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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 has major impacts on 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 embedded in 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 the mineralization rate was slow, 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 any detrimental effect of about 3000 lbs A^{-1} mature spring wheat straw, but was not enough to over the detrimental 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 was 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 2001 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 2002, 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 were 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 29, 2002 and corn residue was removed Oct 8, 2002. A heavy rain after the wheat residue removal prevented any primary tillage until Sept 16. The remaining residue was shredded then a chisel plow with twisted shanks was used for the primary tillage. After the corn residue was removed, the remaining residue was shredded and a tandom disk used in the initial tillage operation to smooth out the field area and cut any longer stalks that were pushed too low for the shredder by the combine wheels. A chisel plow with twisted shanks was used over the entire field area 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 of 2003, 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.

The plots were lightly field cultivated and packed with rolling baskets then planted with sugarbeet variety Beta 6600 on May 1, 2003. The plots were over seeded and hand thinned later to a population of 30,500 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 2002. Appropriate herbicides, insecticides, and fungicides were applied throughout the growing season as needed to control pests. On September 24, 2003 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 NO_3-N was monitored by two methods during the year. One 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 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 2 in the corn and wheat residue plots on Oct 22, 2002 after all the primary tillage operations were finished and left throughout the winter. Another set of four sleeves was taken at the same time; this set was immediately capped and frozen to mark the initial point.

> Note: We would have placed sleeves in the wheat residue in late August or early September after the residue removal but heavy rain prevented primary tillage and sleeve insertion operation. Typically these sleeves would have been removed just prior to the final tillage operation in October and new sleeves inserted after tillage.

In the spring prior to any fertilizing and tilling, the sleeves were removed from the field, capped, and frozen. After sugarbeet was planted, sleeves were placed in the 2^{nd} and 5^{th} row of each 0 and 90 lb N A^{-1} plots in replication 2 of the corn and wheat residues. 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 30 day 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.

The second 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 done at 2 wk intervals starting soon after sugarbeet was planted and continued until the canopy was closed; there was a total of four samping events. The soil was dried at 25^o C for 48 hrs, ground, extracted with 1 M KCl, 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 sugarbeet 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 that was on the plot areas averaged 0.82 and 0.54%N, respectively. The 6750 lbs A^{-1} of corn residue (dry weight) was nearly 2.5 times greater than wheat residue at 2800 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.

Corn Residue

There was a significant effect of residue treatment on the sugarbeet root yield and recoverable sucrose (Table 1). There was also a highly significant quadratic response of sugarbeet root yield, root quality, and recoverable sucrose to the N rates (Table 1). However, there were no interactions between residue treatments or N rates.

Sugarbeet root yield and recoverable sucrose increased with increasing N rates up to about 90 lbs N A^{-1} at which point they maximized (Fig 1 and 2). Response to N fertilizer was similar for both the RR and RL residue treatments. In both residue treatments maximum root yield and recoverable sucrose were maximized with 90 lbs N A^{-1}. Root yields and recoverable sucrose were less with RL than RR and the differences between the two residue treatments was consistent at all N rates. This indicates that the effects of corn residue on sugarbeet production was not caused by N immobilization. Otherwise similar yields would have been observed in the RL treatments as in the RR treatments though it would have taken more N to do so. Since both response curves are similar, equally spaced, and maximized at the same N rate, N availability did not cause the difference.

Root quality was not affected by the residue treatments, but N rates had a highly significant effect on root quality. Root quality increased with increasing N rates up to 60 lbs N A^{-1}, which was similar to root quality at 90 lbs N A^{-1}, then began to decline with increasing N rates (Fig 3).

Spring Wheat Residue

Residue treatments had no significant effect on sugarbeet root yield, root quality, or recoverable sucrose (Table 1). However, the response to N rates was highly significant. There were no significant interactions between residue treatment and N rates for any of the measured variables. The response of sugarbeet root yield and recoverable sucrose to N rates was linear in nature with maximums occurring at about 60 lbs N A^{-1} (Fig 1 and 2). Root yields tended to increase slightly at higher N rates, but recoverable sucrose did not and may have actually decreased slightly (Fig 2).

Unlike with corn residue, root quality did not increase with increasing N rates at the lower N rate levels with the wheat residue. Rather root quality remained high for the lower N rates until greater than 60 lbs N A^{-1} were applied when root quality declined (Fig 3).

Soil NO_3-N

Laboratory analysis of the soil cores harvested in the plastic sleeves and anion/cation exchange resin is still in progress and cannot be reported at this time. During the development of this report it was also discovered that the soil NO_3-N from these plots in the fall of 2002 have not been analyzed yet. Therefore, we cannot tell what the residual N was in the soil for each of these residues in the fall prior to sugarbeet production. Previous work on this research project has indicated that with the same management was done here the residual should be between 35 and 45 lbs N A^{-1} in the top 4 ft of the soil profile, however, this is only an estimate at this time.

The periodic soil sampling from the 0 and 90 lbs N A^{-1} treated plots are completed and the results shown in Fig 4. There are consistencies between the two residue types. There was a substantial increase in available N at the 90 lb N A^{-1} rate compared to the control (0 lb N A^{-1}). Of course this is expected and is the result of the addition of N fertilizer. In the 90 lbs urea-N treatment, availability of N increased up to 35 days after planting (DAP) and reflects the hydralization of urea-N to ammonia (NH_3) and ammonium (NH_4) then nitrified to nitrate (NO_3). In the control the NO_3-N levels remained relatively low and steady until 35 DAP. The NO_3-N levels in both N rates declined at later sampling dates and were not greatly different from each other at 68 DAP. The last sampling was taken just as the sugarbeet canopy was beginning to close the row. By the time the sugarbeet crop begins to reach canopy closure the absorption of soil N is quite rapid and the amount of inorganic N actually measured in the soil is usually quite low.

With both residue types and both N rates, soil NO_3-N was less with the RL residue treatments than RR through the first month or so of the growing season (Fig 4). After 35 DAP there was no difference between RR and RL treatments in the corn residue plots. In the wheat residue plots, it was the 49 DAP sampling that indicated little difference between RR and RL treatments. Though the two residue types could not be combined for analysis because of the experimental design, it is interesting to note that NO_3-N is greater in the wheat residue plots compared to corn residue plots regardless of N rate or residue treatment (Fig 4).

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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			Barley		
Source of Variation[dd]	Root Yield	Root Quality	Recov Sucrose	Root Yield	Root Quality	Recov Sucrose	Root Yield	Root Quality	Recov Sucrose
	------------------------------ significance level[d] ------------------------------								
Res. Trt	*	Ns	*	Ns	Ns	Ns	Ns	Ns	Ns
N rates	***	***	***	**	***	**	***	*	***
N rate linear	***	**	***	***	***	*	***	**	***
N rate quadratic	***	***	***	Ns	***	**	***	Ns	***
Res. Trt by N rate	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Res. Trt by N rate linear	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Res Trt by N rate quadratic	Ns	Ns	Ns	Ns	Ns	Ns	**	Ns	**

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

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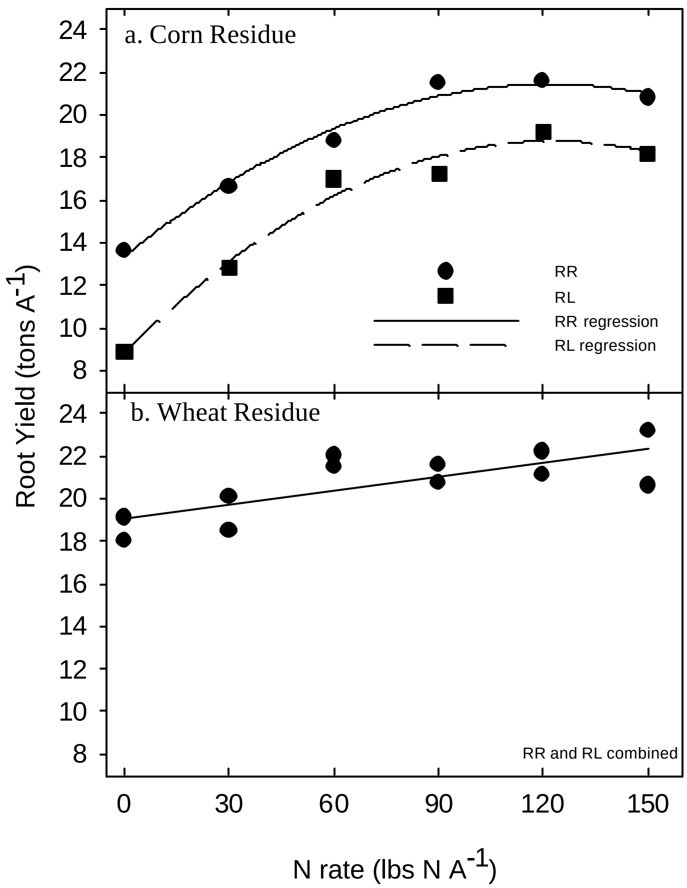

Figure 1. 2003 Sugarbeet root yield response to nitrogen fertilizer rates in two residue types (a. corn residue and b. wheat residue) when the residue was removed (RR) or left on the field (RL).

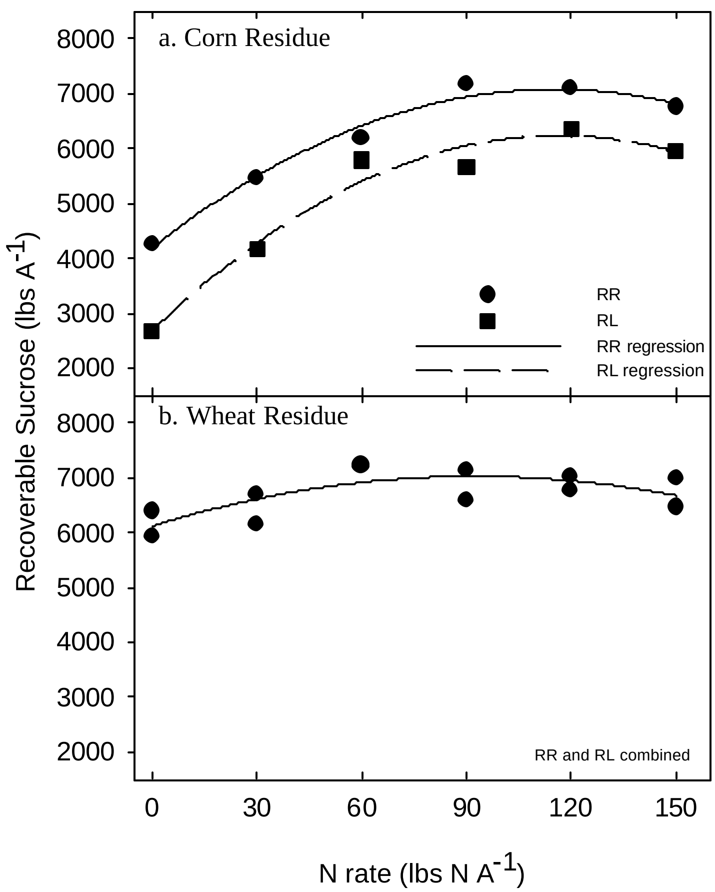

Figure 2. 2003 Sugarbeet recoverable sucrose response to nitrogen fertilizer rates in two residue types (a. corn residue and b. wheat residue) when the residue was removed (RR) or left on the field (RL).

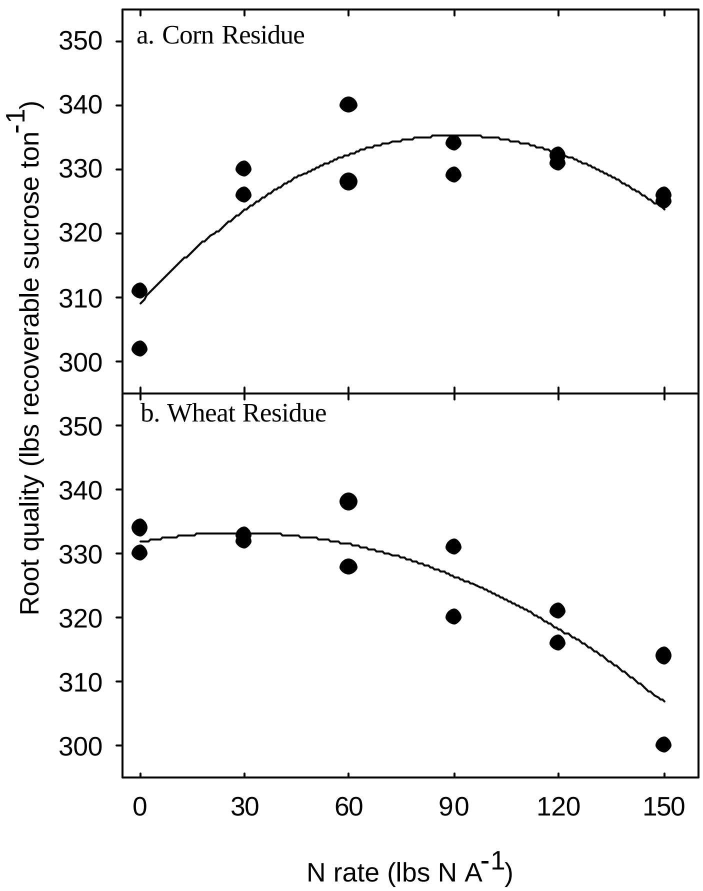

Figure 3. 2003 Sugarbeet root quality (lbs of recoverable sucrose ton^{-1}) response to nitrogen fertilizer rates in two residue types (a. corn residue and b. wheat residue) when the residue was removed (RR) or left on the field (RL).

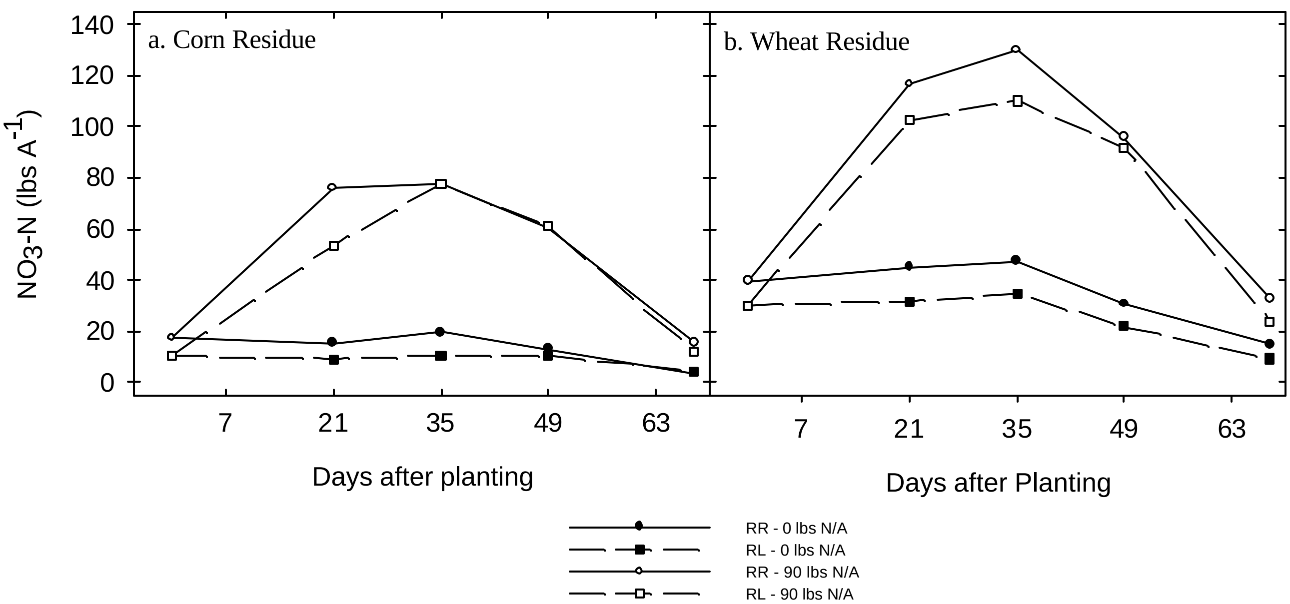

Figure 4. Soil NO_3-N in sugarbeet plots during the first half of the 2003 growing season as affected by residue type (a. corn residue and b. wheat residue), time (days after planting), fertilizer N rates (0 and 90 lbs N A^{-1}), and if residue is removed (RR) or left on the field (RL).