NITROGEN AVAILABILITY, TIME OF RELEASE AND MOVEMENT IN ROTATIONS

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Introduction

Previous studies have found that N is released through the decomposition of sugarbeet tops (Moraghan and Smith, 1996: Reitmeier et al., 1999). There is also evidence that N credits may be justified following other broadleaf crops, such as potato and sunflower. This evidence follows work by Vanotti and Bundy (1995) and Bundy et al. (1993) suggesting that N credits from annual legumes are provided not by decomposition of the roots or release of N directly into the soil from the roots as some might assume, but by a change in soil biology, increased organic matter mineralization and decomposition of low C/N legume top residue. Yet there is concern that N may not be released soon enough from low C/N residues for subsequent availability to short season crops. Growers may therefore tend to be conservative in the amount of N credits given to subsequent crops from sugarbeet residues or other broadleaf crops. This study was conducted to determine when N is released from soil/residue/fertilizer and its movement in the soil through a growing season.

Methods

Field studies

A wheat field following sugarbeet in 1998 and two wheat fields following sugarbeet in 1999 were examined. Sugarbeet top N levels and residual N in the fall to a depth of 6 feet were determined in a 150 feet (½ acre) grid in 1997 and 1998 prior to growing wheat. Soil NO_3-N levels were determined on the 0-6 inch, 6-24 inch, 24-48 inch and the 48-72 inch core depth at each location. Sugarbeet tops were collected, shredded and analyzed for N levels in 1997 and one site was evaluated (section 34) in 1998. The site in section 29 was shredded by hail in early September, so no top collection was made to evaluate experimentally how much N to credit the field. However, aerial photography and satellite imagery from the south field was used to determine the credit to give the field in section 29 (the north field). Variable-rate N was applied to the wheat fields in each year prior to seeding using a variable-rate ammonia applicator.

The following spring after wheat emergence, an area about 8 feet long by 8 feet wide at each of the same 150 foot grid sites as the soil/plant sampling the previous year was killed by an application of Roundup. Five soil cores were obtained from each grid. In 1998, cores were taken at a soil depth of 0-6 inch and 6-12 inches for the growing season sampling, followed by a post-harvest sampling of 0-6 inch, 6-24 inch, 24-48 inch and 48-72 inch depth. In 1999, cores were taken from the 0-6 inch, 6-12 inch, and 12-24 inch depth, followed by a similar post-harvest sampling as in 1998. These soil samples were analyzed for NO_3-N.

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The soil NO_3-N levels found in each year are the total NO_3-N found from the transformation of ammonia to nitrate, the mineralization of organic matter and the decomposition of sugarbeet tops. Organic matter content for the section 29 fields varied from 2.4% to 3.5%. The organic matter content for the section 34 fields varied from 2.5% to 4.5 % (Figure 1). The nitrogen application map for the field studied in 1998 and the two fields studied in 1999 are shown in Figure 2.

Figure 1. Organic matter maps for fields 29W (wheat 1998) and fields 29E and 34N (wheat 1999).

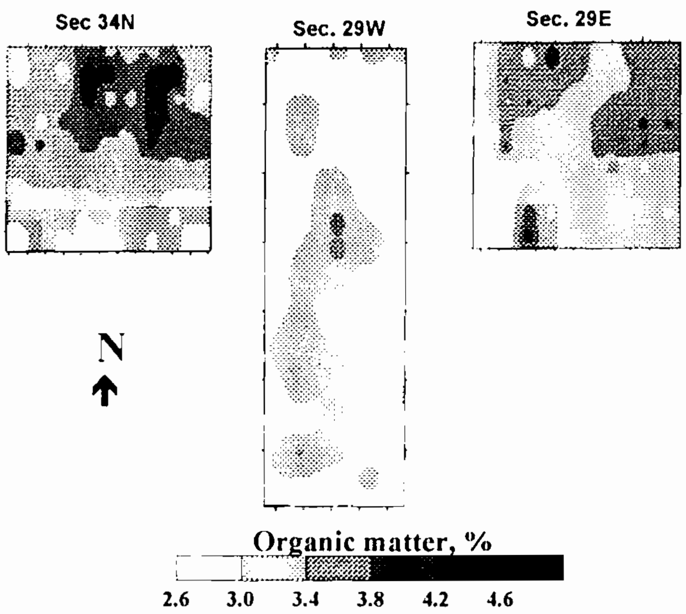
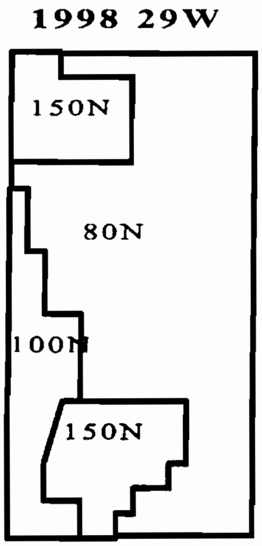
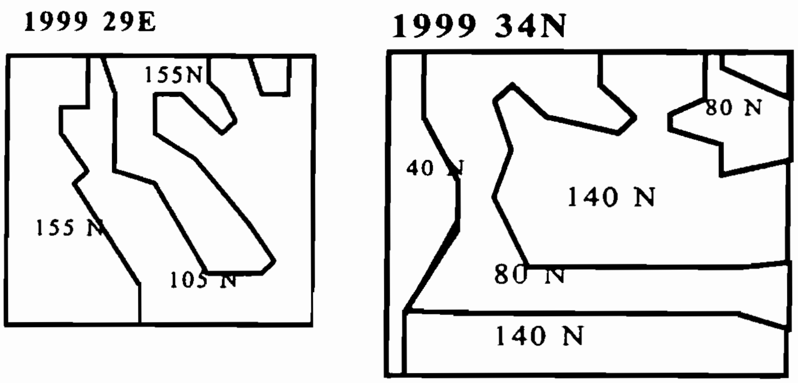


Figure 2. N application, 1998 and 1999. N credits were determined using aerial photography (color slide film). Values displayed are application rates of anhydrous ammonia N, lb/acre.





Residue burial study-

In 1999, plots were established in fields of corn, canola, sunflower, potato, sugarbeet and spring wheat by applying additional N as a topdress at rates of 0, 50 lb N/acre, and 100 lb N/acre as urea. These plots were established to provide different N content of residue to use as a buried residue study in 2000. Residue was collected prior to grain harvest, chopped and 24 grams was placed in a fine-mesh fiberglass bag. The bags were buried at two locations, Fargo and St. Thomas, ND. At Fargo, the bags were buried so that the tops were three inches deep and two inches deep at St. Thomas. Bags were randomized in a split plot design. The bags were removed at four times, mid-May, late May, mid June and early July. There was no significant rainfall at either site following spring thaw until mid June, however, the soil at each location was somewhat moist at each earlier sampling date.

Following removal, the bags were washed and any residue washed out of the bag was collected in a 200 mesh screen and saved along with the larger residue for analysis. N was analyzed using a micro-kjeldahl method, and %C was analyzed using a carbon analyzer.

Results and Discussion

Field 29W, 1998

In field 29W, when comparing the 1998 first in-season 0-12 inch depth NO_3-N levels with the after-harvest 1997 0-12 inch depth levels, there were large differences in the amount of NO_3-N present (Table 1). In the fall of 1997 immediately following sugarbeets, mean NO_3-N levels were 19 lb/acre, compared with a mean of 130.9 for the 5/15/98 sampling. The mean ammonia-N fertilizer application rate was 102 lb/acre. The mean N reduction due to sugarbeet tops was 48 lb/acre. If all of the ammonia was converted to nitrate and beet tops supplied the N credit determined prior to its application, and all of the N from the previous fall found in soil test results was still in the top 12 inches of soil, the amount of N actually found should have been 169 lb/acre assuming no contribution of N from the organic matter. At the second sampling taken at 6/1/98, this number was more closely approximated by a mean NO_3-N level at the 0-12 inch depth of 159.7 lb/acre. The third sampling taken June 15 had a mean NO_3-N level of 88.4 lb/acre, while the fourth sampling, taken July 1 was 137.4 lb NO_3-N/acre. The mean NO_3-N level August 17 following wheat harvest was 101.3 in the 0-12 inch depth and a total of 144 lb/acre to a depth of 4 feet. The total NO_3-N available at each sampling date is displayed in Figure 3. The August sampling date following harvest is shown in Figure 4.

Another observation during the experiment was the value of N at the surface 0-6 inches compared to levels at depth. The 5/15 sampling was 112.3 lb/acre, the 6/1 sampling dropped to 94.4 lb/acre, and the 6/15 through harvest sampling was between 57.2 and 68.5 lb/acre. The 6-12 inch depth varied, perhaps as a result of rainfall patterns. From 5/15 through 6/1, 0.9 inches of rain fell, largely in two events at the beginning and end of the period. As a consequence of this, NO_3-N may have leached below the 6 inch sampling depth at the 6/1 sampling date. From 6/1 through 6/15, only 0.12 inches of rain fell, so evaporative processes may have pulled soil water again towards the surface and resulted in lower levels of NO_3-N at the 6-12 inch depth. The period from 6/15 to 7/1 was another rainy period (1.26 inches), with NO_3-N again increasing at the 6-12 inch depth.

Figure 3. 0-2 foot NO_3-N levels, field 29W, 1998 over sampling dates.

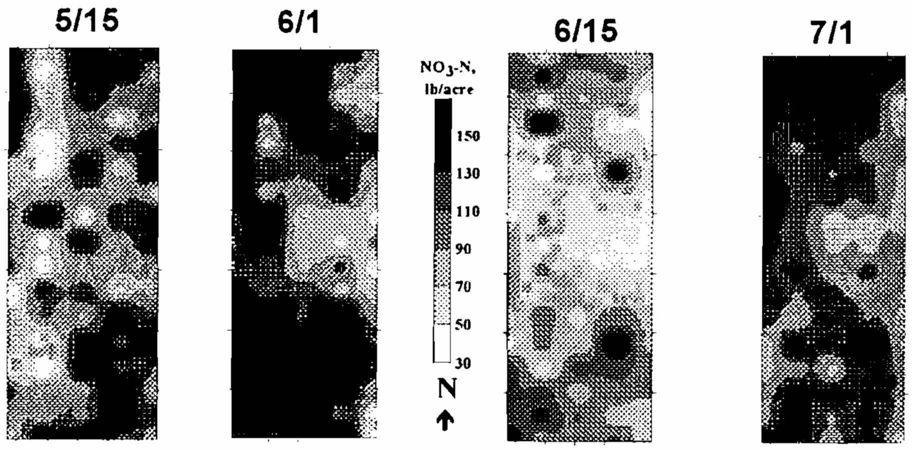
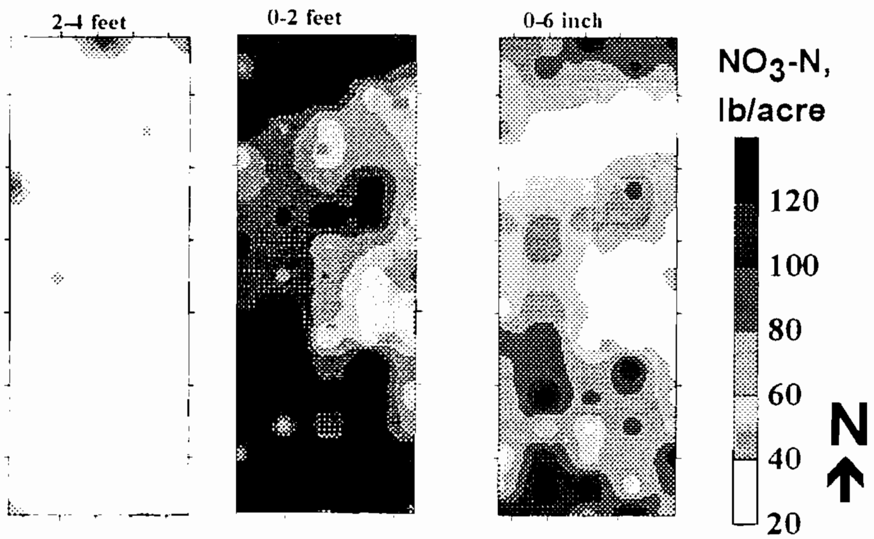


Figure 4. NO_3-N levels following spring wheat harvest, field 29W, 1998.



The three fertilized zones, 150 lb N/acre, 100 lb N/acre and 80 lb N/acre, were examined more closely for NO_3-N levels at the 0-12 inch depth at the 6/1 sampling date at which soil N levels were maximized. These data are summarized in Table 2 and show that the area supported by the 150 lb N/acre rate contained 133 lb NO_3-N, while the 100 lb N/acre and 80 lb N/acre rates contained 115 lb and 113 lb NO_3-N/acre respectively. The areas supported by the lower N rates yielded as well as those with the higher fertilizer N rates (Table 2). Mean yields within each zone varied from 55 to 56.9 bu/acre. There were no significant differences between mean yields in each zone.

Table 1. Field 29W, 1998 NO_3-N levels through the growing season.

Sampling date	Mean NO_3-N levels, lb/acre				
	0-6 inch	6-12 inch	0-1 foot	1-2 foot	2-4 foot
10/97	13.1	6.0 (est)	19.1 (est)	11.9 (est)	16.6
5/15/98	112.3	18.6	130.9		
6/1/98	94.4	65.3	159.7		
6/15/98	57.2	31.3	88.4		
7/1/98	68.5	68.9	137.4		
Harvest 8/17/98	61.8	39.3	101.2	21.3	21.4

Table 2. NO_3-N levels by zone, 6/1 sampling date and yields by zone. Field 29W, 1998.

Zone	NO_3-N, lb/acre	Yield, bu/acre
150 lb N/acre	133	56.4
100 lb N/acre	115	56.9
80 lb N/acre	113	55.0
Significance (yield only)		None

Field 29E, 1999.

The significant snow melt and an additional 3.4 inches of rainfall between 4/1/99 and the first sampling date of 5/20/99 may have contributed to the deeper position of NO_3-N compared to the field studied in 1998. Of the total 131.7 lb NO_3-N in the top 0-2 foot depth, only 17.7 lb was at the 0-6 inch depth and more than half was found in the 12-24 inch depth (Table 3). The second sampling date (6/9/99) found an even greater amount at the 12-24 inch depth and a total NO_3-N content of about 20 lb/acre more than at the 5/20/99 date. A total of about 2 inches of rain fell between these two sampling dates in four 0.4 to 0.5 inch events.

Table 3. Field 29E, 1999 NO_3-N levels by depth and by date of sampling.

Sampling date	Mean NO_3-N levels, lb/acre				
	0-6 inch	6-12 inch	0-1 foot	1-2 foot	2-4 foot
10/98	10.3	4.0 (est)	14.3 (est)	7.7 (est)	12.0
5/20/99	17.7	47.1	64.8	66.9	
6/9/99	29.3	37.0	66.3	85.1	
Harvest, 8/27/99	25.0	30.0 (est)	55.0	59.0 (est)	44.5

Figure 5. Field 29E 0-2 foot NO_3-N by sampling date.

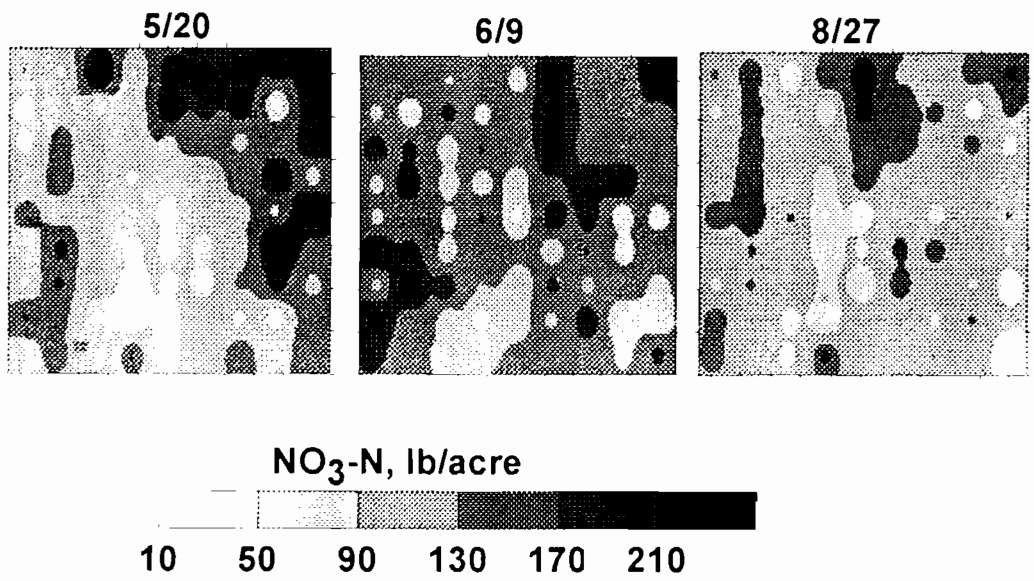
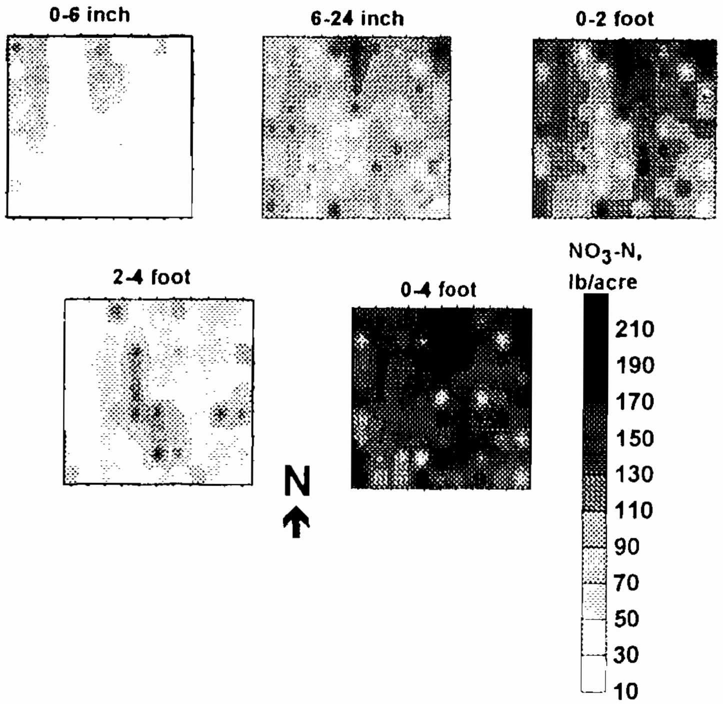


Figure 6. Field 29E, NO_3-N levels following spring wheat harvest, 8/27/99.



Approximately 3 inches of rain fell between the 6/9 sampling date and the 8/27 after harvest sampling date. NO_3-N continued to move downward in the soil, especially out of the 6-12 inch depth. Figure 5 shows a general increase in the 0-2 foot NO_3-N from 5/20 to 6/9, followed by a general decrease from 6/9 to 8/27. The 44.5 lb/acre at the 2-4 foot depth is an increase of 32.5 lb/acre over the fall 1998 levels following sugarbeets.

Table 4. NO_3-N levels by zone, 6/9 sampling date and yields by zone. Field 29E, 1999.

Zone	NO_3-N, lb/acre	Yield, bu/acre
155 lb N rate	155.3	83.4
105 lb N rate	147.7	80.4
Significance (yield only)		Yes

Despite a 50 lb/acre N credit given due to sugarbeet top greenness in the fall of 1998, NO_3-N levels were only about 7 lb/acre less at the 6/9 sampling date. As in 1998 in field 29W, even though some small increases in total NO_3-N following the May sampling dates, a very large proportion of N was available for the spring wheat crop at the earliest sampling date. The higher N rate translated into three bu/acre more response. The higher yield may not be related to higher N availability, but may be related to other favorable soil factors which are inherent in that zone compared to the higher sugarbeet top color zone.

Field 34N

Field 34 N behaved similar to field 29E in the manner of NO_3-N position and movement during the growing season. Table 5 shows that N was released early in the season and moved downward in the profile due to early spring rains and snow-melt. It shows that more than half of the NO_3-N was present at the 12-24 inch depth at the first and subsequent sampling dates.

Table 5. Field 34N, 1999 NO_3-N levels by depth and by date of sampling.

Sampling date	Mean NO_3-N levels, lb/acre				
	0-6 inch	6-12 inch	0-1 foot	1-2 foot	2-4 foot
10/98	9.5	6.0 (est)	15.5 (est)	12.1(est)	27.2
5/20/99	18.3	49.8	68.1	90.7	
6/9/99	33.3	38.2	71.4	74.9	
Harvest, 8/27/99	29.6	29.4 (est)	59.0	58.9 (est)	39.6

Soil NO_3-N levels are shown in figures 7 and 8 to be high at the 0-2 foot depth at the first two sampling dates, then decrease at harvest. At harvest, the levels are relatively low at the surface, increase with depth, with the 2-4 foot depth containing significant levels compared to the fall 1998 sampling.

Figure 7. Field 34N, 1999, 0-2 foot depth by sampling date.

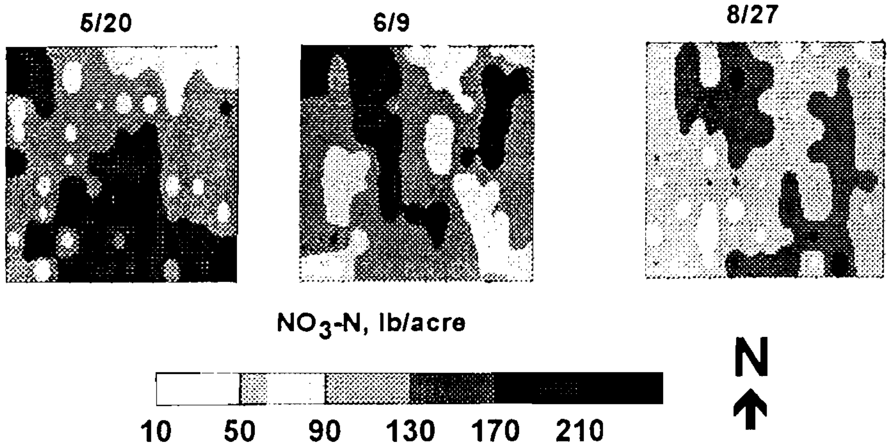


Figure 8. St. Thomas field 34N 1999 NO_3-N levels, 8/27/99.

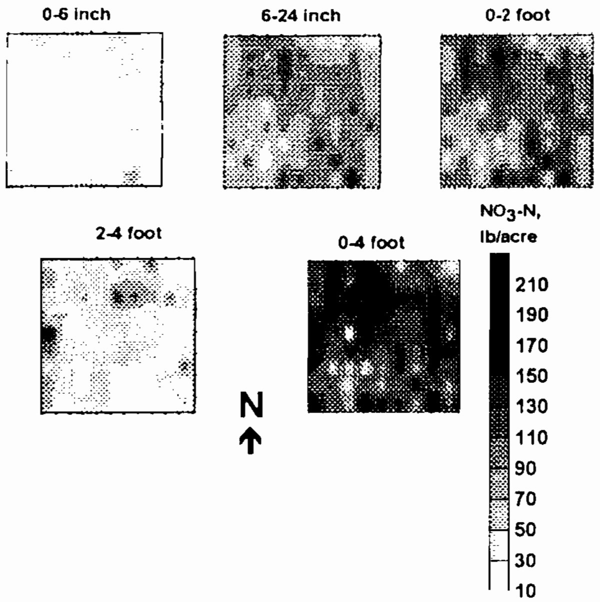


Table 6. NO_3-N levels by zone, 6/9 sampling date and yields by zone. Field 34N, 1999.

Zone	NO_3-N, lb/acre	Yield, bu/acre
140 lb N rate	170.2	85.2
80 lb N rate	150.8	87.2
40 lb N rate	161.9	83.7
Significance (yield only)		None

In the zone described by the N rate reduction of 60 lb/acre, the 6/9 sampling at the 0-2 foot depth was reduced by 20 lb/acre compared to the 140 lb N rate. The zone described by the 100 lb/acre N rate reduction was reduced by only 9 lb/acre. Because earlier sampling did not reach below 2 feet, it is not know whether higher levels of N would have been found below the 2 foot depth relative to those found in the 140 rate zone. However, a reduction of 60 lb/acre in N rate translated into only a 20 lb/acre reduction in NO_3-N, giving support to the use of a rate reduction in the greener leaf color of the previous summer's photography and satellite imagery. There was no significant differences in yields regardless of N rate, indicating that N was adequate through the season for high yields in the field regardless of N credit. It also indicates that the N credit was justified, or the high yields would not have been possible.

Residue Study

At the time of this publication, analysis of all residues is not complete. However, Table 7 shows that there were differences in the change of weight in residue and N remaining between crops. Potato, sunflower and especially sugarbeet were most easily decomposed, while spring wheat and corn were least decomposed. The results support the finding of the field study that sugarbeet residue is rapidly decomposed and N mineralized and released into the soil for subsequent crops. It also supports the idea of introducing a N credit for potato and sunflower.

Table 7. Change in weight and N content of residue from 11/99 to 6/19/2000. Beginning weight was 24 g.

Crop	St. Thomas		Fargo	
	Weight, g.	**% change**	**Weight**	**% change**
Canola	-14.59	-60.8	-17.18	-71.6
Corn	-13.91	-58.6	-16.86	-70.3
Potato	-18.44	-76.8	-23.52	-98.0
Sugarbeet	-21.86	-91.1	-24.00	-100.0
Sunflower	-17.47	-72.8	-20.28	-84.5
Spring wheat	-13.13	-54.7	-15.98	-66.6

Summary

Three fields were investigated for soil NO_3-N following variable-rate N applications based on sugarbeet leaf color and soil sampling. In all three fields, N was available at the earliest May sampling dates and continued at high levels throughout the growing season. In years with more rainfall, nitrate movement into deeper layers of the profile was evident, supporting a previous view that problems with a sugarbeet/wheat/potato rotation in coarser textured soils contribute to deep N accumulation if not managed through adjustments in the use of sugarbeet as a previous crop credit to wheat and the use of deeper soil sampling than normal following the potato crop. In fields with small differences between yellow/green leaf color, more conservative approaches to N credits may be supported provided adequate soil sampling describes ending N levels to subsequent crops. However, in the greenest areas of the experimental fields adjustments of up to 100 lb N/acre were justified and ending N levels were similar to those in areas of the field where no adjustments were made.

Residue burial studies support the field experiments by showing that residue decomposition is rapid, with 70-90% of sunflower, potato and sugarbeet residues decomposed by mid-June, and a high value of N released back to the soil.

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