ESTIMATING SOIL NITROGEN MINERALIZATION DURING THE GROWING SEASON IN SUGAR BEET GROWN AFTER CORN, WHEAT, AND SOYBEAN.

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Three major sources of nitrogen (N) contribute to a sugar beet crop: 1) Residual soil nitrate-N left from the previous crop; 2) Fertilizer N; and 3) N mineralized during the growing season from the previous crop residue and soil organic matter. Fertilizer N recommendations currently account for only residual soil nitrate-N (Lamb et al., 2001). Nitrogen credits are given for certain crops grown the year previous to sugar beet which can reduce fertilizer N recommendation. However, N mineralized from the soil organic matter (includes both previous crop residues and less definable organic materials in the soil) are not specifically accounted for.

Nitrogen mineralization has been difficult to access and include in N recommendations (Rice and Havlin, 1994). Many attempts have been made to develop indices of N mineralization, but the methodologies to do so have been elusive. These attempts have included laboratory methods of chemical extractions (Keeney, 1982) and incubation studies (Stanford and Smith, 1972); field methods of buried bag (Eno, 1960), ion exchange resins or membranes (Schnabel, 1983; Qien et al., 1993), soil nitrate-N testing (Magdoff et al., 1984); and plant tissue testing during the growing season (Rice and Havlin, 1994). Laboratory incubations have been invaluable in describing the relationship of N mineralization to temperature and moisture (Stanford et al., 1973; Stanford and Epstein, 1974), but their applicability to field conditions is questioned. Plant tissue testing can be very labor intensive and expensive.

Ion exchange resin and membranes have shown promise in estimating N mineralization under actual soil and field conditions. Ion exchange membranes have been useful in measuring relative N mineralization among treatments, but absolute N mineralization is not possible because there is no specific soil volume associated with them (Kolberg et al., 1997). DiStefano and Gholz (1986) combined intact soil cores with ion exchange resin (IER) to measure insitu N mineralization in natural field conditions. The method was adapted for use in forest and rangeland ecosystems (Binkley et al., 1992; Hook and Burke, 1995). Kolbert et al., (1999) adapted this method for use in a dry land agroecosystem in Colorado. One of the issues with IER and intact soil cores is how many samples are needed to achieve an acceptable level of precision. Kolberg et al. (1997) found that 5-7 cores were necessary to achieve a precision of +/- 1.5 mg N kg^{-1} soil at a 20% confidence level. The primary limitation to the number of samples to use is the labor and time in the laboratory analysis of the IER.

Objectives

1. Estimate the quantity of N mineralized in sugar beet plots during the growing season.
2. Determine if N mineralized is affected by either previous crop grown or the application of fertilizer N.

Materials and Methods

The Mineralization Trial in 2006 was designed to piggy back onto the Previous Crop Trial already implemented in the field. The previous crop trial was established at the University of Minnesota’s Northwest Research and Outreach Center near Crookston, Minnesota. The soil at this site was classified as a Wheatville very fine sandy loam (Coarse-silty over clayey, mixed over smectitic, superactive, frigid aeric Calciaquoll) and transitions into a Gunclub silty clay loam (fine-silty, mixed, superactive, frigid aeric Caciaquoll).

In the Previous Crop Trial, crops of corn, soybean, and wheat were grown in 2005. After the crops were harvested the soil was chisel plowed then a second chisel tillage operation took place in late October in preparation for winter. In spring 2006, the previous crop plots were subdivided and various rates of N fertilizer was applied as urea. The plots were tilled with a field cultivator to incorporate the fertilizer and prepare the seed bed. Sugar beet was planted on May 8, 2006 in plots 11 ft wide (6 rows, 22-inches wide) by 30 ft long.

On May 17 and 18 soil cores contained in plastic tubes (PST) were placed in rows 2 and 5 of plots previously grown to corn, soybean, and wheat in 2005 and receiving 0 and 90 lbs N A^{-1} fertilizer in three replications. Only the 0 N rate was used in the previous corn plots. A pickup with a mounted Gidding soil probe was driven into the plots straddling three sugar beet rows. The soil probe had easy access to the center row thus the pickup made two passes per plot; one pass straddling rows 1, 2, and 3 and the second pass straddling rows 4, 5, and 6.

Mounted on the Giddings Soil Probe was a steel soil coring tube. This tube is 15 inches long and 2.625 inches inside diameter plus a soil cutting tip that adds approximately 2.5 inches to the overall length. The tube is specially designed to receive a 12 inch long by 2.375 inch inside diameter plastic tube (PST) as an insert. Once the PST is inserted into the tube, the cutting tip is screwed onto the tube and holds the PST in place. The unit is pressed into the soil to a depth of eight inches plus the length of the cutting depth. The cut soil core is slightly smaller than the PST and is forced into the PST. The tube is pulled from the soil, the cutting tip unscrewed, and the PST containing the soil core is removed from the steel tube. This process leaves a hole in the ground the same diameter as the steel tube and the eight plus inches deep (accounting for cutting tip). A mixture of sand and copper sulfate ($CuSO_4$) is pored into the hole to fill the space left from the cutting tip. This mixture allows drainage within the hole and the $CuSO_4$ restricts root growth through the sand that may access the sample described in the next paragraph.

The PST and the contained soil core is now prepared for reinsertion to the soil. First the soil core itself is pushed slightly further into the PST. At the bottom of the core, a nylon bag filled with ion exchange resin is fitted to the inside of the PST and below the soil core. The entire system is enclosed within a nylon stocking and placed back in the hole from which the soil core was extracted. Approximately 4 inches of the PST is exposed above the soil surface and the soil core surface is usually the same level as the soil outside the PST. The resin bag is filled with 10 gms each of a cation exchange resin and an anion exchange resin with a high affinity for ammonium-N and nitrate-N, respectively. The resin bag is quite pliable and fits snuggly within the PST and is about half inch deep. The resin is to capture any ammonium- or nitrate-N that may leach from the soil core as water moves through the core and into the resin bag. The entire systems can be visualized in Fig 1.

Each plot receives 24 PSTs, 12 in each of the rows 2 and 5 of the plots. Six PSTs and their soil cores were harvested when the PSTs were installed and represent the starting point in inorganic N accumulation. The remaining 18 PST units (PST, soil core, and resin bag) were left in the field for a later harvest date. All PST units were placed within the sugar beet row to allow normal cultivation of the sugar beet plots. Six PST units per plot were harvested on June 28, August 9, and September 20. At the time of harvest the resin bags from each PST unit was placed in a capped vial, the PST with the soil core was capped, and all was shipped back to the laboratory for analysis. At the June 28 and August 9 harvests, the resin bags from the PST units that were to remain in the field were harvested and replaced with fresh resin bags. This was done to prevent plant root access to the resin bag and to make sure the ammonium- and nitrate-N holding capacity of the resin was not reached. These resin bags were also shipped back to the laboratory for analysis.

All soil cores were measured and weighed after removal from the PST. The six cores from a plot were then homogenized and a subsample was weighed, dried at 105^{o} C, and reweighed to determine moisture content at the time of harvest and to determine the soil cores approximate bulk density. The bulk soil was air dried, ground, and a subsample was analyzed for ammonium- and nitrate-N concentration using a 1 M KCl extractant. The six resin bags from each plot and harvest date were divided into two groups of three bags. The bags were washed with deionized water to remove contaminating soil. The three bags were then subjected to three consecutive extractions of 600 mls of 1M KCl. The extractions are combined with a similar extraction from the second group of three resin bags. An aliquot of the combined extraction is analyzed for ammonium- and nitrate-N. The ammonium- and nitrate-N extracted from the six soil cores and their respective resin bags are combined and using the soil core depth, soil core surface area, and soil core bulk density, the total amount of inorganic N per acre was calculated. Ammonium- and nitrate-N extracted from resin bags harvested when the respective soil core remained in the field were added to their respective soils cores.

Soil core length varied slightly among the soil cores so all data were normalized to a uniform depth of 7.5 inches. All ammonium- and nitrate-N data were combined and are represented as accumulated N in this report.

Results and Discussion

Statistical analyses were originally conducted across all sampling dates. Accumulated N was significantly different among sampling dates, N rates, previous crops by N rates, and sampling date by N rates. Averaged across previous crops and N rates there was 45 lbs N A^{-1} in the surface 7.5 inches of soil on May 17-18 when the experiment was initiated. By June 28, 80 lbs N A^{-1} had accumulated which is an increase in 35 lbs N A^{-1} over the previous sampling date. Part of this increase can be attributed to N mineralization and part is attributed to the hydrolysis of urea fertilizer and eventual nitrification of N. There was little change in accumulated N on August 9th (83 lbs N A^{-1}) suggesting that the extremely dry soil conditions was inhibiting N mineralization. An additional 15 lbs. N A^{-1} accumulated by the last sampling date of September 20th (96 lbs. N A^{-1}) This was probably caused by a stimulation of N mineralization after a two inch rain fell on August 12.

More detailed statistical analysis was done within individual sampling dates. There was no significant difference in accumulated N among previous crops at any sampling date when no N fertilizer was applied (Table 1). However, N was consistently least following corn and greatest following soybean. Following wheat, N accumulation was closer to that following soybean than that following corn, but the difference between previous crops of soybean and wheat increased as the sugar beet season progressed. The relationship in accumulated N throughout the sugar beet growing season and previous crops receiving no N fertilizer is shown in Fig 2.

Where 90 lbs N A^{-1} fertilizer was applied, there was little difference in accumulated N following either soybean or wheat at the initiation of the experiment or on the last sampling date of September 20 (Table 1). The 90 lbs. N A^{-1} following corn was not monitored. At intermediate sampling dates, accumulated N was significantly greater following wheat than following soybean. Following both previous crops, applying 90 lbs N A^{-1} fertilizer significantly increased accumulated N relative to the 0 N rate. The N accumulation relationships between the previous crops of soybean and wheat with or without N fertilizer are shown in Fig 3.

In the 2006 growing season, the data clearly show N accumulation following previous crops of soybean was greater than following other crops and least following corn. Interestingly, N accumulation following soybean, whether N fertilizer was applied or not, increased slight early in the sugar beet growing season, was stagnant in mid-season, then increased substantially late in the growing season. Conversely, N accumulation following wheat, whether N fertilizer was applied or not, increased sharply early in the growing season followed by little change throughout the rest of the growing season. Given the extreme dryness of the 2006 growing season it will be interesting to see if these same trends in N accumulation occur in the 2007 growing season.

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Table 1. Inorganic N accumulation during the sugar beet growing season when 0 or 90 lbs N A^{-1} fertilizer was applied after previous crops of corn, soybean, or wheat. Statistics are based analysis of individual sampling dates.

		Sampling Day$^{\delta}$			
Previous Crops	N rates	10 DAP	52 DAP	94 DAP	136 DAP
	-- lbs N A^{-1} --	--------- lbs N A^{-1} $_{(7.5\ \text{inch depth})}$ -----------			
Corn	0	22.1	38.5	49.3	55.7
Soybean	0	30.1	59.6	68.3	80.2
Soybean	90	70.4	105.8	108.7	142.8
Wheat	0	27.9	52.2	58.2	58.3
Wheat	90	76.4	145.0	128.3	141.1
$LSD_{(0.05)}$		9.0	25.1	23.9	22.5
$LSD_{(0.10)}$		7.3	20.2	19.3	18.2

δ DAP represents Days After Planting