NITROGEN MINERALIZATION RATE OF ANIMAL MANURE ACROSS PRODUCTIVITY LEVEL MANAGEMENT ZONES

M.E. Moshia, R.Khosla, D.G. Westfall, J.G. Davis, and R. Reich
[1]Colorado State University., Fort Collins, CO
moshia@warnercnr.colostate.edu

ABSTRACT

Accurate quantification of Nitrogen (N) mineralization in manure from different productivity level management zones (MZs) could result in efficient and safe utilization of manure as N fertilizer. Soil characteristics and crop responses change between different MZs and the loss of N and other nutrients into the environment can occur when the supply of soil nutrients by animal manure and other sources exceeds the demand by crops. The objective of this study was to compare nitrogen mineralization rates of dairy cattle manure within and across three productivity level MZs. To accomplish this, a 120 day laboratory incubation study was conducted at the Natural Resources Ecology Laboratory (NREL) at Colorado State University using a completely randomized design set as a 2 factor factorial with 4 treatments and 3 productivity level MZs. Treatments for the study included the field equivalent of, 22 Mg ha^{-1}, 44 Mg ha^{-1}, 67 Mg ha^{-1} and 134 Mg ha^{-1} of applied animal manure. Soils used in the study were collected from the top 15 cm of high, medium and low productivity MZs from Fort Collins, Colorado, on a continuous corn (Zea *mays L.*) field. The soil was classified as fine-loamy, mixed, mesic, Aridic Haplustalfs. Results show that manure mineralization was significantly different ($p \leq 0.05$) across all treatments within each of the productivity level MZs. However, manure mineralization was not significantly different ($p \leq 0.05$) among all MZs on all treatments. Higher inorganic N values were observed from low productivity MZs in the 67 Mg ha^{-1} and 134 Mg ha^{-1} treatments as compared to 22 Mg ha^{-1} and 44 Mg ha^{-1} treatments. The high productivity MZs resulted in higher mineralized N values in the 22 Mg ha^{-1} and 44 Mg ha^{-1} which were not significantly different ($p \leq 0.05$) from low and medium productivity MZs on the same treatment. Lower manure application rates responded positively on high MZs, while higher manure application rates responded positively on low MZs. The information obtained in this study will give support to precision manure management across productivity level MZs for crop production and environmental protection.

Keywords

Nitrogen mineralization, Animal manure, Productivity level management zones.

INTRODUCTION

Accurate quantification of Nitrogen (N) mineralization in manure from different productivity level management zones (MZs) could result in efficient and safe utilization of manure as N fertilizer. Understanding N mineralization rate and the efficient use of animal manure as N fertilizer can decrease the potential for ground water contamination. The N contained in animal manure has a potential as a valuable fertilizer, however due to environmental constraints, it may also be a factor that limits its use on agricultural lands (Barbarika et al., 1985). Binder et al. (1996) stated the importance of synchronizing manure nutrient mineralization with crop use. Also, environmental loss of nutrients can occur when supply of nutrients by animal manure and other sources exceeds the demand by crops. The aforementioned scientific rationale states clearly the challenges related to the use of animal manure as fertilizer.

The application of organic amendments to soil is increasing as both an environmentally favorable waste management strategy and as a means of improving soil organic matter (SOM) content in low-fertility soils or spatially variable soils. Precision agriculture has the potential to manage such infield spatial variability. Recent studies in Precision Agriculture have focused on the use of site-specific management zones as a method of applying crop inputs efficiently (Khosla et al., 2002). Site-specific management zones, hereafter referred to as management zones (MZs), are sub-regions of a field that express a homogeneous combination of yield limiting factors (Doerge, 1999).

Various soil characteristics influence the rate of N mineralization. Mzuku et al. (2005) has reported that soil particle size distribution vary significantly across productivity level MZs. Mzuku et al. (2005) further reported that, the percent of sand particles increased from the high to low productivity MZs while clay particles increased from low to high productivity MZs. Soil texture influences soil water holding capacity and soil water content was reported to increase from low productivity MZs to Medium and then High productivity MZs (Mulla and Bhatti, 1997). Soil texture directly affects soil electrical conductivity (EC) which is one of the key soil properties considered when delineating productivity level MZs (Franzen and Kitchen, 1999). Schjönning et al. (1999) have both confirmed that soil characteristics are influential on N mineralization rate.

Hadas et al. (1983) has studied the effect of temperature and soil type on mineral N release from animal manure under a controlled environment. The study revealed no significant differences between clay and sandy soils at 25 ºC but the authors had no plausible explanation for the result. Previous studies have reported that, net mineralization of soil organic matter is more rapid in sandy soils than in clay soils (Verberne et al. 1990). Verberne et al. (1990) further reported that the lower net mineralization in clay soils is assumed to be caused by greater physical protection of soil organic matter and microbial biomass.

Previous laboratory studies have investigated the N mineralization from applied animal manure (Bonde and Lindberg, 1988). However, there are no known published sources that reported the investigation of the N mineralization of variable rates of dairy animal manure within and across different MZs.

OBJECTIVES

The objective of this study was to evaluate, quantify and compare the nitrogen mineralization of variable rates of dairy cattle manure within and across soils of three management zones in a controlled environment.

MATERIALS AND METHODS

Soils used for the study were collected from the surface (0 – 15 cm depth) of fine-loamy, mixed, mesic Aridic Haplustalf profile in Fort Collins, Colorado, on a continuous corn (*Zea mays* L.) field. Soils were sampled from three productivity MZs classified as high, medium and low productivity. The procedure for classifying fields into productivity level MZs is documented by Fleming et al. (2000).

Soils were air-dried at room temperature, sieved through a 2 mm sieve and subjected to physical and chemical analyses. Selected soil and manure properties analyzed are presented in Table 1. Soils used in the study had no history of manure application.

Laboratory Study

Fifty-grams of soil were placed into plastic specimen cups (10 cm tall x 10 cm diameter). Manure was added to soils and mixed at rates of 1.12 g, 2.24 g, 3.41 g, and 6.82 g, which is equivalent to field applications of 22, 44, 67, and 134 Mg manure ha^{-1}.

All treatments were mixed thoroughly before moistening with deionized water. Soil moisture was adjusted to 75% field capacity with the addition of deionized water at the beginning of the incubation study. Soil field capacity corresponds to gravimetric water content of the soils in each of the three MZs.

Soil samples with no manure were also included as a control to estimate soil N mineralization. This value was subtracted from the treatments to estimate the rate of N release from the manure. Treatments were placed in a 1 liter wide mouth mason jars and incubated in dark for 120 days in a controlled environment at 25 ± 1 °C. To determine the amount of N mineralized, one sample of each treatment was collected after 0, 5, 10, 15, 30, 45, 60, 90 and 120 days of incubation. Soil samples of 50 g each were extracted with 250 ml of 2 M KCl and the concentrations of NH_4-N and NO_3-N (inorganic nitrogen) were determined by continuous flow injection colorimetry using an AutoAnalyzer. All inorganic N concentrations are expressed on an oven-dry basis.

Calculations

Mineralization rates in the incubated soils were determined as described by Kaboneka et al. (1997). Net N mineralization was calculated as the difference between soil inorganic N (NH_4^+-N + NO_3^--N) in amended and unamended soils.

(a) Net $N_m = N_{m\ \text{amended soil}} - N_{m\ \text{unamended soil}}$

Where N_m = N mineralization (mg N kg^{-1} soil)

(b) The percent N mineralization was calculated as follows:

% N mineralization = [(X-Y) / Z] x 100 Where: X = mg of N mineralized from amended soil, Y= mg of N mineralized from unamended soil and Z = mg of N added in animal manure amendments.

Experimental design and data analysis

The incubation experiment was set as 2 factor factorial with 4 treatments and 3 productivity level MZs. Treatments for the study were arranged in a completely randomized design. The statistical analyses were performed using the PROG GLM procedure in SAS (SAS Institute, 2007). Treatments means were compared using tukey's HSD at 5 % level of significance (Steel et al., 1997). All graphs were fitted with nonlinear regression.

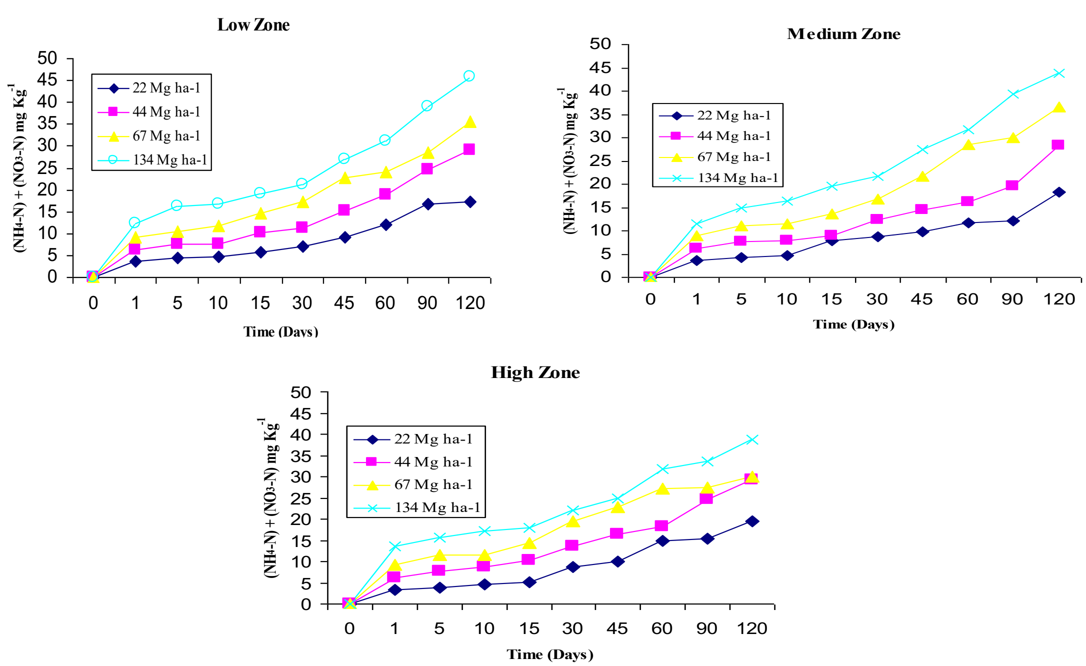
Table 1: Selected surface soil (0-15 cm) properties for Management Zones at study site and selected properties for dairy cattle manure.

Analyzed properties	PRODUCTIVITY MANAGEMENT ZONES			Dairy Cattle Manure
	Low	Medium	High	
Sand (%)	45.2	53.2	47.2	____
Silt (%)	24.4	16.4	16.4	____
Clay (%)	30.4	30.4	36.4	____
Bulk density (g/cm3)	1.36	1.37	1.33	____
Textural Class	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay	
pH	7.8	7.8	7.8	7.8
EC (d S m^{-1})	1.0	0.9	0.8	4.75
Total C (g/kg)	19.60	18.18	15.62	392
Total N (g/kg)	0.775	0.543	1.114	9.80
NH_4-N (mg/kg)	4.7	5.3	7.6	1171
NO_3-N (mg/kg)	15.2	15.1	27.5	22.3

RESULTS AND DISCUSSION

The manure treatments of 22 Mg $ha^{-1,}$ 44 Mg ha^{-1}, 67 Mg ha^{-1} and 134 Mg ha^{-1} mineralized significantly different ($p \leq 0.05$) within each productivity MZ. Fig. 1 displays the non linear regression of the net N mineralized over a period of 120 days for the four manure treatments within each individual MZ. This means that, lower manure treatments resulted in lower N mineralization as compared to higher manure treatments which resulted in higher N mineralization.

Fig 1. Mineralized N from 4 manure application rates across Low, Medium, and High productivity level MZs.

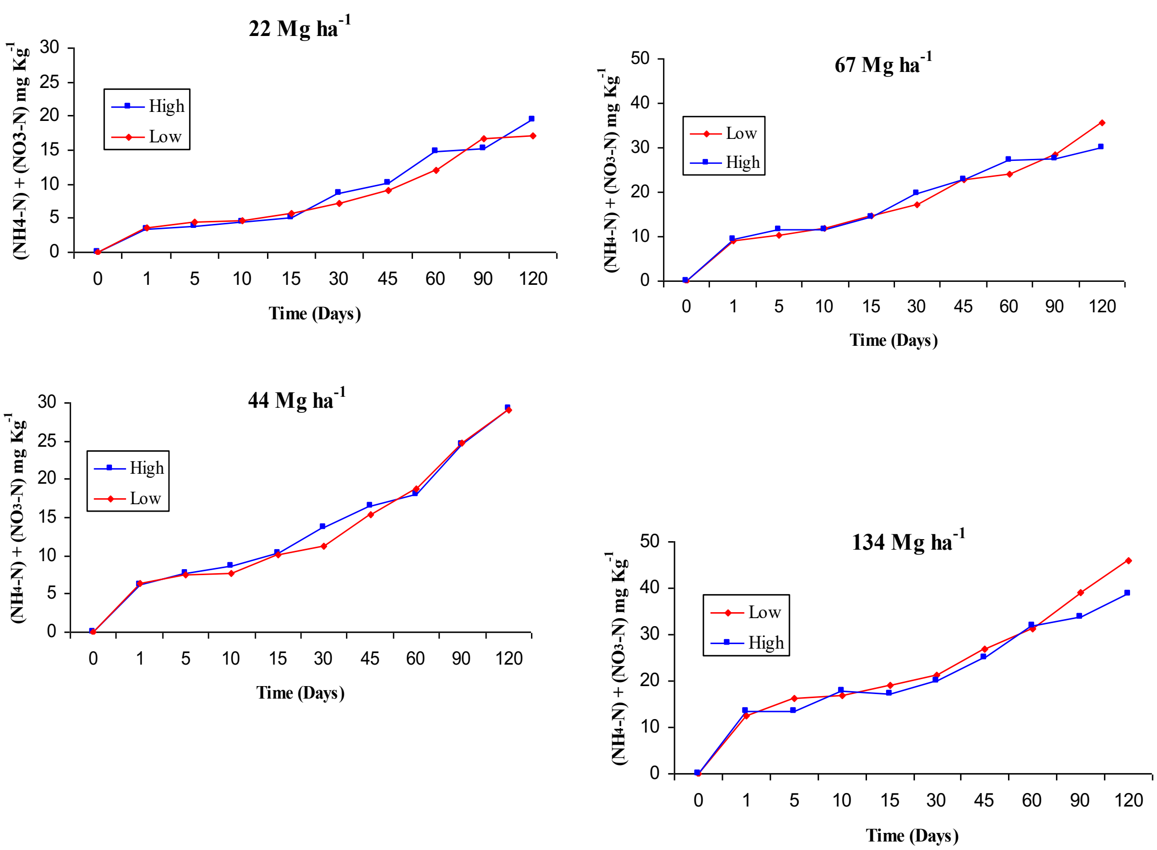


Nitrogen mineralized from different manure applications over incubation times were significantly different ($p \leq 0.05$) across all treatments within each productivity level MZ (table 2). This implies that as incubation time increased, the net N mineralization increased significantly across all MZs.

Table 2. Least Square Means difference between 4 manure application rates within Low, Medium and High productivity Management Zone ($P \leq 0.05$).

Low Zone				
Treatments	22 Mg ha^{-1}	44 Mg ha^{-1}	67 Mg ha^{-1}	134 Mg ha^{-1}
22 Mg ha^{-1}	NS	0.0043	<.0001	<.0001
44 Mg ha^{-1}	–	NS	0.0144	<.0001
67 Mg ha^{-1}	–	–	NS	0.0018
134 Mg ha^{-1}	–	–	–	NS
Medium Zone				
Treatments	22 Mg ha^{-1}	44 Mg ha^{-1}	67 Mg ha^{-1}	134 Mg ha^{-1}
22 Mg ha^{-1}	NS	0.0399	<.0001	<.0001
44 Mg ha^{-1}	–	NS	0.0020	<.0001
67 Mg ha^{-1}	–	–	NS	0.0114
134 Mg ha^{-1}	–	–	–	NS
High Zone				
Treatments	22 Mg ha^{-1}	44 Mg ha^{-1}	67 Mg ha^{-1}	134 Mg ha^{-1}
22 Mg ha^{-1}	NS	<.0001	<.0001	<.0001
44 Mg ha^{-1}	–	NS	0.0006	<.0001
67 Mg ha^{-1}	–	–	NS	0.0003
134 Mg ha^{-1}	–	–	–	NS

Fig. 2. N mineralized on Low and High productivity level MZs treated with 22 Mg ha^{-1}, 44 Mg ha^{-1}, 67 Mg ha^{-1} and 134 Mg ha^{-1} manure application rates.



There was no significant difference ($p \leq 0.05$) observed between low and high productivity level MZs (fig 2). Based on the results of the study, the lack of clear variability in soil texture and soil pH between the low and high MZs might have been a reason for no significant different values in N mineralization. However, higher N values were observed for low MZ as compared to high MZ in the 67 Mg ha^{-1} and 134 Mg ha^{-1} treatments. For the low MZ, total accumulated nitrogen of 228.8 mg kg^{-1} and 174.3 mg kg^{-1} were observed in the 134 Mg ha^{-1} and 67 Mg ha^{-1} of manure treatments respectively. In the 134 Mg ha^{-1} manure treatment, the high MZ recorded a total accumulation of 211.2 while in the 67 Mg ha^{-1}, a total accumulation of 173 mg ka-1 was observed.

In the 22 Mg ha^{-1} and 44 Mg ha^{-1} treatments, which were the lower manure application rates, the high MZ recorded higher values of mineralized N when compared to the low MZ at the same treatments. The non significant mineralized N values of 80.4 mg kg^{-1} and 85.3 mg kg^{-1} were recorded in the low and high MZs respectively on the 22 Mg ha^{-1} treatment. In the 22 Mg ha^{-1} of manure application, N mineralized higher in the low MZ than in high MZ only in the first 15 days of incubation. For the manure treatment of 44 Mg ha^{-1}, total accumulated N values of 130.5 mg kg^{-1} and 134.6 mg kg^{-1} were recorded for the low and high MZs respectively. In the same treatment, the low MZ recorded an average N accumulation of 14.5 mg kg^{-1} while the high MZ recorded 14.9 mg kg^{-1}.

The nonlinear curves of inorganic N accumulation in low and high MZs with time are presented in Fig 2. Hadas et al. (1983) reported no significant differences between sandy and clay soils when N mineralization was measured at an incubation temperature of 25 ^{o}C. In our study, the high MZ had 47.2 % sand and 36.4 % clay as compared to the low MZ which had 45.2 % sand and 30.4 % clay (table 1). Our study did not show any significant differences between the two MZs. According to Mzuku et al., 2005, low MZs are generally higher in sandy soils and as compared to high MZs which generally has lower sandy soils. This was completely different in our study where high MZ had higher sandy soil than low MZ. Both the low and high MZs had soil pH values of 7.8 (table 1).

Our results suggests that, when manure is to be applied as a source of N across MZs, lower application rates should be considered for high MZ and higher application rates be considered for low MZs. Application of higher manure rates on low MZ is significant for supplying enough N and increasing organic matter content of this low producing areas since low MZs are generally low on organic matter content. Applications of lower manure rates on high MZs will mean that we are being environmentally conscious. Animal manure is generally high in phosphorus and high MZs contain high clay percentage. Low manure application rates will supplement nitrogen without a threat of manure being transported to surface water through erosion.

CONCLUSION

Lower manure application rates resulted in higher nitrogen values on high MZ than higher manure applications on the same MZ. Higher manure application rates responded positively on low MZ than lower application rates on low MZ. With higher manure application rates resulting in higher N mineralization values on low zones, the major challenge becomes the environmental protection of ground water. Nitrogen is mobile in the soil and the application of higher manure rates on low MZs might result in ground water contamination since low MZ have low clay content. Application of higher rates of manure on high MZs might not be a good idea because manure can be easily eroded with the top soil on soils with high % sand. Since sustainable agriculture has become a very important concept in the present day farming, the information obtained in this study may aid in precision manure management across MZs for crop production and environmental protection.

REFERENCE

Barbarika, A.J., J.S. Lawrence, and D. Colacicco. 1985. Factors affecting the mineralization of Nitrogen in sewage sludge applied to soils. *Soil Sci. Soc. Am. J.* 49:1403–1406.

Binder, D.L., D.H. Sander, K.D. Frank, and W.L. Shires. 1996. Nitrogen fertilizer equivalency of anaerobically digested municipal sludge. p.41-46. *In* Proc. 12th. North Cent. Ext.-Ind. Soil Fert. Conf. St. Louis, MO. 20-21Nov. Brookings, SD.

Bonde, T.A., and Lindberg, T. 1988. Nitrogen mineralization kinetics in soil during long-term aerobic laboratory incubations: A case study. *J. Environ. Qual*. 17, 414–417.

Doerge, T. 1999. Management zone concepts. SSMG-2. *In* Clay et al. (ed.) SSMG.

Flavel, T.C., and D.V. Murphy. 2006. Carbon and N Mineralization rates after application of organic amendments to soil. J. *Environ Qual*. 35: 183-193.

Fleming, K.L., D.G. Westfall, D.W. Wiens, and M.C. Brodahl. 2000. Evaluating farmer defined management zone maps for variable rate fertilizer application. *Precis. Agric*. 2:201–215.

Franzen, D.W. and N.R. Kitchen. 1999. Developing management zones to target nitrogen applications. In SSMG 5 Clay et al. (Ed) SSMG. Norcross, GA.

Hadas, A., B. Bar-Yosef, S. Davidov, and M.Sofer. 1983. Effect of pelleting, temperature, and soil type on mineral N release from poultry and dairy manures. *Soil Sci. Soc. Am. J.* 47:1129-1133.

Kaboneka, S., Sabbe, W.E. and Mauromoustakos, A., 1997. Carbon decomposition kinetics and N mineralization from corn, soybean, and wheat residues. *Comm. in Soil Sc. and Plant Analysis* 28, pp. 1359–1373.

Khosla, R., K. Fleming, J.A. Delgado, T. Shaver, and D.G. Westfall. 2002. Use of SSMZs to improve nitrogen management for Prec. Ag.. *J. Soil Water Conserv.* 57:513–518.

Mulla, D.J. and Bhatti, A.U. 1997 .An evaluation of indicator properties affecting spatial patterns in N and P requirements for winter wheat yield. In Precis. Ag., 1st European Conference on Precis. Ag.; Stafford, J.V. (ed.),Warwick University: 145–153.

Mzuku, M., R. Khosla, R. Reich, D. Inman, F. Smith and L. MacDonald. 2005. Spatial variability of measured soil properties across SSMZs, *Soil Sci. Soc. Am. J. 69:* 1572–1579.

Schjonning,P., I.K. Thomsen and J.P. Moberg. 1999. Turnover of organic matter in differently textured soils. I. Physical characteristics of structurally disturbed and intact soils, *Geoderma 89:*177–198.

Verberne, E.L.J., J. Hassink, P. De Willigen, J.J.R. Groot, J.A. Van Veen. 1990. Modelling organic matter dynamics in different soils. *Neth J Agric Sci.* 38: 221–238.