Mineralization of Broiler Litter as Affected by Soil Texture in the Southeastern Coastal Plain

Robert K. Hubbard, David Bosch, Laura Marshall, Timothy C. Strickland, Diane Rowland, Timothy Griffin, C. Wayne Honeycutt, Stephan Albrecht, Karamat Sistani, H. Allen Torbert, Brian Wienhold, Bryan Woodbury, and J. Mark Powell

All Authors Are Employed by USDA-ARS. Senior Author is Located at the Southeast Watershed Research Laboratory, Tifton, GA

Abstract:

A field study was conducted to determine nitrogen (N) mineralization from broiler litter (BL) in two Coastal Plain soils of differing texture, sandy or clayey. The soils were a Tifton loamy sand (fine-loamy, siliceous, thermic, Plinthic Kandiudults) and a Greenville sandy clay loam (clayey, kaolinitic, thermic Rhodic Kandiults). These soils represented the broad range in surface textures commonly found in soils used for agricultural production in the southeastern Coastal Plain. Nitrogen mineralization in the Tifton soil was evaluated during the summer of 2004, while that in the Greenville soil was evaluated during spring 2005. Published protocols used for the study were designed by the ARS mineralization team. The 2004 study (Tifton soil) was impacted by excessive rainfall associated with Hurricanes Frances and Jeanne. The 2005 study (Greenville soil) was impacted by excessive rainfall associated with Hurricane Dennis. Amounts of N in the soil from BL mineralization were identical for both soils, 46.45 ug N g^{-1} soil, but differences occurred in timing of the mineralization processes. In the sandy Tifton soil depletion of NH_4-N and nitrification of the NH_4-N to NO_3-N occurred simultaneously. The NH_4-N from the BL was depleted in 21 days while peak NO_3-N concentrations in the soil were found at 28 days. In the clayey Greenville soil NH_4-N concentrations from BL mineralization increased for 21 days and then decreased until reaching background levels by 70 days. Nitrate concentrations never did increase in the BL amended Greenville soil, indicating both that the nitrification rate was much slower than the ammonification rate, and most likely, that what NO_3-N was produced was lost from the soil by denitrification under wet conditions. Previous research has shown that mineralization rate is positively correlated with sand content and negatively correlated with clay content of soils, and the results of this study concurred with those findings.

Introduction:

When BL is added to soils, heterogeneous microorganisms attack the organic N compounds resulting in mineralization. Ammonification is the primary step in organic N mineralization and is defined as the biological process by which organic forms of N are transformed to ammonium (NH_4-N). Nitrification is an obligate aerobic process involving oxidation of NH_4-N to nitrate (NO_3-N). After application to soil, the transformations of N from BL and other manures or slurries are controlled largely by three factors: temperature, soil water status, and soil type or texture. Several authors have found that increased sand content generally leads to increased C and N mineralization from manures, presumably due to both increased aeration in sandy soils and increased physical protection of C and N substrates as the soil clay content increased. The objective of this study was to determine in-field mineralization of organic N from BL in surface soils representing the textural range commonly found in southeastern Coastal Plain agricultural soils.

Materials and Methods:

The study was conducted at two Georgia Coastal Plain sites having different soil types. The study was part of a larger ARS mineralization research project with sites located in multiple states including Alabama, Georgia, Kentucky, Maine, Nebraska, Oregon, and Wisconsin and measurements being made in different calendar years. In 2004 BL N mineralization was determined on a Tifton loamy sand (fine-loamy, siliceous, thermic Plinthic Paleudults) at a site located near Tifton, GA. In 2005 BL N mineralization was determined on a Greenville sandy clay loam (fine-loamy, siliceous, thermic Rhodic Paleudults) at a site located near Dawson, GA (Figure 1).

The study followed the protocol for the field component of the ARS mineralization study as described in detail by Honeycutt et al. (2005). Ninety-six cylinders (15.24 cm long by 7.62 cm diameter) made of Schedule 40 PVC pipe were installed on the Tifton soil in April 2004 and on the Greenville soil in April 2005 using a completely randomized design.

There were two treatments: amendment with BL and no BL amendment. For the amendment with BL treatment, calculations were made based on BL N contents so that each core received sufficient BL to supply 350 kg N per ha-furrow-slice.

At the same time as BL amendment (or no amendment) anion exchange resin beads (Anion Exchange Resin, IONAC A-554, Cl- Form, Type II, Beads (16-50 Mesh)) contained in cloth bags were placed at the bottom of each core. These were held in place at the bottom of each cylinder using plastic caps with drainage holes. The purpose of the anion resin beads was to capture NO_3-N leaching through the soil. The basic design was 6 replicates of each treatment (with or without BL amendment) and 8 sampling dates following experiment initiation. Twelve cylinders (6 amended with BL and 6 without BL) were collected from each site and returned to the laboratory at 0, 3, 7, 14, 21, 28, 49, and 70 days after BL amendment.

Figure 1. Site diagram showing study site locations on soils map of the Georgia Coastal Plain according to textural groupings. (From Hubbard et al., 1990).

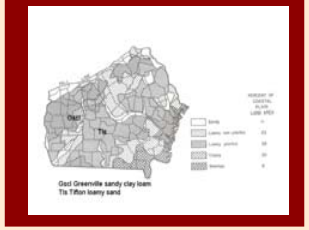


Table 1. Properties of soils used.

Soil							
Series	Family	pH	Total Carbon	Total Nitrogen	Sand	Silt	Clay
			g kg^{-1}				
Tifton	Fine-loamy, siliceous, thermic, Plinthic Kandiudults	5.80	5.2	0.3	900	60	40
Greenville	Fine-loamy, siliceous, thermic, Rhodic Paledults	5.09	6.2	0.4	670	100	230

Surface texture measured on samples from 0-15 cm.

Transporting Cores to the Laboratory

Results:

Table 2. Chemical properties of the broiler litter used in the experiments

Soil	Tifton loamy sand	Greenville sandy clay loam
Year	2004	2005
% Moisture	15.12*	19.00
pH	8.43**	8.51
TN %	2.57	2.66
Ammonium N %	0.24	0.46
Nitrate N %	0.03	0.01
TC %	26.47	27.64
C:N ratio	10.30	10.39
P_2O_5 %	2.95	2.18
K_2O %	2.90	2.40
Ca %	2.06	1.57
Mg %	0.46	0.38
S %	0.44	0.36
Mo ppm	378	383
Fe ppm	3270	4468
Al ppm	5804	4465
B ppm	41.6	63.4
Cu ppm	351	506
Zn ppm	268	274
Na ppm	4890	5064

* Percent moisture was calculated relative to oven dry weight of the litter. **Values reported are the means of two litter samples analyzed for each mineralization test. All samples were analyzed at the Soil, Plant, and Water Laboratory of the University of Georgia, College of Agricultural and Environmental Sciences except for TC% and pH, which were analyzed at the Southeast Watershed Research Laboratory (SEWRL). Results from the UGA laboratory are reported on an as-received wet basis. Results from the SEWRL laboratory have been corrected for moisture content.

Reinstalling Cores in the Tifton Loamy Sand Soil

Table 3. Effects of broiler litter on N mineralization during a 70 day period (Tifton loamy sand).

Treatment	Day	NH_4-N	LSD	NO_3-N	LSD	Total Inorganic N	LSD	Net Inorganic N
		ug g^{-1}						
Unamended	0	1.19[b]	0.72	0.0[a]	0.0	1.19[b]	0.72	6.19
BL amended	0	7.38[a]	0.72	0.0[a]	0.0	7.38[a]	0.72	
Unamended	3	1.03[b]	1.56	0.65[b]	2.63	1.68[b]	2.54	8.18
BL amended	3	5.93[a]	1.56	3.93[a]	2.63	9.86[a]	2.54	
Unamended	7	3.09[b]	0.69	10.54[b]	3.44	13.63[b]	3.52	11.70
BL amended	7	7.18[a]	0.69	18.15[a]	3.44	25.33[a]	3.52	
Unamended	14	3.19[b]	0.46	10.20[b]	5.54	13.39[b]	5.47	19.47
BL amended	14	6.44[a]	0.46	26.42[a]	5.54	32.86[a]	5.47	
Unamended	21	2.70[a]	0.11	15.38[b]	12.39	18.08[b]	12.42	32.16
BL amended	21	2.69[a]	0.11	47.54[a]	12.39	50.24[a]	12.42	
Unamended	28	2.58[a]	0.15	21.32[b]	10.92	23.90[b]	10.84	46.45
BL amended	28	2.62[a]	0.15	67.74[a]	10.92	70.35[a]	10.84	
Unamended	49	1.38[a]	0.11	23.66[b]	3.69	25.04[b]	3.72	6.77
BL amended	49	1.41[a]	0.11	30.40[a]	3.69	31.81[a]	3.72	
Unamended	70	0.90[b]	0.14	10.75[b]	4.48	11.66[b]	4.50	26.00
BL amended	70	1.07[a]	0.14	36.02[a]	4.48	37.09[a]	4.50	

Table values are means of six observations. NO_3-N = the sum of that in the soil and that captured by the resin beads. Total Inorganic N = (NH_4-N + NO_3-N); Net Inorganic N = BL amended soil – BL unamended soil. Statistical analyses were done within each study day. Where letters are different, treatment means were significantly different at the 0.05 level.

Core Installed in Tifton Loamy Sand

Removing Resin Beads From a Cloth Bag

Table 4. Effects of broiler litter on N mineralization during a 70 day period (Greenville sandy clay loam).

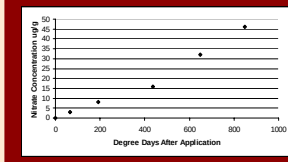
Treatment	Day	NH_4-N	LSD	NO_3-N	LSD	Total Inorganic N	LSD	Net Inorganic N
		ug g^{-1}						
Unamended	0	2.96[b]	7.20	14.34[a]	9.38	17.30[b]	10.55	23.58
BL amended	0	29.04[a]	7.20	11.84[a]	9.38	40.88[a]	10.55	
Unamended	3	1.75[b]	2.40	21.79[a]	11.88	23.55[b]	13.22	30.98
BL amended	3	34.67[a]	2.40	19.86[a]	11.88	54.53[a]	13.22	
Unamended	7	3.12[b]	8.82	18.46[a]	8.82	21.58[b]	13.59	26.51
BL amended	7	36.42[a]	8.82	11.67[a]	8.82	48.09[a]	13.59	
Unamended	14	1.45[b]	7.97	3.19[a]	7.30	4.64[b]	11.62	46.45
BL amended	14	45.41[a]	7.97	5.67[a]	7.30	51.09[a]	11.62	
Unamended	21	1.52[b]	3.40	20.10[a]	9.64	21.62[b]	9.31	22.97
BL amended	21	41.21[a]	3.40	3.38[b]	9.64	44.59[a]	9.31	
Unamended	28	1.54[b]	10.87	19.80[a]	8.92	21.34[a]	15.23	9.89
BL amended	28	24.45[a]	10.87	6.78[b]	8.92	31.23[a]	15.23	
Unamended	49	0.68[b]	8.42	15.65[a]	14.23	16.33[a]	15.37	8.30
BL amended	49	12.12[a]	8.42	12.51[a]	14.23	24.63[a]	15.37	
Unamended	70	1.49[a]	0.65	21.91[a]	11.91	23.40[a]	11.89	3.41
BL amended	70	1.71[a]	0.65	25.10[a]	11.91	26.81[a]	11.89	

Table values are means of six observations. NO_3-N = the sum of that in the soil and that captured by the resin beads. Total Inorganic N = (NH_4-N + NO_3-N); Net Inorganic N = BL amended soil – BL unamended soil. Statistical analyses were done within each study day. Where letters are different, treatment means were significantly different at the 0.05 level.

Conclusions:

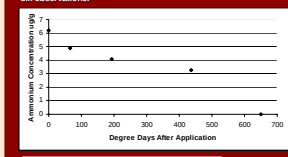
Using net inorganic N, the difference between total inorganic N in the BL amended soil and that in the unamended soil, it was determined that mineralized N from the BL was identical for both soils, 46.65 ug N g^{-1} soil. Mineralization to NO_3-N was complete in the sandy soil by 28 days. However, in the clayey soil nitrification was delayed, such that NH_4-N accumulated in the soil for the first 21 days. It then declined to background levels by study day 70, but NO_3-N did not accumulate in this soil, most likely due to denitrification under wet conditions with C for the denitrifiers supplied by the BL. Previous research has shown a positive correlation for mineralization of organic N with sand content of the soil, and a negative correlation with clay content; results from this study concurred with those findings. It can be concluded from this study that BL mineralization rates will be significantly slower on the more clayey Coastal Plain soils than on very sandy ones, and that farm managers should take these rates into consideration when planning timing and amounts of BL applications.

Figure 2. Accumulation of nitrate in Tifton loamy sand soil following amendment with broiler litter, as a function of degree days after application (DDAA; 0° C base). Data points are means of six observations.



NO_3-N_{conc} = -2.77 + 0.052 (DDAA)

Figure 3. Consumption of ammonium in Tifton loamy sand soil following amendment with broiler litter, as a function of degree days after application (DDAA; 0° C base). Data points are means of six observations.



NH_4-N_{conc} = 5.92 - 0.0083 (DDAA) R^2 = 0.899

Figure 4. Consumption of NH4-N in Greenville sandy clay loam soil following amendment with broiler litter, as a function of degree days after application (DDAA; 0° C base). Data points are means of six observations.