside the plastic sleeve. The soil tube has a special tip to cut the soil slightly smaller than the plastic sleeve to ensure no soil compaction during the insertion process. The tube was raised from the soil and the sleeve containing the soil was removed. A small nylon bag of anion/cation exchange resin was fitted into the bottom of the soil core and inside the plastic sleeve. The entire unit (plastic sleeve, soil, and nylon bag) was enclosed in a nylon stocking and reinserted into the hole left from the probing operation. Four sleeves were placed in each whole plot of replication 3 in the wheat plots on August 19th after the primary tillage operations was completed. On October 6th these soil sleeves were pulled and frozen for later chemical analysis. On October 8th, after all tillage operations were completed, four more soil sleeves were placed in each whole plot of both the corn and wheat residue areas of rep 3. These sleeves were left in the field over winter. Each time the soil sleeves were placed in the field another set of four sleeves was taken at the same time; this set was immediately capped and frozen to mark the initial point.

In the spring prior to any fertilizing and tilling, the soil sleeves that over wintered in the experimental area were removed from the field, capped, and frozen. After sugarbeet was planted, sleeves were placed in the 2nd and 5th row of each 0 and 90 lb N A^{-1} plots in replication 3 of the corn and wheat residues (May 3rd, 2004). A total of 20 sleeves per plot were taken with four being immediately capped and frozen and the rest left in the field, as described above, for later retrieval. At about 5 week intervals, four sleeves were recovered from each plot; the resin bag was removed and the sleeve capped and frozen. Each of the remaining sleeves were then lifted, resin bags exchanged for fresh bags, then the entire unit was put back into the soil. All the harvested resin bags were placed in a plastic vial and frozen until NO_3-N analysis in the laboratory. Frozen soil cores in the sleeves were measured, weighed, divided into the bottom 12.5 inches and the remaining top of the core. A sample was taken from each section for gravimetric moisture determination and the rest was dried at 25^{o} C for 2 days, ground, and analyzed for NO_3-N. The resin bags will be thawed, mixed and shaken with three consecutive sets of 200 mls of 1 M KCl solution for 30 minutes. The KCl solution will be suctioned off and analyzed for NO_3-N.

Statistical analysis was done using Proc GLM in SAS (2002) and single degree orthogonal contrasts to make the appropriate comparisons. Data could not be analyzed across residue types because there was no randomization or replication of residue type. Therefore, each residue type was treated as a separate experiment in the analysis. The ensuring discussion will also keep the residue types separate except at a few points.

In the following discussion, root yield is the observed weight of the harvested sugar beet root (tons A^{-1}), root quality (lbs recoverable sucrose ton^{-1} of root) is a calculated value taking into account the gross sugar concentration minus the loss to molasses, and recoverable sucrose is a calculated value taking into account root yield and net sucrose concentration or root quality.

Results

The initial wheat and corn residue on the plots averaged 0.77 and 0.51%N, respectively. The 6726 lbs A^{-1} (dry weight) of corn residue was nearly 1.4 times greater than wheat residue at 4839 lbs A^{-1}. This suggests that not only would soil N be immobilized during the decomposition period, the total amount of N being immobilized during corn residue decomposition might create a greater critical situation in terms of N availability to the sugarbeet crop. The quantity of wheat residue was considerable greater than in previous years (2800 lbs A^{-1} in 2002-2003 experimental year). This was due to the excellent growing conditions experienced in the 2003 growing season and was reflective of what occurred in most commercial fields.

Residual soil NO_3-N after the corn and wheat crop was 42 and 62 lbs A^{-1}, respectively, in the top four feet of soil when sampled on October 6, 2003. The top 2 feet of soil contained 20 and 38 lbs NO_3-N A^{-1} after the same respective crops. Using the University of Minnesota N fertilizer recommendations for sugar beet production about 90 lbs N A^{-1} would have been recommended following the corn crop and 70 lbs N A^{-1} following the wheat crop.

Corn Residue

There were significant interactions between residue treatments and N fertilizer rates on both sugar beet root yield and recoverable sucrose (Table 1). Leaving corn residue on the field resulted in less root yield and recoverable sucrose compared to where corn residue had been removed (Fig 1a and 2a). This occurred at all N fertilizer rates, but the difference was greater at the lower N rates. At higher N rates the differences were smaller. Both root yield and recoverable sucrose were maximized with about 90 lbs N A^{-1} when the corn residue had been removed. Where the corn residue had been left on the field sugar beet root yields (Fig 1a) and recoverable sucrose (Fig 2a) may be still increasing slightly at the highest N fertilizer rate. It is possible that additional N fertilizer may have increased root yields and recoverable sucrose sufficiently so that both would have been equal between the two residue treatments. This is quite dissimilar to the results of this experiment in 2002 and 2003 (Sims, 2004) where root yields and recoverable sucrose maximized at the same N fertilizer rate regardless of corn residue treatment. However, the 2004 results are similar to those of 2002 and 2003 in that root yields and recoverable sucrose was less where corn residue had been left compared to where it had been removed at all N fertilizer rates used in the experiment.

Sugar beet root quality was not significantly affected by the residue treatment, but was by the N fertilizer rates (Table 1). Root quality declined at N rates above the 120 lbs N A^{-1} fertilizer rate regardless of whether corn residue had been left on the field or removed (Fig 3 a). These results are similar to those observed in 2002 and 2003.

Spring Wheat Residue

There were significant interactions between the residue treatments and N rates on sugar beet root yield and recoverable sucrose (Table 1). Both root yield and recoverable sucrose were less where wheat residue was left on the field compared to where it had been removed at the lower N fertilizer rates (Figs 1b and 2b). When 90 lbs N A^{-1} or more were applied, there was no difference between residue treatments on either root yield or recoverable sucrose. Maximum values of both variables were observed at about the 90 lb N A^{-1} rate. These results are dissimilar from those observed in this experiment in 2002 and 2003 (Sims, 2004) where there was little difference in either variable between wheat residue left on the field or removed at any of the N fertilizer rates except possibly the check or 0 N rate.

Table 1 also indicates a significant interaction between residue treatments and N rates on sugar beet quality. This interaction is a bit more difficult to observe in Figure 3b. As N fertilizer rate increases, sugar beet quality tends to decrease. Figure 3b has been depicted with a linear relationship between root quality and N fertilizer rate averaged across both residue treatments. However, there may be reason to suspect most of the decrease in root quality occurred at N rates greater than 60 lbs N A^{-1}. This would be fairly consistent with observation from previous years of this experiment where there were no differences between the residue treatments.

Brief Summary

The results of this experiment do not provide evidence to suggest that the current University of Minnesota N fertilizer recommendations should be adjusted for sugar beets grown after corn. Sugar beet yields tend to be less when following corn than when following wheat, but this cannot be analyzed directly in this experiment because of the way the trial needed to be established. That is, this trial was conducted as two separate experiments, one following corn and the other following wheat. Due to limited land availability and maneuverability of equipment necessary to establish the trial, I simply could not randomize the previous crops. However, in all years of this trial both experiments were established side by side.

When sugar beet was grown after wheat in 2002 and 2003 maximum root yield and recoverable sucrose were maximized at N rates less that those that would normally have been recommended by the University of

Minnesota. In addition, there was no difference in root yield and recoverable sucrose at any of the fertilizer N rates whether the wheat residue was removed or left on the field. Where differences between residue treatment were observed it was only at the 0 N rate or check. In 2004 this was not the case and 90 lbs N A^{-1} were required to correct the detrimental effects of the wheat residue on sugar beet root yield and recoverable sucrose. One factor that probably contributed to different results among years were differences in wheat residue generated the previous year. In the fall of 2001 and 2002 there was about 3000 lbs A^{-1} or less of wheat residue left on the soil compared to over 4800 lbs A^{-1} in the fall of 2003. Power and Legg (1978) found references indicating that there would be little detrimental effects of 3000 lbs A^{-1} wheat residue on nutrient availability. There was 50% more residue than this going into the 2004 sugar beet growing season. Moraghan et al. (2003) found the 40 lbs N A^{-1} over came any detrimental affect on root yield from 3000 lbs A^{-1} wheat residue, but it was not enough to over come any detrimental effects of 6000 lbs A^{-1} of wheat residue.

When sugar beet was grown after corn, corn residue left on the field always resulted in less root yield and recoverable sucrose than when the corn residue had been removed. This occurred in all years of the trial. However additional N fertilizer was never able to over come this detrimental affect. In 2002 and 2003, N fertilizer had no impact on this detrimental effect and the sugar beet response curves to N fertilizer rates were identical whether corn residue had been left or removed. Only in 2004 was there an indication the additional N might have reduced the detrimental affects of corn residue, but that N rate was beyond the range we used in the experiment. In all years, however, maximum sugar beet root yield and recoverable sucrose occurred at N rates similar to what would have been recommended. In 2002 and 2003 this was the case whether corn residue was removed or left on the field. In 2004, this was the case when corn residue had been removed, but where corn residue was left N additions above those that would have been recommended did increase sugar beet root yield though not greatly. The main conclusion from this is that the negative impact of corn residue appears not to be N available related.

Regardless of whether sugar beet was grown following a wheat crop or corn crop increasing N rates above those that would have been recommended by the University of Minnesota tended to reduce sugar beet quality. Under applications of N fertilizer were not as critical when sugar beet followed wheat as when it followed corn.

Soil NO_3-N

Laboratory analyses of the soil cores in plastic sleeves and anion/cation exchange resin harvested during the 2004 growing season are still in progress and cannot be reported at this time. Soil samples collected from the 0 and 90 lb N A^{-1} N rates were collected during the 2004 growing season, but these are also being analyzed at this time.

Soil cores from the plastic sleeves and anion/cation exchange resin collected in the fall of 2002 and during the 2003 growing season (not analyzed at the time of the SBREB research report in 2004) have been analyzed and will be discussed here. Typical statistical analysis has not been done on these data because there is not true replication since all the cores (4 subsamples) were collected from only one replication in the field trial. Rather, I will discuss trends in the data.

Nitrate-N accumulation for both N fertilizer rates, both residue treatments, and both previous crop residues are shown in Figure 4. Nitrate-N accumulation followed somewhat similar patterns regardless what was the previous crop. Similarities were: 1) greater NO_3-N accumulation when the previous crop residues were left on the field compared to where they were removed; 2) little or no accumulation of NO_3-N during the winter months; 3) an increase in NO_3-N accumulation after sugar beet was planted; 4) a relatively more rapid accumulation of NO_3-N when 90 lbs N A^{-1} had been applied compared to the check (0 N); 5) adding 90 lbs N A^{-1} tended to reduce an difference in NO_3-N accumulation between where the previous crop residue was left or was removed from the field; and 6) where no N was applied NO3-N accumulation differences between where the previous crop residue was left or removed were maintained throughout the growing season.

Some differences do seem to have occurred between the two previous crops. After mid-June where 90 lbs N A^{-1} had been applied, the accumulation of NO_3-N following wheat tended to level off (little or no accumulation of NO_3-N after that time compared to earlier in the growing season. When corn was the previous crop, NO_3-N was still accumulating after June 15th, but at lower rate than earlier in the growing season. When no N fertilizer was applied NO_3-N accumulated throughout the entire growing season at a relatively constant rate regardless of the previous crop, but that accumulation was much slower than when 90 lbs N A^{-1} had been applied.

Nitrogen mineralization from the soil organic matter and previous crop residue is controlled by many factors such as temperature, moisture, type of residue, quantity of residue and whether sufficient N is available for the decomposition process, which is especially important in residue decomposition. Two things are apparent from the data presented here: 1) Removing the previous crop residue may be reducing the accumulation of inorganic soil N; and 2) adding sufficient fertilizer N tends to enhance the accumulation of inorganic soil N enough so that any differences caused by removing the previous crop residues is diminished. It will be interesting to see if the NO_3-N accumulation in 2004 follow similar patterns as were observed in 2003.

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Table 1. Statistical analysis for sugarbeet root yield and quality and recoverable sucrose response to residue removed or left on the field and N fertilizer rates.

Residue Type	Corn			Wheat		
Source of Variation[δδ]	Root Yield	Root Quality	Recov Sucrose	Root Yield	Root Quality	Recov Sucrose
Res. Trt	**	Ns	**	Ns	Ns	Ns
N rates	***	Ns	***	***	*	***
N rate linear	***	Ns	***	***	**	***
N rate quadratic	***	*	***	***	Ns	***
Res. Trt by N rate	**	Ns	**	**	Ns	*
Res. Trt by N rate linear	***	Ns	***	**	*	**
Res Trt by N rate quadratic	Ns	Ns	Ns	Ns	Ns	Ns

[δ] Ns, *, **, and *** represent non-significant and significance levels of 0.05, 0.01, and 0.001, respectively.
[δδ] Res. Trt means residue treatments of residue removed or residue left on the field.

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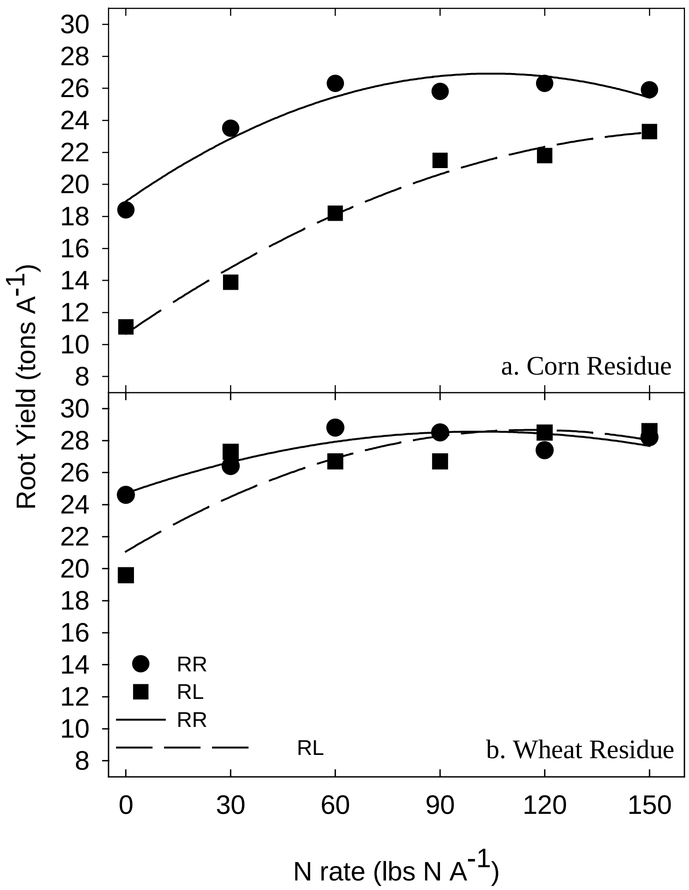

Figure 1: 2004 Sugar beet root yield as affected by nitrogen fertilizer application rate and the removal (RR) or leaving (RL) of the previous crop residue when the previous crop was corn (a) or wheat (b).

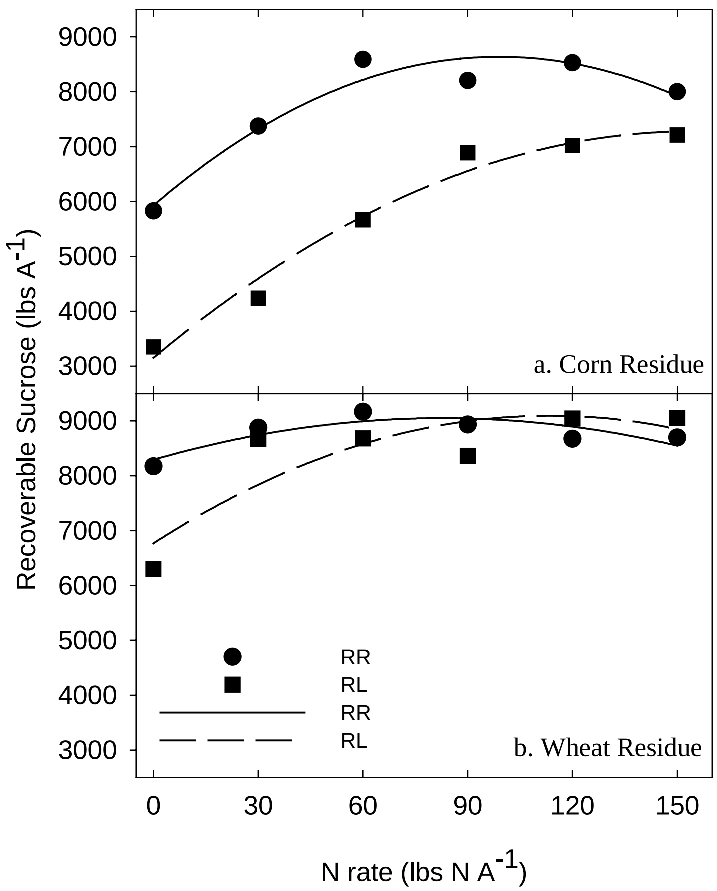

Figure 2: 2004 Sugar beet recoverable sucrose as affected by nitrogen fertilizer application rate and the removal (RR) or leaving (RL) of the previous crop residue when the previous crop was corn (a) or wheat (b).

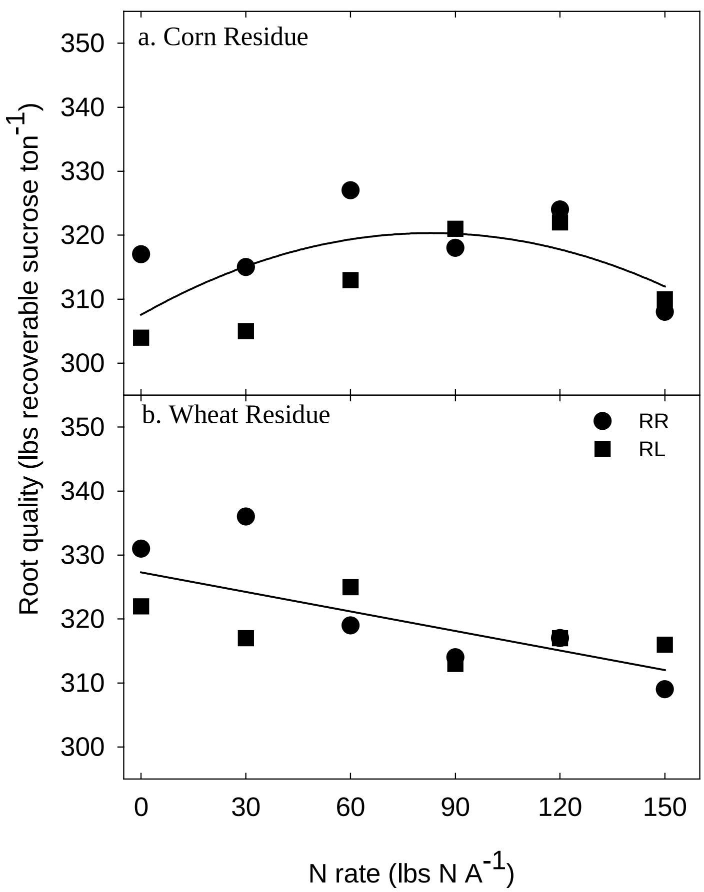

Figure 3: 2004 Sugar beet root quality (recoverable sucrose ton^{-1}) as affected by nitrogen fertilizer application rate and the removal (RR) or leaving (RL) of the previous crop residue when the previous crop was corn (a) or wheat (b).

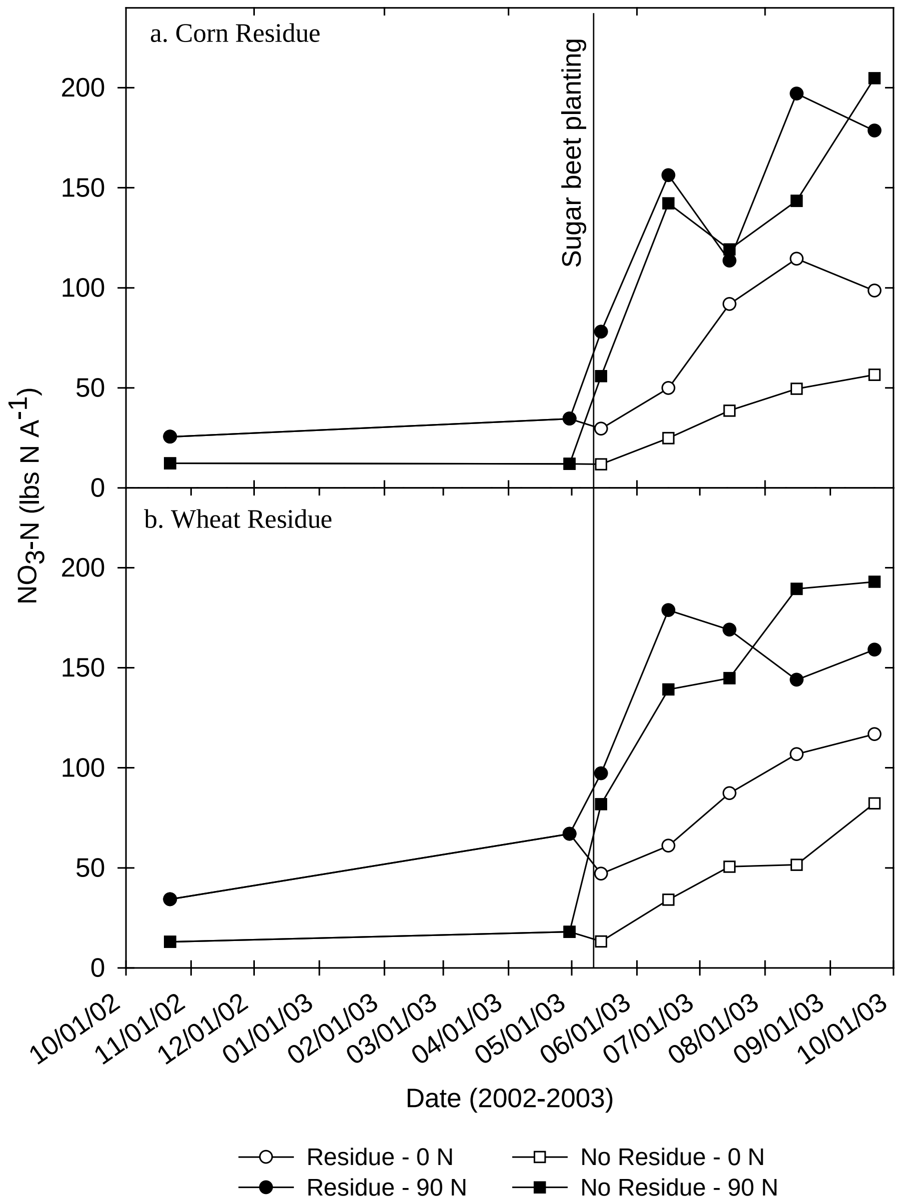

Figure 4: Soil NO_3-N accumulation (top 10 inches) in sugar beet plots starting in the fall of 2002 and continuing through the 2003 growing season as affected by the removal or leaving on the field of the previous crops residue (corn: a; wheat;b) and whether 0 or 90 lbs N A^{-1} as fertilizer was applied.