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Effect of liming and poultry manure additions on C, N and P mineralization in an acid ultisol

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Abstract

A laboratory incubation study was conducted over a period of 6 weeks at 30°C to evaluate the effects of liming (pH 7.0) and varying rates of poultry manure additions (0, 0.25, 0.50 and 0.75%) on microbial respiration, NO_3-N and available P production in an acid (pH 4.8) Ultisol. The results indicated that liming, with and without poultry manure additions significantly increased microbial respiration NO_3-N and available P concentrations in the soil. Liming soil amended with poultry manure also significantly increased these parameters over the corresponding unlimed treatments. Nitrate N and available P production generally peaked at the end of the 4th week of incubation. The results further showed that NO_3-N production in poultry manure — amended acid soil can be predicted from the CO_2 evolution data.

Introduction

Soil acidity has been a major concern of research effort because it affects the soil's chemical and biological properties. Potentially toxic heavy metals such as Al^{3+} and Mn^{2+} are solubilized in acid soils (Ulrich *et al.*, 1980; James and Riha, 1984). Microbial activities including organic matter decomposition and nitrification (Strayer *et al.*, 1981; Bitton *et al.*, 1985; Stroo and Alexander, 1986), dinitrogen fixation (Muchovej *et al.*, 1986), soil respiration and enzyme activities (Bitton and Boylan, 1985) are often depressed in such soils.

To ameliorate the adverse effects of acidity on soil productivity, liming has become an accepted agronomic practice which effectively reduces the toxic concentrations of Al^{3+} and Mn^{2+} (Jarvis, 1986) and improves soil microbial activity (Agarwal *et al.*, 1972). Organic manures have also been observed to have liming effects (Agbim, 1977; Olayinka and Adebayo, 1983). Aluminium is detoxified by humid acids (Schnitzer and Skinner, 1963; Hoyt and Turner, 1975).

The intensive system of poultry keeping generates large quantities of droppings which can be disposed of on agricultural land to supply plant nutrients. The release of nutrients is due to microbial decomposition, a process that is found to be depressed in acid soils. Soil acidity can, however, be controlled by liming. It is not known how the release of plant nutrients would be affected in limed and unlimed poultry manure-amended soil, made acidic in reaction as a result of continuous nitrogen fertilizer application. It is, therefore, the aim of this investigation to evaluate the effects of poultry manure additions with and without liming on microbial respiration and N and P mineralization in an acid Ultisol.

Materials and Methods

A bulk soil sample was obtained from the plough layer (0-15cm) of an Ultisol (Iwo series) at the Obafemi Awolowo University Teaching and Research Farm, Ile-Ife. The soil became acidic in reaction as a result of fifteen years' continuous nitrogenous fertilizer application. The sample, air-dried and passed through 2mm sieve, was used for the laboratory incubation experiment. Particle size analysis by the hydrometer method (Bouyoucos, 1962) showed that the soil contained 86% sand, 7% clay and 7% silt. Chemical analysis also showed the following: pH (0.01M $CaCl_2$), 4.8; Organic C, 0.55%; Total N, 0.03%; Bray-I P, 10.1 ppm; exchangeable Ca, K, Mg, Na, H^+ and CEC 1.05, 0.32, 0.79, 0.18, 0.15 and 2.49 meq/100g respectively.

Fresh poultry manure was collected from the Obafemi Awolowo University commercial farm, Ile-Ife. Chemical analysis showed the manure contained the following: total N, 1.75%; organic C, 12.53%; P, 0.66%; Ca, K, Mg and Na 1.29, 0.96, 0.53 and 0.30% respectively. Dolomitic lime was obtained from a local store in Ile-Ife.

Experimental Procedures

Two levels of dolomitic lime (unlimed pH 4.8 and limed at the rate of 10 t ha to pH 7.0) and four rates of poultry manure (O, 0.25, 0.50 and 0.75% corresponding to 0, 6, 12 and 18 mt/ha on dry weight basis) constituted the eight treatments in factorial design with three replicates. The treatments included the following:

Control (Acid soil, pH 4.8)
Soil + Lime (pH, 7.0 with 10 tonnes dolomitic lime/ha)
Soil + 0.25% poultry manure
Soil + 0.25% poultry manure + Lime
Soil + 0.50% poultry manure
Soil + 0.50% poultry manure + Lime
Soil + 0.75% poultry manure
Soil + 0.75% poultry manure + Lime.

The treatments, thoroughly mixed with 150 g soil samples, were transferred into 500-ml incubation flasks. After moistening to 60% moisture-holding capacity, the treatments were incubated at 30°C for 6 weeks. Carbon dioxide evolved was absorbed in 10 ml of 1N KOH and determined weekly. Excess OH^- was first titrated with 0.5N H_2SO_4 in the presence of phenolphthalein indicator. The $CO_3^{=}$ formed was later titrated with the acid using bromophenol blue as an indicator (Jackson, 1958). Organic C was determined by dichromate digestion (Walkley and Black, 1934); pH was measured potentiometrically in a soil: solution ratio of 1:2 in 0.01M $CaCl_2$; available P was extracted by Bray and Kurtz (1945) method; total N was by a microkjeldahl digestion procedure; nitrate nitrogen was extracted in a mixture of 1N $CuSO_4$ and 0.6% Ag_2SO_4 solution and determined colorimetrically using the phenoldisulfonic acid method (Jackson, 1958).

Results and Discussions

Carbon dioxide evolution:

Table 1 shows the weekly mean rates of CO_2 evolution from treatments over a 6-week period. There was a flush of CO_2 evolution at the end of the first week of incubation in all treatments. Such a flush has been found on incubation of moistened soils with and without organic amendments (Jenkinson and Ayanaba, 1977; Olayinka and Adebayo, 1984). The amount of CO_2 evolved was, however, significantly lower ($P = 0.05$) in the control because of the stability of indigenous soil humus (Alexander, 1977; Puig-Gimenez and Chase, 1984). After the first week, amounts of CO_2 evolved from all treatments, except the control, declined up to the end of incubation. While CO_2 evolution increased in the control between the end of the first and second weeks, there was a stationary phase in limed soil that received 0.75% poultry manure. These trends showed that soil amendment with poultry manure with and without liming significantly ($P = 0.05$) enhanced microbial respiration over the control. In the absence of lime, the soil was probably not acidic enough to depress microbial respiration. Working with simulated acid rain, Bitton *et al.* (1985), found significant decreases in soil respiration only at pH below 3.

Generally, significant differences ($P = 0.05$) in CO_2 evolution were observed between the limed and unlimed controls except towards the end of the incubation period. This is reflected in the significantly higher overall rates of CO_2 evolution for the limed treatments. Liming the soil amended with poultry manure significantly increased ($P = 0.05$) CO_2 evolution over poultry manure alone especially at the higher rates (0.50, 0.75%) of application. A similar enhancement of microbial activity due to liming was observed by Agarwal *et al.* (1972). The 6-week mean values (Table 1) showed significant increases ($P = 0.05$) in CO_2 evolution with increases in poultry manure additions with and without liming.

TABLE 1: MEAN RATES OF CO_2 EVOLUTION (mg) FROM EACH TREATMENT AT 30°C OVER A 6-WEEK PERIOD OF INCUBATION.

Treatments	*Weeks*						
	1	*2*	*3*	*4*	*5*	*6*	*Mean*
Control	1.36a*	1.69a	1.25a	0.99a	0.81a	0.59a	1.12a
Soil + Lime (pH 7.0)	5.50b	2.17b	1.10a	0.73b	0.73a	0.70a	1.82b
Soil + 0.25% poultry manure	5.87c	3.23c	1.80b	1.17a	1.10b	1.03b	2.37c
Soil + 0.25% poultry manure + Lime	7.85d	4.48d	2.46c	1.91c	1.25c	1.03b	3.16d
Soil + 0.50% poultry manure	7.52d	3.49e	1.95g	1.54d	1.17bc	0.88b	2.76e
Soil + 0.50% poultry manure + Lime	7.71d	6.46f	3.08d	2.64e	1.65d	1.28c	3.80f
Soil + 0.75% poultry manure	7.71d	5.69g	2.24e	1.76c	1.10b	0.99b	3.25d
Soil + 0.75% poultry manure + Lime	7.85d	7.60h	3.23d	2.42f	1.87e	1.43d	4.07g
SE	0.11	0.07	0.07	0.04	0.07	0.04	0.04
Mean	6.42	4.35	2.14	1.65	1.21	0.99	2.79

* Means carrying the same letters are not significantly different ($P = 0.05$) according to Duncan's Multiple Range Test.

Nitrate production

Nitrate nitrogen concentrations generally increased ($P = 0.05$) weekly up to the end of the second week of incubation (Table 2). The depression in microbial respiration found after the first week of incubation (Table 1) would indicate that the increased NO_3-N concentrations observed during the second week could be due to a re-mineralization of previously immobilized nitrogen. Between the second and third weeks, except in limed soil amended with 0 25% poultry manure, NO_3-N levels were either not significantly increased or were significantly decreased. This indicates a net N immobilization. Between the third and fourth weeks of incubation, there was further mineralization and re-mineralization of N as indicated by significant increases in NO_3-N concentrations. This could be attributed to turnover of microbial biomass (Table 1).

Except in soil that received 0.25% poultry manure, whether limed or unlimed, and limed soil that received 0.75% poultry manure, which have their peaks at the end of the fifth and sixth weeks respectively, maximum NO_3-N production was found at about the end of the fourth week of incubation (Table 2). This corresponded with the four-week period of high microbial activity often observed with the addition of organic manures to soil (Olayinka and Adebayo, 1984).

Poultry manure additions with and without liming significantly increased ($P = 0.05$) NO_3-N concentrations in the soil. For each sampling period, liming was not effective in increasing NO_3-N production in treatments containing 0.25% manure addition, except at the end of the third and fourth weeks of incubation. Overall, however, liming significantly increased the NO_3-N production in this treatment. Liming and poultry manure additions at the rates of 0.50 and 0.75% significantly increased ($P = 0.05$) NO_3-N concentrations over the corresponding unlimed treatments. The effect of liming was probably more pronounced at the highest rates of poultry manure additions since nitrification produces H^+ ions which tend to increase soil acidity and hence adversely affect the process.

The overall mean concentrations of NO_3-N showed that the concentrations in the limed and unlimed control treatments were significantly lower ($P = 0.05$) than in the remaining treatments. Hence, compared to the control, the absence of liming in poultry manure-amended treatments did not depress poultry manure decomposition. The NO_3-N concentrations in limed and unlimed soil amended with the highest manure rate were significantly higher ($P = 0.05$) than in the remaining treatments (Table 2).

TABLE 2: MEAN NITRATE NITROGEN CONCENTRATIONS (mg/g) PER TREATMENT AT 30°C OVER A 6-WEEK PERIOD OF INCUBATION.

Treatments	*Weeks*						
	1	*2*	*3*	*4*	*5*	*6*	*Mean*
Control	2.0a*	4.0a	2.6a	4.1a	4.0a	3.6a	3.4a
Soil + Lime (pH 7.0)	5.6f	6.9e	7.0b	8.4b	4.9a	6.3a	6.5b
Soil + 0.25% poultry manure	7.3de	12.3c	7.5b	11.8c	12.0b	11.2cd	10.3c
Soil + 0.25% poultry manure + Lime	8.5cd	10.5cd	11.1c	15.8de	13.9bc	14.9bc	12.4d
Soil + 0.50% poultry manure	6.4ef	9.2de	9.5d	9.0b	11.2b	10.0d	9.2e
Soil + 0.50% poultry manure + Lime	9.4bc	10.0cd	13.0e	13.4cd	15.9cd	14.4c	12.7d
Soil + 0.75% poultry manure	8.7cd	15.7b	15.4f	17.6e	17.4d	17.4b	15.4f
Soil + 0.75% poultry manure + Lime	10.3b	15.9b	17.0g	21.5f	21.7e	22.4e	18.1g
SE	0.50	0.87	0.52	0.84	1.00	1.19	0.35
Mean	7.3	10.50	10.4	12.7	12.6	12.5	11.0

* Means carrying the same letters are not significantly different ($P = 0.05$) according to Duncan's Multiple Range Test.

TABLE 3: MEAN AVAILABLE P CONCENTRATIONS (mg/g) PER TREATMENT AT 30°C OVER A 6-WEEK PERIOD OF INCUBATION.

Treatments	*Weeks*			
	2	*4*	*6*	*Mean*
Control	9.7a*	12.3a	16.6a	12.9a
Soil + Lime (pH 7.0)	16.3b	23.6b	20.2ab	20.0b
Soil + 0.25% poultry manure	21.0cd	21.3b	21.6abc	21.3b
Soil + 0.25% poultry manure + Lime	20.3bc	30.4c	24.7bc	25.2c
Soil + 0.50% poultry manure	24.0d	31.5c	27.2c	27.6c
Soil + 0.50% poultry manure + Lime	33.3e	42.7d	33.9d	36.6d
Soil + 0.75% poultry manure	42.6f	40.4d	43.2e	42.1e
Soil + 0.75% poultry manure + Lime	45.5f	55.1e	42.1e	47.6f
SE	1.35	1.34	1.87	0.99
Mean	26.6	32.2	28.7	29.2

* Means carrying the same letters are not significantly (P = 0.05) different according to Duncan's multiple range test.

Available phosphorus release:

Available P concentrations increased throughout the period of incubation in the control (Table 3). The peaks of available P were attained at the end of the fourth week of incubation, except in unlimed soil amended with the lowest and highest manure rates with peaks at the end of the second week. Between the fourth and sixth weeks of incubation, there were reductions in available P concentrations. Because there was no significant correlation between available phosphorus and CO_2 evolution, these reductions might be due to chemical fixation.

At the end of the second and fourth weeks, available P concentrations in the poultry manured-amended soil as well as soil with poultry manure and lime were significantly higher (P = 0.05) than in the controls. Liming significantly increased P mineralization in soil amended with poultry manure at the end of the fourth week of incubation. The other increases in available P with liming at the end of the second and sixth weeks were not significant, except in limed soil that received the 0.05% manure rate.

Both lime and poultry manure additions had significant (P = 0.01) effects on CO_2 evolution, NO_3-N and available P concentrations in soil. There was significant (P = 0.01) interaction effect between poultry manure addition and liming only on CO_2 evolution.

No significant correlation was found between CO_2 evolution and available P concentration. On the other hand, significant positive correlations were found between CO_2 evolution and NO_3-N concentrations at the end of each week of incubation except the third week when a non-significant negative correlation was obtained. The six-week means of CO_2 evolution were also positively correlated (r = 0.93; P = 0.01) with NO_3-N concentrations and their relationship is described by the regression equation.

$$Y = 15.93x - 1.11 \text{ (Fig. 1).}$$

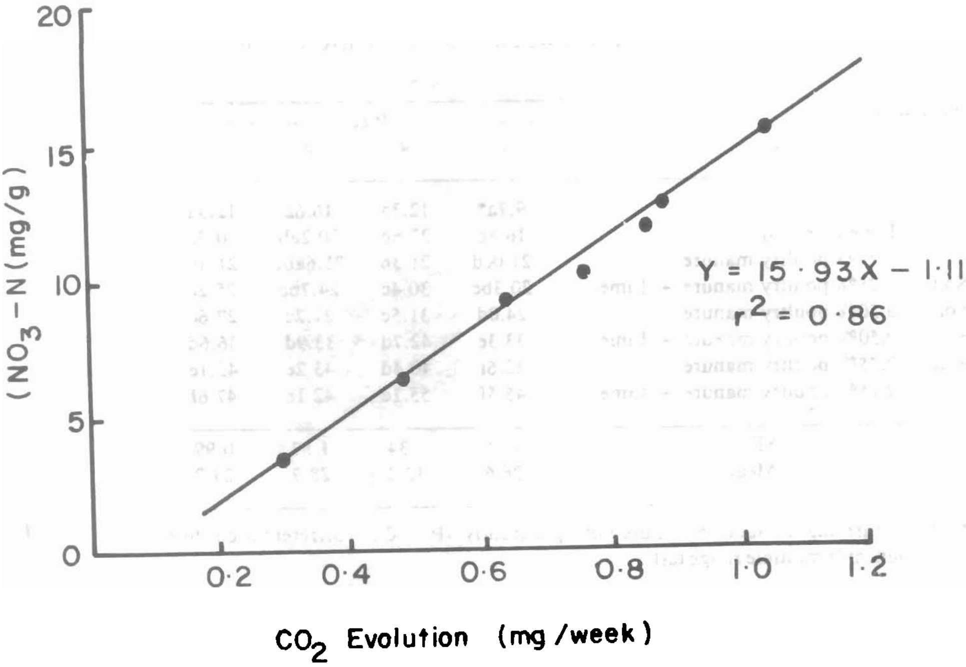

Fig. 1: Estimated linear regression between CO_2 evolution and nitrate nitrogen in soil over 6 weeks of incubation at 30°C.

The increasing co-efficients of determination (r^2 = 0.54, 0.76, 0.81) between the fourth and sixth weeks of incubation might indicate a phase of increasing N re-mineralization in the death phase of microbial growth. These findings are in line with those of Agbim *et al.* (1977) with respect to the predictability of N mineralization from CO_2 evolution data.

These results showed that liming poultry manure-amended acidic Ultisol enhanced microbial decomposition of the organic manure, and the release of NO_3-N and available P. Hence, liming along with poultry manure application would be beneficial to plants grown in an acidic Ultisol.

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