IN-SITU NITROGEN MINERALIZATION OF MANURE AMENDED SOIL

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ABSTRACT

Because manures are highly variable in their chemical and physical characteristics, region-specific field studies are required to make accurate nitrogen (N) mineralization predictions. Often, the predictions given to farmers are based upon best judgment, not research based data. This investigation was designed to conduct an in-situ study of manures from different livestock sources and to determine and predict the differences in their mineralization rates. The in-situ resin core method was used to measure N mineralization. Tubes (360) were placed in corn rows, with 60 tubes each receiving hog, beef, chicken, turkey, or no manure. Fifteen tubes of each treatment were removed at three weeks, with the remaining tubes planned to be removed at 6, 12, and 40 weeks. The NO_3-N and NH_4-N concentrations were analyzed and compared with each manure's C/N ratio, acid detergent fiber (ADF), and neutral detergent fiber (NDF). The results for the three week period demonstrated that the % N mineralized of total N applied was significantly higher for the hog (14.2%), turkey (10.1%), and chicken (11.7%) manures than for the beef manure (3.3%). Percent N mineralized significantly correlated with NDF ($p<.0001$, $R= -0.52$), while C/N ratio did not significantly correlate with % N mineralized ($p=0.1384$, $R= -0.19$). Also, NO_3-N concentrations were higher than NH_4-N concentrations. It is too early to make any solid conclusions. Once the remaining removal times are analyzed and compared with the manure characteristics and environmental factors, conclusions about the predictability of N mineralization in this study can be made.

INTRODUCTION

In this research, we are measuring the amount of nitrogen (N) mineralized from manure amended soil. We hope to use this information to develop predictive relationships of N mineralization on manure amended soils. The ultimate goal will be to use this information to develop manure management practices for producers.

Often, farmers apply manures and also apply a standard amount of commercial fertilizers. This practice of applying organic and commercial fertilizers can overload soils with available N. This excess N can potentially leach below the root zone and contaminate groundwater supplies. If we can determine how much N is mineralized from a manure, we can better predict a farmer's field N budget. Better predictions would allow farmers to more accurately match manure and commercial fertilizer application with crop need. This should result in reduced fertilizer costs and help prevent potential groundwater contamination.

The resources currently used for predicting the benefits of manure application are based on data from soils with lower pH and higher moisture regimes. Often, the N mineralization rates given to farmers are based upon the best judgment of researchers (Pratt et al., 1973), not research based data. Other recommendations are made from older waste management handbooks and unlisted sources (Waskom and Davis, 1999).

Because manures are highly variable in their chemical and physical characteristics, region-specific field studies are required to make accurate mineralization predictions. The main objective in this study is to conduct an in situ study of manures from different livestock sources and to determine and predict the differences in mineralization rates. Additional objectives are to compare in situ data with laboratory data (Smith et al., 1998), relate manure characteristics to N mineralization rates and amounts, and to provide a validation data set for the MINIMO model.

MATERIALS AND METHODS

The experiment was conducted on three plots in an irrigated (linear move) corn field at the USDA Great Plains Agricultural Research Station in Akron, Colorado. Each plot measured 20 feet by 60 feet and was divided up into 5 equal-sized smaller plots.

Five manures and a control were selected for this study: beef 1, beef 2 , hog, turkey and chicken. Presently, all manures but the beef 2, which was selected to be studied in conjunction with a similar study in Nebraska, have been characterized for carbon, nitrogen, and fiber content (Table 1). Each manure was run through a meat grinder twice and well mixed to provide a homogenous sample.

Table 1. Chemical and physical characteristics of manure samples used in study.

Manure type	C/N	Total N	ADF*	NDF**	NH_4-N	NO_3-N
		%			mg/kg	
Turkey	7.3	3.57	60.4	62.2	61	7.9
Hog	11.7	2.72	38.4	55.5	152.4	0.1
Chicken	12.6	1.16	40.6	52.6	91.5	0.2
Beef 1	13.8	2.18	44.3	69.8	37.7	0.1
Beef 2	Not Yet Characterized					

* ADF is the acid detergent fiber
** NDF is the neutral detergent fiber

The ground manures were weighed out to simulate application rates of 26.4 Mg/ha (12 dry tons per acre) to be applied to each experimental unit. The experimental units were aluminum conduit tubes measuring 5 cm in diameter by 15 cm long. Bags were installed in the bottom of each tube to capture ions leaching from the soil core as demonstrated by DiStefano and Gholz, (1986). These bags were made from Lycra® material for maximum durability and filled with 20 ml of ion-exchange resin. The ion-exchange resin consisted of equal amounts of Na-saturated cation (USF C-211) and Cl-saturated anion (USF-464) exchange resin. Twenty ml of resin was selected after our preliminary laboratory tests demonstrated that 20 ml provided more consistent results than 15 ml and had less leachate getting past the resin bag.

The tubes were installed on June 29, 1999. Two data loggers were installed in the field to record daily high, low and average soil temperatures from thermocouples installed at 3 cm and 12 cm. The manures were applied after the tubes were driven into the soil and then withdrawn. The manure was mixed into the top 2.5 cm of the soil while the resin bag was placed at the bottom 1.5 cm of the tube and held in place with a nylon retainer cloth. The tubes were then reinserted into the soil with a small portion of the tube remaining above the surface and lightly tamped around the sides to ensure good soil contact. The incubation tubes were placed within the corn rows and in between the corn plants to avoid tractor wheel traffic. To minimize soil disturbance and facilitate easier tube insertion and removal, a special probe was machined so that the conduit tube could be placed inside the probe and inserted with a soil sampler.

Removal times of 3, 6, 12, and 40 weeks after tube installation were scheduled. For each removal date, a complete set of tubes from each replication was extracted from the field. The soils were removed from the tubes, sifted twice through a 2 mm sieve, mixed thoroughly, and weighed. Fifty ml of 2N KCl were added to each of two 5g samples and shaken for 30 minutes. Extractants were filtered through Buchner funnels under vacuum and analyzed with a LACHAT® Continuous Flow Analyzer System for NO_3-N and NH_4-N concentration and then averaged. The resin bags were extracted using three serial extractions. The following method gave us a removal rate of greater than 95% inorganic nitrogen from the resin bags.

Extractions 1 and 2

1. Add 180 ml 2N KCl to flasks with resin bags.
2. Shake flasks for 30 minutes.
3. Quantitatively transfer and filter extractant through Buchner funnels under vacuum and bring up to 250 ml volume. Take 10 ml aliquot and analyze each through autoanalyer individually.

Extraction 3

1. Add 60 ml 2N KCl to resin bag in 100 ml specimen cup.
2. Shake cup for 30 minutes.
3. Quantitatively transfer and filter extractant through Buchner funnels under vacuum and bring up to 100 ml volume. Take 10 ml aliquot and analyze each through autoanalyer individually.

Concentrations from each of the three aliquots were added together and then added to soil NH_4-N and NO_3-N levels. Inorganic nitrogen (NO_3-N and NH_4-N) from the soil and resin bag was expressed on a kg/ha basis using the following formula:

$$\frac{1.25\text{x}10^9\text{cm}^3}{\text{h.f.s.}} \times \frac{\text{mg N}}{\text{kg}} \times \frac{\text{g soil}}{\text{cm}^3} \times \frac{1\text{ kg}}{1000\text{g}} \times \frac{1\text{ kg}}{1\text{x}10^6\text{mg}} = \frac{\text{kg net N mineralized}}{\text{h.f.s.}} \qquad (1)$$

(h.f.s. = hectare furrow slice 15 cm deep)

The soil in the tubes had an average volume of 245 cm^3, and the bulk density was calculated on a per tube basis. Net mineralization on a soil mass basis was then calculated as:

$$\text{Net manure N mineralized} = (\text{treatment soil mineral N} + \text{treatment resin mineral N}) \; \text{minus} \; (\text{control soil mineral N} + \text{control resin mineral N}) \qquad (2)$$

The experiment was set up as a split plot in time design with three replications and five subsamples. The manure treatments were designated whole plots, and the removal dates were subplots. Data were analyzed using descriptive statistics and analysis of variance using SAS (Statistical Analysis System, V7) to determine significant differences among treatments, subplots, and replications.

RESULTS AND DISCUSSION

At this stage in the research, we have analyzed the first removal date for NO_3-N and NH_4-N concentrations and we will be reporting results on these data. The total amount of N mineralized in relation to the total amount of N applied (Figure 1) was significantly higher for hog, turkey, and chicken manures than for beef manure.

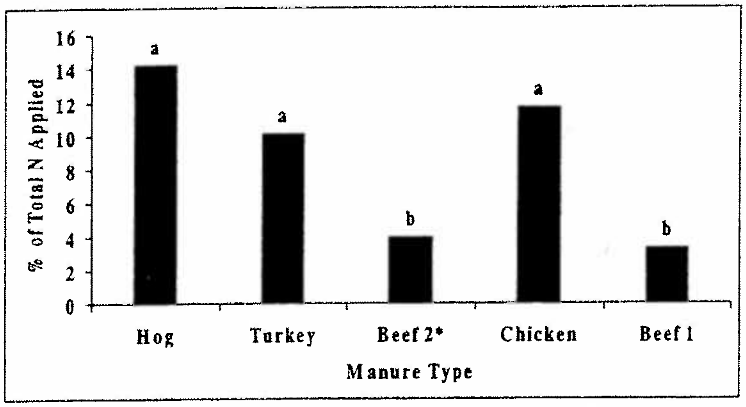

Figure 1. Mineralized N expressed as percent of total N applied.

Mean separation method used: Student-Newman-Keuls Test

Number of Means	2	3	4	5
Critical Range	4.22	5.23	5.86	6.33

* Preliminary Values

This difference could be due to dissimilar C/N ratios, because the beef C/N ratio was higher than the others (Table 1). However, although the beef manure had a C/N ratio almost double the turkey manure, it was only slightly higher than the chicken and hog manures, so why such a difference in mineralization? Another factor to consider may be the neutral detergent fiber (NDF) content. The NDF is made up of cellulose, hemicellulose, and lignin portions of vegetative materials. The beef, hog and chicken C/N ratios were similar, but the beef NDF content was nearly 23% higher than the hog and chicken NDF, and this may explain the large difference in the amount of N mineralized. When tested, the correlation of percent N mineralized with NDF was highly significant ($p<.0001$), with an R-value of -0.52. The C/N ratio was not significantly correlated with the percent N mineralized ($p=0.1384$, $R= -0.19$).

Switching from percent to actual values, the hog and turkey manures had significantly higher total N mineralization than the beef and chicken manures. The most obvious reason for this is that the initial inputs of the hog and turkey manures were higher than the chicken and beef manures (Table 2). Also, even though the beef manure inputs were approximately double that of the chicken manure, the amount of N mineralized from the beef manure was nearly half that of the chicken manure. Nitrate-N concentrations were higher than NH_4-N concentrations for all manures (Figure 2), indicating that nitrification appears to be occurring under aerobic conditions.

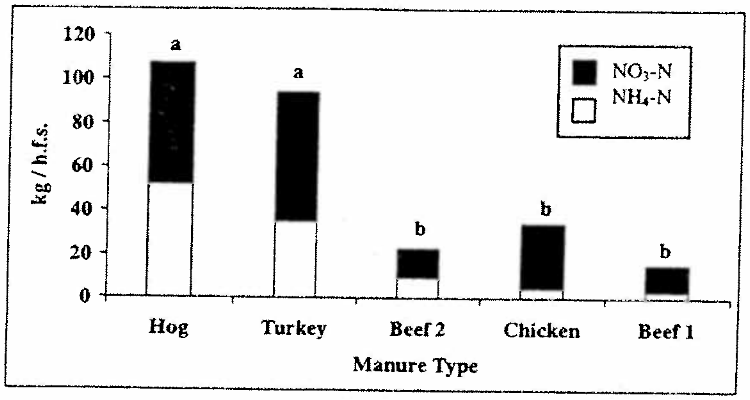

Figure 2. Net total N mineralization.
Mean separation method used : Student-Newman-Keuls Test

Number of Means	2	3	4	5
Critical Range	23.84	29.54	33.10	35.71

Table 2. Application rates of manures and total N.

Manure	Mg/ha manure	kg/ha N
Turkey	26.4	941
Hog	26.4	718
Chicken	26.4	305
Beef 1	26.4	576
Beef 2	26.4	N/A

CONCLUSIONS

It is very early in this experiment to make any solid conclusions. Once the remaining removal times are analyzed and environmental factors of soil temperature and soil moisture content are analyzed, we should be able to adjust the MINIMO model so that mineralization predictions are more accurate and flexible for different manures and soil conditions.

REFERENCES

DiStefano, J.F. and J.L. Gholz. 1986. A proposed use of ion exchange resin to measure nitrogen mineralization and nitrification in intact soil cores. Comm. Soil Sci. Plant Anal. 17:989-998.

Pratt, P.F., F.E. Broadbent, and J.P. Martin. 1973. Using organic wastes as nitrogen fertilizers. Calif. Agri. (June) 73:10-13.

Smith, G. M., M. F. Vigil, and J. Davis. 1998. Nitrogen mineralized from manure amended soils. pp. 34-39, *in* 1998 Great Plains Soil Fertility Conference Proceedings. Denver, CO; March 3-4, 1998.

Waskom, R. M. and J.G. Davis. 1999. Best Management Practices for Manure Utilization. Bulletin 568A. Colorado State University. Fort Collins, CO.

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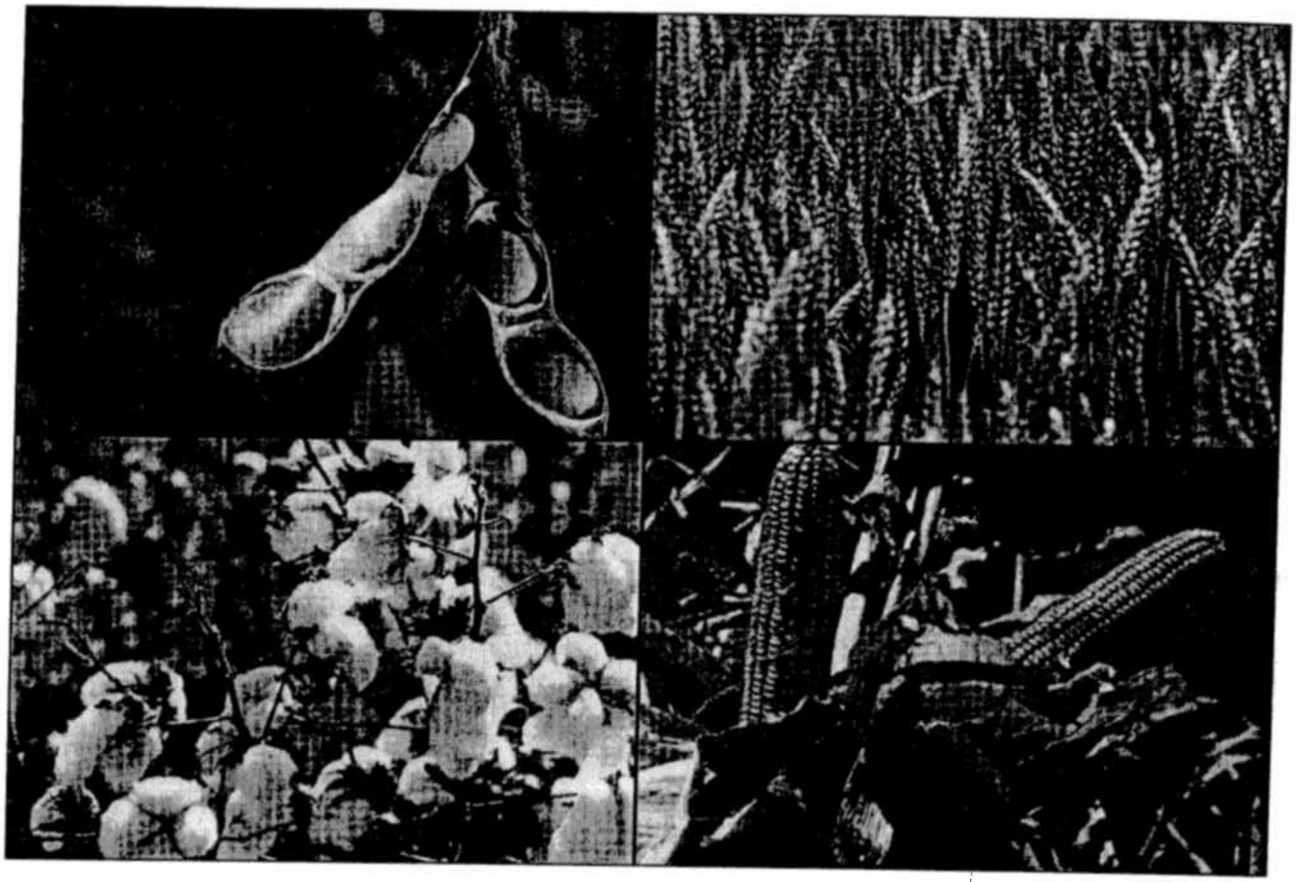

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