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Carbon Mineralization from Poultry Manure–Straw/ Sawdust Amended Alfisol

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Abstract

Organic amendments which were mixed with sieved (2mm) air-dry soil at the rate of 3% included poultry manure and 4:1, 2:1 and 1:1 mixtures of poultry manure and corn (Zea mays L.) staw or sawdust obtained from Canarium schweinfurthii (Engl.) respectively. The treatments, including control, were incubated for 8 weeks at 30°C in the laboratory. Amounts of C evolved as CO_2 which is an index of C mineralization were determined weekly.

The incorporation of organic amendments increased the amounts of C mineralized from the treatments. Two peaks of C evolution were observed at the ends of the 1st and 3rd weeks. The first peak was probably due to the easily oxidizable C while the second peak was the result of the activity of micro organisms adaptable to the more recalcitrant C fractions. Carbon evolution from poultry manure-straw/sawdust treatments were significantly higher (32–85%) than in the presence of poultry manure alone. Both the mean rates and cumulative amounts of C mineralized generally increased with increasing contents of straw and sawdust. However, the type of plant residue mixed with poultry manure did not significantly influence the amounts of C mineralized at the comparative rates of addition. The % of added C mineralized decreased with increasing contents of straw and sawdust.

Correlation studies showed that the C/N ratios of the amendments had significant negative effect ($r = -0.91$) on the degree of C mineralization in soil. Carbon/nitrogen ratio had no significant effect on the cumulative amounts of C mineralized.

These results indicate the importance of C/N ratio to the rate of decomposition of organic amendments in soil, *the efficiency of poultry manure in the mineralization of C from straw and sawdust and the consequent formation of organic matter. In terms of the degree of C mineralized, a 2:1 mixture of poultry manure and straw/sawdust is recommended.*

Introduction

The release of nutrients from organic sources in soil is the result of microbial activities which are influenced by such factors as C/N ratio, chemical composition, soil reaction, temperature, aeration and moisture content (Alexander, 1977; Martin and Haider, 1980; Kononova, 1966; Olayinka and Adebayo, 1984). Because soil micro organisms decompose organic materials in the process of obtaining cell C and energy for growth, the availability of substrate C would, therefore, have great effect on the rate of mineralization. Lignocellulosic materials, for example, straw and sawdust have high C:N ratios and tend to degrade slowly, may reduce soil respiration, immobilize nutrients and depress plant growth (Inoko, 1982; Rennie and Heimo, 1984; Olayinka and Adebayo, 1985; Sain and Broadbent, 1974).

Soil organic matter is a characteristic constituent of the soil ecosystem and controls the physical, chemical and biological properties of the soil (Tate, 1987). Organic matter degrades fast under the warm humid conditions of the tropics (Ayanaba *et al.*, 1976). Hence, constant addition of organic materials has been advocated for the maintenance of soil organic matter pools in tropical soils (Ayanaba *et al.*, 1976; Metzger *et al.*, 1987). Yet potential sources of organic matter like poultry manure, straw and sawdust are often burnt or disposed of in other ways that can exacerbate environmental pollution.

The formation of soil organic matter is the result of the microbial decomposition of organic materials returned or added to the soil. Olayinka (1990) found that poultry manure and its admixtures with corn straw and sawdust significantly increased soil organic C content. Poultry manure has low C/N ratio and hence mineralizes so fast as to contribute little to the long-term content of soil organic matter. Conversely, carbonaceous straw and sawdust may decompose so slowly as to have little effect on the short-term content. The addition of poultry manure to straw and sawdust would reduce the C/N ratios, enhance microbial activity and the consequent formation of soil organic matter. The following study was set up to evaluate the rate and extent of C mineralization in soil amended with poultry manure and its admixtures with corn (*Zea mays* L.) straw and sawdust from *Canarium schweinfurthii* (Engl.) (Yor. Agbabubu), a common source of timber in the forest zone of Nigeria.

Materials and Methods

Soil Sample

A bulk soil sample was collected from the plough-layer (0–15cm) of Iwo series (Oxic Paleustalf) at the Obafemi Awolowo University Research Farm, Ile-Ife. The sample, air-dried and passed through 2mm screen was used for the laboratory incubation experiment. Particle size analysis by the hydrometer method (Bouyoucos, 1962) showed that the soil contained 75% sand, 12% clay and 13% silt. Chemical analysis of the soil is as follows: pH (0.01M $CaCl_2$) 5.9; Organic carbon 0.60, total N 0.05%; Bray–1 P 6.1 $mgkg^{-1}$; Exch. Ca 1.94, K O. 38, Mg 1.78; Na 0.15, CEC 4.27 cmol kg^{-1}.

Poultry manure, corn straw and sawdust

Poultry manure was obtained from the Obafemi Awolowo University Commercial Farm. Dry corn (*Zea mays* L.) straw from unfertilzed plots at the Soil Science Section of Obafemi Awolowo University Research Farm, was milled before use. Sawdust from *Canarium schweinfurthii* (Engl.) was obtained from a local sawmill in Ile-Ife. The chemical compositions of these wastes are shown in Table 1.

Incubation of amendments

The laboratory incubation was carried out at 30°C over a period of 8 weeks. The organic amendments were mixed at the rate of 3% with 100g portions of soil (dwb). The amendments consisted of the following: poultry manure, and poultry manure mixed with corn straw or sawdust in the ratios 4:1, 2:1 and 1:1 respectively. The treatments, in triplicates, were as follows:

01: Control (soil alone)
02: Soii + poultry manure (PM)
03: Soil + poultry manure and corn straw mixed 4:1 ($PMST_1$).
04: Soil + poultry manure and corn straw mixed 2:1 ($PMST_2$).
05: Soil + poultry manure and corn straw mixed :1 ($PMST_3$).
06: Soil + poultry manure and sawdust mixed. 4:1 ($PMSD_1$).
07: Soil + poultry manure and sawdust mixed 2:1 ($PMSD_2$).
08: Soil + poultry manure and sawdust mixed 1:1 ($PMSD_3$).

The treatments, watered to 60% moisture–holding capacity and incubated in stoppered 500ml conical flasks, were arranged in completely randomized block design. Blanks consisting of acid-washed sand were also set up. Carbon dioxide evolved was absorbed in 10ml of 1M KOH and was determined by titration with standardized 0.5M HCl after carbonate had been precipitated with 3M $BaCl_2$ using phenolphthalein as indicator.

Soil organic carbon was determined using Walkley–Black (1934) procedure. For the organic amendments, the Walkley–Black (1934) method was used without correction factor. Soil pH was read potentiometrically in a soil:solution ratio of 1:2 in 0.01M $CaCl_2$. Total N was determined using steam distillation technique (Bremner and Keeney, 1966) after digestion of samples with conc. H_2SO_4 in the presence of Kjeldahl catalyst. Available P was by Bray and Kurtz (1945) extraction method. Exchangeable cations were extracted using 1N NH_4 OAc solution (Chapman, 1965). Potassium and Na were read using flame photometry while Ca and Mg were by atomic absoption spectrophotometry. The organic amendments were digested with conc H_2SO_4 – H_2O_2 before the determination of the cations and phosphorus.

The % C mineralized in soil was calculated using the equation developed by Wiseman and Zibiliske (1988) thus:

% C mineralized = ((A – B)/X) x 100)

where A = C evolved from amended soil

B = C evolved from unamended soil

X = C added in organic amendment.

Results and Discussion

Effect of waste additions on chemical compositions of organic amendments

The chemical compositions of poultry manure, corn straw, sawdust and their admixtures are presented in Table 1. Apart from the significantly higher (P = 0.05) C/N ratios and contents of organic carbon, the corn straw and sawdust had significantly lower (P = 0.05) contents of nutrients than in poultry manure. Hence, while the addition of carbonaceous wastes to poultry manure significantly increased (P = 0.05) organic carbon contents and C/N ratios of the mixtures, total N, P, K and Mg contents were significantly reduced.

Pattern and Cumulative amounts of C mineralized from treatments at 30°C

The pattern of C mineralization from treatments over a period of 8 weeks is shown in Table 2. There was a flush of C evolution during the 1st week of incubation. The addition of organic substances and the moistening of air-dry soil have been found to increase microbial activity during the initial stages of decomposition (Birch, 1958; Olayinka and Adebayo, 1984; Salonius *et al.*, 1967). The flush observed in the presence of organic amendments was significantly higher (P = 0.05) than in the control. While this flush accounted for 63% of the C mineralized in the control, it accounted for 15 – 24% of those in soil that received organic amendments. Puig–Gimenez and Chase (1984) found that this first-week flush accounted for 75% of C evolved from a temperate sandy loam soil. The trend obtained in this experiment is attributable to the relative stability of native soil organic matter with the result that the labile component is exhuasted within a short time. Throughout the 8-week period of incubation, the amount of C mineralized from the control was significantly lower (P = 0.05) than from the remaining treatments. This is an evidence of the enhancement of microbial activity by the organic substrates added to the soil.

A decrease in C evolution observed at the end of the 2nd week in all treatments indicated increasing resistance to decomposition. This could be related to the fact that heterogenous substrates consisting of low C/N poultry manure and high C/N straw and sawdust were being mineralized. An increase in C mineralization was, however, found at the end of the 3rd week. A similar observation was made by Hsieh *et al.*, (1981) in sewage sludge amended soil. Because lignaceous residues have been applied, this observation could be due to increased efficiency of mineralization as a result of the succession of the decomposing flora from bacteria to fungi. Fungi are known to be well-suited to the high C/N ratios of woody residues (Alexander, 1977; Hattori, 1988; Schuman and Belden, 1991).

With the exception of the 3rd and 5th weeks, C mineralized in the presence of straw and sawdust were significantly higher (P = 0.05) than in poultry manure amended soil. This indicates an enhancement of the mineralization of sawdust and straw in the presence of poultry manure. The weekly amounts of C evolved within the first four weeks of incubation generally increased with increase in the ratios of straw and sawdust added to the poultry manure (Table 2). From the end of the 5th week, there was no significant difference (P = 0.05) between the two highest rates of poultry manure – straw/sawdust additions, viz. $PMST_2$ and $PMST_3$; $PMSD_2$ and $PMSD_3$. Differences in the decomposition rates of these organic amendments were therefore, more pronounced within the first four weeks of incubation, a period during which microbial activity is recognized to be relatively high (Olayinka and Adebayo, 1984; Olayinka, 1990b).

The mean rates of weekly and cumulative C mineralized significantly increased (P = 0.05) with increase in the contents of straw and sawdust (Tables 2 and 3). However, the mean rates from soil that received organic amendments containing comparative amounts of straw and sawdust were not significantly (P = 0.05) different. Although the C/N ratios of the poultry manure – straw/sawdust amendments ranged between 9 and 32, these values are not detrimental to microbial activity (Alexander, 1977)

Degree of C mineralization from treatments

The % C mineralized from the treatments was generally less than 1% (Table 3). The values are however expected to be higher under field conditions as observed by Herman *et al.,* (1977).

The % C mineralized from the native soil C in the control was significantly lower (P = 0.05) than in soil that received organic amendments being 18–45% that of the latter (Table 3). Soil organic matter is in the form of humic acids which are known to be stable and resistant to microbial degradation (Alexander, 1977). The % C mineralized from the poultry manure amended soil was significantly higher (P = 0.05) than in the remaining treatments. This can be attributed to the low C/N ratio of poultry manure. In the poultry manure – sawdust amended treatments, the degrees of C mineralization were significantly lower (P = 0.05) than those of the remaining treatments except the control. This is attributable to the relatively higher C/N ratios (14 – 32) of sawdust compared to the straw amendments (C/N9–19) (Table 1).

Correlation studies

Simple correlations were carried out between C/N ratio, % C and cumulative amounts of C mineralized. Carbon/nitrogen ratio had a significant (P = 0.05) negative correlation (r = –0.91) with % C mineralized. The trend obtained with the cumulative C is indicative of the adaptation of soil micro organisms with time to the available organic substrates. Eighty-three (83%) of the variation in % C mineralized was due to the C/N ratios. Carbon-nitrogen ratio is known to have profound effect on organic carbon mineralization (Alexander, 1977; Olayinka and Adebayo, 1984).

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Table 1: **Chemical compositions (% dry weight) of poultry manure, corn (*Zea mays* L.) straw, sawdust from *Carnarium schweinfurthii* Engl. and mixtures of straw/sawdust with poultry manure**

	Organic Carbon	Total N	P	Ca	K	Mg	Na	C/N
				%				
Poultry manure (PM)	12.7	2.10	0.71	1.42	1.06	0.58	0.33	6
Corn Straw (ST)	35.7	0.84	0.33	0.09	0.12	0.04	0.02	43
Sawdust (SD)	65.1	0.55	0.21	0.08	0.06	0.03	0.01	118
PM+ST, 4:1 ($PMST_1$)	16.2	1.90	0.60	1.14	0.83	0.47	0.22	9
PM+ST, 2:1 ($PMST_2$)	20.1	1.64	0.55	0.95	0.71	0.41	0.18	12
PM+ST, 1:1 ($PMST_3$)	25.5	1.37	0.48	0.72	0.55	0.35	0.18	19
PM+SD, 4:1 ($PMSD_1$)	25.3	1.80	0.58	1.24	0.80	0.42	0.25	14
PM+SD, 2:1 ($PMSD_2$)	31.4	1.48	0.50	0.90	0.74	0.39	0.22	21
PM+SD, 1:1 ($PMSD_2$)	40.2	1.25	0.45	0.68	0.50	0.30	0.20	32
SE	0.75	0.10	0.04	0.23	0.03	0.02	0.11	1.53
Mean	30.24	1.44	0.49	0.80	0.60	0.33	0.18	30.44
LSD (0.05)	2.40	0.31	0.12	0.74	0.10	0.08	0.35	4.89

Table 2: **Mean amounts ($mg \times 10^{-1}$) of C evolution from each treatmnt at 30^{0}C over a 8 - week period**

Treatments	1	2	3	4	5	6	7	8	Mean
				Weeks					
Control	0.55a*	0.10a	0.07a	0.07a	0.02a	0.02a	0.02a	0.02a	0.11a
PM	0.63b	0.21b	0.45b	0.43b	0.50b	0.57b	0.50b	0.45b	0.47b
$PMST_1$	1.27d	0.38c	0.50b	0.52c	0.55b	0.75c	0.67d	0.57c	0.65c
$PMST_2$	1.38cd	0.49d	0.71c	0.62de	0.64c	0.83d	0.75e	0.65d	0.76d
$PMST_3$	1.50c	0.63e	1.10d	0.70e	0.67cd	0.86d	0.78e	0.71e	0.87e
$PMSD_1$)	0.73b	0.36c	0.92e	0.59cd	0.66c	0.61b	0.55c	0.52c	0.62c
$PMSD_2$	1.06e	0.54d	1.04d	0.67de	0.74de	0.71c	0.64d	0.60d	0.75d
$PMSD_3$	1.06e	0.74e	1.15d	0.80f	0.79e	0.74c	0.66d	0.60d	0.82e
SE	0.08	0.04	0.07	0.04	0.04	0.03	0.02	0.02	0.03
Mean	1.02	0.43	0.74	0.55	0.57	0.64	0.57	0.52	0.63

*Means followed by different letters are significantly different (Duncan's Multiple Range Test, P = 0.05).

Table 4 **Cumulative amounts (mg x 10-1) and percent (%) of C mineralized from each tratment at 300C at the 3end of 8 weeks.**

Treatments	Cumulative C				% C mineralized			
	1*	2	3	Mean	1	2	3	Mean
Control	0.70	1.01	0.90	0.87a**	0.12	0.17	0.15	0.11a
PM	3.52	3.97	3.61	3.70b	0.92	1.04	0.95	0.47b
$PMST_1$	4.88	5.43	5.32	5.21c	0.82	0.91	0.89	0.65c
$PMST_2$	5.97	6.24	6.00	6.07de	0.81	0.85	0.81	0.76d
$PMST_3$	7.36	6.63	6.86	6.95f	0.80	0.72	0.75	0.87e
$PMSD_1$)	5.25	4.75	4.80	4.94c	0.68	0.62	0.62	0.62c
$PMSD_2$	5.47	6.23	6.30	6.00de	0.53	0.60	0.61	0.75d
$PMSD_3$	7.54	6.08	6.00	6.54ef	0.56	0.45	0.44	0.82e
			SE	0.24				0.03
			Mean	5.04				0.66

*Replications of treatments
**Means followed by different letters are significantly different (Duncan's Multiple Range Test, P = 0.05).