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ORGANIC MATTER BUILD-UP IN A TROPICAL ALFISOL UNDER A LEGUME-BASED INTEGRATED NUTRIENT MANAGEMENT SYSTEM

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Abstract- This study was carried out on a degraded tropical alfisol for three consecutive years (2004, 2005 and 2006) to investigate the effect of a legume based integrated nutrient management system on the build-up of soil organic matter (SOM). The treatments consisted of poultry manure applied at two levels (0, 5 t ha^{-1}), three levels of N-fertilizer (0, 50, and 100 kg N ha^{-1}) applied as urea, three levels of P-fertilizer (0, 30 and 60 kg P ha^{-1}) applied as single superphosphate) and two soybean treatments (with or without legume residue). The treatments were arranged as a factorial experiment using Randomised Complete Block Design (RCBD) and replicated three times. The treatments were applied each of the three years of the experiment and the test crop was maize. Soil samples were collected, processed and analysed before the commencement of the experiment and after harvests each year for Soil Organic Matter (SOM) as well as other soil properties. Results show that the impact of poultry manure was the greatest on SOM build-up while that of legume was very slight. With regard to N-fertilizer and P-fertilizer, their impact on SOM build-up when singly applied non existent as SOM entered deficit at the end of three years of their application. However, the combined effect of poultry manure at 5 t ha^{-1}, legume residue incorporation and N-fertilizer at 100 kg ha^{-1} produced the highest build-up of SOM with an increase of 36.3% over the initial amount of 15.7 g kg^{-1} after three years of experiment.

Keywords- Organic Matter build-up, Poultry Manure, Legume residue, inorganic fertilizers

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Introduction

Soil degradation is one of the most serious environmental problems. As observed by Glantz [6], the degradation of soils is typically a “creeping environmental problem” i.e. a cumulative environmental change that evolves at an imperceptibly slow pace, which hinders the initiation of counter balancing measures. It is particularly troubling that soils today are destroyed at a much faster rate than they can be formed by natural processes [7]. This rapid decrease in soil fertility is a common feature of arable land in Africa. One of the major causes of the deteriorating soil fertility is the rapid loss of soil organic matter.

Soil Organic Matter (SOM) or humus is formed during the biological decomposition of plant and animal residues and important soil functions like water and nutrient holding capacity, tilth and the recycling of carbon and plant nutrients are attributable to its presence in the soil. The loss of SOM and a healthy soil biological activity reduces soil fertility, degrades soil structure and water holding capacity and ultimately leads to desertification. SOM holds the key to sustainable Soil Management and therefore, the prevention of Soil degradation [7].

For long, the addition of organic matter has been viewed as an alternative to the use of chemical fertilizer which is gradually becoming unpopular among farmers because of its adverse environmental effect such as soil acidification, pollution of water bodies as well as its scarcity and high cost. However, unless the organic matter is derived from a N_2-fixing crop that is used as an intrinsic component of the cropping system, organic matter addition simply implies recycling of nutrients and not replenishment [9]. Also, nutrient concentrations in residues are generally low, inevitably leading to huge requirements of organic residues to meet crop demands. This, according to Merckx, et al [9] leads to a second problem of how the huge amounts required will be produced and managed in soils of inherently low fertility viz-a-viz labour, space and time. In his study conducted to evaluate the effects of organic residue treatments on soil nutrients and maize yield, Adetunji [3] reported that burning of residues resulted in appreciable increases in soil nutrients that could not be sustained even till harvest while incorporating residues resulted in smaller increases that were more sustainable. The study also reported increased maize yield in residue incorporated plot and profound influence of fertilizer application. Production was highest when fertilizer application was combined with residue management [1,3,11]. It is also argued that the immediate nutrient use efficiency of organic amendments is low, implying that more of the nutrients are stored in soil organic matter pools from which the nutrient release characteristics are poorly documented. Without organic amendments and in the absence of N_2-fixing crops, the only source of N is the native soil organic N pool, the size of which is believed to be a poor predictor of crop N uptake. Also, in their work, Amusan, et al [5] reported a complimentary effect of manure and legume on maize yield, soil organic matter and soil phosphorus. This paper reports a research conducted on a tropical alfisol in 2004, 2005 and 2006 to investigate the effect of integrated application of soil amendments on the build-up of soil organic matter.

Materials and Methods

Surface soil samples (2-20cm) were taken from the experimental site in Abeokuta, South Western Nigeria. The site had not received fertilizer for five years prior to the experiment. The project site was located on the upper slope of a highly weathered sedentary soil (Iwo series). The soil is sandy loam in texture and classified as Kandic Paleustalf [4]. The soil samples were air dried, sieved through a 2mm sieve and analyzed for selected physical and chemical properties.

Particle size distribution was determined by the hydrometer method [10] using sodium hexameter-phosphate as the dispersing agent. Soil p^H was determined potentiometrically in distilled water at soil to water ratio 1:1. Exchangeable bases (K, Na, and Mg) were extracted with neutral normal NH_4OA_c. Potassium and Na in the extract were determined by flame photometry while Ca and Mg were read by atomic absorption spectrophotometer. Exchangeable acidity was determined by titration of normal KCl extract against 0.05 sodium hydroxide to a pink end point using phenolphthalein as indicator [8]. Effective cation exchange capacity (ECEC) was obtained by summation of exchangeable bases and exchangeable acidity. Available P was determined by using the Bray 1 method. Total N was determined by regular macro-Kjeldahl method while the organic matter was determined using the wet oxidation method.

The poultry manure (PM) used for experiment was from the government poultry farm at Alabata village, Odeda Local Government, Ogun State, Nigeria. The PM was dried and analyzed by standard procedures for the following characteristics: total P (24.80g kg^{-1}); total N (20.00g kg^{-1}); NH_4-N (1.40%); organic C (26.5%); C:N (18.9); Na (0.42%); K (0.72%); Ca (0.21%); Mg (0.16%); Zn (50.00mg kg^{-1}); Cu (90.00mg kg^{-1}); Mn (30.00mg kg^{-1}).

The field experiment was conducted in 2004, 2005 and 2006 as a factorial experiment arranged as Randomized Complete Block Design (RCBD) with three replicate. The treatments consisted of three nitrogen rates (0, 50 & 100kg N ha^{-1}) applied as urea (46%N); three rates of phosphorus (0, 30 & 60kg P ha^{-1}) applied as single superphosphate (18% P_20_5) and two rates of poultry manure (0, 5 t ha^{-1}). Soybean (*Glycine max*, variety TGX 1448-2E) was introduced earlier in the season to precede maize cultivation. It was sown by drilling and spaced 30cm apart. At 12 weeks after planting, the pods were harvested while the stovers (residues) were incorporated into the soil. The amount of residue incorporated was estimated at 5 t ha^{-1}.

Two maize seeds (*Zea mays*, variety DMR-ESR-Y) were planted per hole and later thinned to one per stand two weeks after emergence. The planting distance was 25cm by 75cm. Each plot size was 3m x 5m and the plant population was 53,333 maize plants per ha. All plots received basal application of 30kg ha^{-1} as muriate of potash. Plots receiving poultry manure had the manure worked into the soil two weeks before planting, weeding was done manually with native hoe at three weeks after planting (3WAP) and seven weeks after planting (7WAP). Twenty leaves were taken from each plot at tarselling for tissue analysis. The plant samples were dried to constant weight and analyzed for N and P. Plot by plot surface soil samples (0-20cm) were taken twice and the samples were analyzed for N, P, organic carbon, pH and exchangeable bases using methods previously described.

The data collected were subjected to analysis of variance using the Statistical Analysis System (SAS). Means were separated by Duncan Multiple Range Test (DMRT).

Results

Some physical and chemical properties of the soil used for the study are presented in [Table-1]. The soil is moderately acidic (p^H 5.8) with low exchangeable bases (CEC 3.06 cmol kg^{-1}) and low available phosphorus. The values for total N (0.9g kg^{-1}), soil organic matter (15.7g kg^{-1}) also fall within the Critical Low Range (CLR) in soils of western Nigeria as published by Adepetu [2]. With low N, low soil organic matter (SOM), low P and low CEC, it is obvious that the soil is inherently low in fertility and would therefore inevitably have to rely on soil amendments for meaningful and sustainable agricultural productivity.

Table 1- Some physical and chemical properties of the soil used for the study

Parameters	Values
pH (H2O)	5.8
Av.P (mg kg-1)	9.5
Na (cmol kg-1)	0.83
K (cmol kg-1)	0.12
Ca (cmol kg-1)	1.1
Mg (cmol kg-1)	0.89
H+	0.12
ECEC (cmol kg-1)	3.06
% Base saturation	96.08
N (g kg-1)	0.9
Organic Matter (g kg-1)	15.7
SILT (%)	20.1
CLAY (%)	11
SAND (%)	68.9

The combined effect of poultry manure and incorporated legume residues on SOM build-up over a period of three years is presented in [Table-2].

Table 2 - Organic Matter as affected by Legume and manure

M	+Legume	-Legume
OM	14.29^c	12.28^d
5M	19.92^a	18.61^b

Values are means of three years

Figures having the same letter as superscripts within a column are not significantly different at $P< 0.05$

M= Poultry Manure

Soil organic matter increased by 18.5% when poultry manure was applied at 5 t ha^{-1} without legume residues. However, when legume residue was incorporated along with the 5 t ha^{-1} manure, SOM increased by 26.9% over the period of study. Without the application of poultry manure, a deficit of SOM was recorded with or without legume residue incorporation. The deficit was however greater without legume (-21.7%) than with legume (-8.9%). These results suggest that the effect of legume residue on SOM build-up is very slight and that the 26.9% increase in SOM when legume residue was combined with poultry manure, was essentially attributable to the poultry manure. The results also confirm the findings of Amusan, et al [5] that the roles of manure and legume residues are complimentary.

[Table-3] shows the combined effect of legume residue and N fertilizer on SOM while [Table-4] shows the combined effect of legume and P-fertilizer on SOM over a period of three years. N- fertilizer applied at 100kg ha^{-1} is observed to have significant effect on SOM with or without legume residue incorporations although the effect is higher with legume (17.6%) than without legume (8.5%). These increases are attributable to the N-fertilizer that must have enhanced the vegetative growth of the test crop (maize) and invariably added to the organic matter status of the soil. The observations are similar to those in [Table-4].

Table 3 - Organic matter as affected by Legume and N-fertilizer

N	+Legume	-Legume
0	15.47^{c}	13.46^{d}
50	17.38^{b}	15.81^{c}
100	18.47^{a}	17.04^{b}

Values are means of three years

Figures having the same letter as superscripts within a column are not significantly different at P< 0.05

N= Nitrogen fertilizer (kg ha^{-1})

Table 4 - Organic Matter as affected by Legume and P-fertilizer

P	+Legume	-Legume
0	16.43^{a}	14.66^{c}
30	17.20^{a}	15.68^{b}
60	17.68^{a}	15.98^{b}

Values are means of three years

Figures having the same letter as superscripts within a column are not significantly different at P< 0.05

P= Phosphorus Fertilizer (kg ha^{-1})

The effect of poultry manure on the build-up of SOM is more pronounced and more revealing in [Table-5], [Table-6]. When poultry manure at 5 t ha^{-1} was combined with N-fertilizer at 100 kg ha^{-1}, SOM increased by 33.6% and by 25.8% when combined with N-fertilizer at 50 kg ha^{-1}. Without poultry manure, a deficit of SOM was obtained even when N-fertilizer was applied at 100kg ha^{-1}.

Table 5 - Organic Matter as affected by Manure and N-fertilizer

N	OM	5M
0	11.89^{f}	17.04^{c}
50	13.43^{e}	19.76^{a}
100	14.53^{d}	20.98^{a}

Values are means of three years

Figures having the same letter as superscripts within a column are not significantly different at P< 0.05

M=Poultry Manure (t ha^{-1}), N=Nitrogen fertilizer (kg ha^{-1}).

Table 6 - Organic Matter as affected by Manure and P-fertilizer

P	OM	5M
0	12.53^{d}	18.55^{b}
30	13.50^{c}	19.38^{a}
60	13.81^{c}	19.85^{a}

Values are means of three years

Figures having the same letter as superscripts within a column are not significantly different at P< 0.05

P=Phosphorus fertilizer (kg ha^{-1}), M=Poultry manure (t ha^{-1}).

The results are similar to those obtained when poultry manure was combined with P-fertilizer [Table-6].

The results of integrated application of legume residue, poultry manure and N-fertilizer [Table-7] further confirms the importance of poultry manure on SOM build-up and the complimentary but slight impact of legume residue over the substance. The highest SOM build-up was obtained when poultry manure at 5 t ha^{-1} was integrated with N-fertilizer at 100kg ha^{-1} plus legume residue incorporation. Without poultry manure and with the exclusion of legume residue, great deficit of SOM was obtained even with the application of N-fertilizer. A similar result was obtained when legume residue was combined with poultry manure and P-fertilizer [Table-8]. The highest SOM of 20.49 g kg^{-1} was obtained when poultry manure at 5 t ha^{-1} was combined with P-fertilizer at 60 kg ha^{-1} with the addition of legume residue. At the same level of poultry manure and P-fertilizer, but with the exclusion of legume residue, SOM build-up was only slightly lower (19.21 g kg^{-1}), confirming earlier suggestion that the effect of legume residue on SOM build-up is marginal.

Table 7- Organic Matter as affected by Legume, Manure and N-fertilizer

L	M	N	
(+Legume)	0	0	12.97^{f}
		50	14.35^{e}
		100	15.54^{d}
	5	0	17.96^{c}
		50	20.41^{a}
		100	21.4^{a}
(-Legume)	0	0	10.80^{a}
		50	12.50^{f}
		100	13.52^{ef}
	5	0	16.12^{d}
		50	19.12^{b}
		100	20.56^{a}

Values are means of three years

Figures having the same letter as superscripts within a column are not significantly different at P< 0.05

M=Poultry manure (t ha^{-1}), N=Nitrogen fertilizer (kg ha^{-1})

Table 8 - Organic Matter as affected by Legume, Manure and P-fertilizer

L	M	P	
(+Legume)	0	0	13.53^{ef}
		30	14.46^{de}
		60	14.87^{d}
	5	0	19.33^{b}
		30	19.94^{ab}
		60	20.49^{a}
(-Legume)	0	0	11.53^{g}
		30	12.54^{fg}
		60	12.75^{f}
	5	0	17.78^{c}
		30	18.82^{bc}
		60	19.21^{b}

Values are means of three years

Figures having the same letter as superscripts within a column are not significantly different at P< 0.05

M=Poultry manure (t ha^{-1}), P=Phosphorus fertilizer (kg ha^{-1})

In an integration involving legume residue, N-fertilizer and P-fertilizer, it is obvious that SOM build-up is controlled by combined effect of legume residue and N-fertilizer as the highest value of SOM was obtained when legume residue was combined with N-fertilizer at 100 kg ha^{-1} and P-fertilizer at 60 kg ha^{-1}[Table-9].

The domineering effect of poultry manure on SOM build-up is further confirmed by the results obtained when poultry manure was integrated with N-fertilizer and P-fertilizer [Table-10]. The highest value for SOM build-up (21.39 g kg^{-1}) was obtained when poultry manure at 5 t ha^{-1} was combined with N-fertilizer at 100 kg ha^{-1} and P-fertilizer at 60 kg ha^{-1}. At the same level of N-fertilizer and P-fertilizer, but without poultry manure, the value of SOM build-up was as low as 14.42 g kg^{-1} which is even a deficit.

Table 9- Organic Matter as affected by Legume (L), N- and P-fertilizer

L	N	P	
		0	14.90^{efg}
	0	30	15.38^{def}
		60	16.12^{cde}
		0	16.27^{cde}
(+L)	50	30	17.63^{abc}
		60	18.24^{ab}
		0	18.11^{ab}
	100	30	18.60^{a}
		60	18.69^{a}
		0	12.37^{h}
	0	30	13.66^{gh}
		60	14.35^{fg}
		0	14.59^{fg}
(-L)	50	30	16.39^{cd}
		60	16.46^{cd}
		0	17.01^{bc}
	100	30	16.98^{bc}
		60	17.12^{bc}

Values are means of three years
Figures having the same letter as superscripts within a column are not significantly different at P< 0.05
L=Legume residue, N=Nitrogen fertilizer (kg ha^{-1}), P=Phosphorus fertilizer (kg ha^{-1})

Table 10- Organic Matter as affected by Manure, N- and P-fertilizer

L	N	P	
		0	10.87^{h}
	0	30	12.00^{gh}
		60	12.80^{fg}
		0	12.11^{gh}
(+L)	50	30	13.95^{ef}
		60	14.22^{e}
		0	14.61^{e}
	100	30	14.55^{e}
		60	14.42^{e}
		0	16.40^{d}
	0	30	17.05^{d}
		60	17.68^{cd}
		0	18.75^{bc}
(-L)	50	30	20.06^{ab}
		60	20.48^{a}
		0	20.51^{a}
	100	30	21.03^{a}
		60	21.39^{a}

Values are means of three years
Figures having the same letter as superscripts within a column are not significantly different at P< 0.05
M=Poultry manure (t ha^{-1}), N=Nitrogen fertilizer (kg ha^{-1}), P=Phosphorus fertilizer (kg ha^{-1})

Discussion

In all the interactions involving poultry manure that were found to be significant for SOM, it could easily be seen that it is the poultry manure component of the interaction that played major role in the responses. An observation similar to this has earlier been reported by Amusan, et al [5]. Going by the current practice in the study area and most small holder African farming communities, the integrated use of manure and crop residue is environmentally sustainable and economical. Animal wastes are actually obtained free of charge as a component of the farming enterprise and if to be sourced externally, it attracts no charge except the cost of transportation which is determined by the distance between the farm and the source of manure. However, the most popular practice, particularly for large ruminant farmers is to allow animals sleep in field to be used for cultivation before the planting season.

It is generally recognised that the incorporation of organic residues leads to more pronounced residual effects due to reduced N and biomass losses. In moist savanna environments, this would imply that farmers have to incorporate legume residues at the end of the cropping season. This would place an additional burden on an already tight labour schedule of farmers and may therefore, not be a realistic practice except if it can be mechanized as practiced by farmers in Southern Brazil.

Conclusions

The study showed that effect of poultry manure and legume residue incorporation on soil organic matter build-up is complimentary. However, the singular application of poultry manure produced greater effect. The singular application of N-fertilizer and P-fertilizer over the three years of study led to a deficit of Soil Organic Matter while the singular application of legume residue produced a slight effect on SOM build up. The combined application of poultry manure at 5 t ha^{-1}, the application of N-fertilizer at 100 kg ha^{-1} and the incorporation of legume residue estimated at 5 t ha^{-1} produced the highest Soil Organic Matter of 21.4 g kg $^{-1}$, representing a build-up of 36.3% over the initial value of 15.7 g kg^{-1}. The implication of these findings is that tropical soils subjected to continuous cropping with the application of inorganic fertilizers alone will always be degraded and lose their fertility over time. The integration of manure and legume residues with the use of inorganic fertilizers will, from the findings of this study, improve the organic matter status of the soil and prevent degradation.

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