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Characterization of a Degraded Ultisol Amended with Cassava Peel, Cattle Dung and Poultry Droppings in Southeastern Nigeria

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Abstract: This study investigated the properties of an ultisol amended with Cassava Peel (CP), Cattle Dung (CD) and Poultry Droppings (PD). The potted experiment was set-up in a greenhouse using a Completely Randomized Design (CRD). Maize (*Zea mays* var. Western Yellow) was used as a test crop. Pre-planting soil characterization showed degradation but some properties were reversed by using CP, CD and PD in two cropping seasons (2004 and 2005). Highest grain yield of 4.84 g pot^{-1} was recorded. A combination of CP and PD yielded 5.57 g pot^{-1} grains. There were significant moisture correlations between performance parameters of maize and soil properties in all the amendments ($p<0.05$). Post-planting study showed that CD-amended soils had a mean total nitrogen value of 4.90 g kg^{-1} while PD improved soil phosphorus and potassium by having 176.67 and 24.30 g kg^{-1}, respectively. Soil amendments increased soil pH while soils from control pots showed a reduced pH from 4.10 (0.1 N KCl) to 3.90 (0.1 N KCl) after second cropping.

Key words: Amendment, degradation, remediation, tropics, ultisols

INTRODUCTION

One of the important ways of improving soil nutrient status and enhancing continuous soil productivity is through the use of organic residues (Oguike and Mbagwu, 2001). Mbonu and Elenwo (2006) reported a decrease in bulk density, improved moisture retention and total porosity using plantain peels and poultry droppings. Organic matter promotes soil aggregation through enhanced binding of soil particles (Six *et al*., 2000). Organic matter is a source of nutrients (Ajayi *et al*., 2003; Ikpe *et al*., 2003). The ability to increase pools of soil organic carbon in agricultural ecosystems is of interest for restoring organic matter pools important to soil health (Hooker *et al*., 2005). Most inorganic fertilizers are associated with problems of soil acidity especially if rampantly used (Obi and Akinsola, 1995), in addition to the fact that they pose considerable financial burden in developing countries (FAO, 1983).

More than 70% of the total land area in south-eastern Nigeria is covered by ultisols (Mbagwu, 1992) characterized by pronounced weathering, low pH, low cation exchange capacity, low base saturation, low fertility and multiple nutrient deficiencies. In the light of these the inherently poor fertility characteristics of tropical soils have made fertility and nutrient availability in them largely controlled by soil organic matter content (Fernandez and Sanchez, 1990).

Few studies have been conducted on the characterization of influences of various sources of organic matter available under tropical conditions (Mba, 2003; Okpara and Mbagwu, 2003). The major objective of this study was to characterize the enhancing properties of cassava peels, cattle dung and poultry droppings as amendments to highly weathered ultisols of southeastern Nigeria.

MATERIALS AND METHODS

Site Description

The study was conducted for two consecutive cropping seasons (2004-2005) on the University Teaching and Research farm at Owerri, Nigeria (latitude 5°21`N and longitude 7°02` E). It is a humid tropical environment. Temperatures are high and change only slightly during the year (mean daily temperature is about 27°C). The average annual rainfall ranges from 2300 to 2400 mm. Three months dryness are characteristic of the site. Soils of the area were earlier characterized and classified as ultisols (Esu, 2005).

Field Work

Thirty soil samples were collected from eroded slope soils of the University farm using a soil auger at a depth of 0-20 cm. These soil surface samples were bulked to produce composite samples and potted for the greenhouse experiment. Soil samples were air-dried and sieved using 2 mm mesh for the purpose of characterization. Fermented organic materials were air-dried, crushed and ground into powdery form in readiness for application.

Greenhouse Study

Potted experiment was set up in 5 replicates using 4 kg surface soil in the greenhouse. Cassava peels, cattle dung and poultry droppings were applied at zero and 50 metric tons/ha either alone or in any two equal combinations to the respective pots. The experimental design was Completely Randomized Design (CRD). Potted soils were maintained at field capacity gravimetric moisture (em = 20%). Maize seeds were sown in potted soils at a seed rate of 1 seed per pot.

Laboratory Analysis

Particle size distribution was estimated by hydrometer method (Gee and Or, 2002). Total nitrogen was determined by micro-Kjeldahl method (Bremner, 1996). Total carbon was measured using a Leco C analyzer (LECO Corp. St. Joseph, MI.), Soil pH was determined with an electrode on a 1:2 soil/water solution (Hendershot *et al*., 1993). Air-dried, sieved and composited soil was extracted with Mehlich-3 extractant solution (Tucker, 1992) in a 1:10 soil/extractant solution ratio and analyzed for extractable nutrients of calcium (Ca), magnesium (Mg), potassium (K) and phosphorus (P) using an inductively coupled argon-plasma spectrophotometer (CIROS CCD model, Spectro Analytical Instrument, MA). Amendments were also extracted and determined as above.

RESULTS AND DISCUSSION

Soil Properties

Soils were sandy and of low nutrient status (Table 1). Soil texture reflected the nature of parent material (Coastal Plain Sands) from which soils were derived.

Low nutrients content and strong acidity can be attributed to high rainfall and consequent leaching of basic cations out of the root zone of soils. Highly acidic nature (pH = 4.1 in 0.1 N KCl) may be responsible for low value of available phosphorus as the element is readily fixed under such soil reactions in highly weathered soils (Ultisols).

Properties of Soil Amendments

Inherent characteristics of Cassava Peel (CP), Cattle Dung (CD) and Poultry Dropping (PD) are shown in Table 2, with CP having highest value in total carbon while PD has greater potentials of supplying total nitrogen, exchangeable basic cations and phosphorus to the degraded ultisol.

Table 1: Selected soil properties (before planting)

Parameters	Value
Sand (g kg^{-1})	40.00
Silt (g kg^{-1})	20.00
Clay (g kg^{-1})	960.00
pH (0.1 N KCl)	4.10
Total carbon (g kg^{-1})	3.00
Total nitrogen (g kg^{-1})	0.30
Exchangeable calcium (Cmol kg^{-1})	0.70
Exchangeable magnesium (Cmol kg^{-1})	0.10
Exchangeable potassium (Cmol kg^{-1})	0.10
Available phosphorus (mg kg^{-1})	5.00

Table 2: Chemical characterization of amendments

Parameters	CP	CD	PD
Total carbon (g kg^{-1})	410.0	390.0	300.0
Total nitrogen (g kg^{-1})	9.6	14.0	21.3
Exchangeable calcium (cmol kg^{-1})	9.0	12.0	112.0
Exchangeable magnesium (cmol kg^{-1})	8.6	9.6	12.0
Exchangeable potassium (cmol kg^{-1})	16.0	7.0	18.0
Available phosphorus (mg kg^{-1})	1.9	2.2	6.3

CP = Cassava Peel; CD = Cow Dung; PD = Poultry Dropping

Table 3a: Effect of amendments on the grain yield of maize

Amendments	First cropping	Second cropping	Total yield
CP	1.06	1.94	3.00
CD	1.50	1.38	2.88
PD	1.63	3.21	4.84
CP/CD	1.20	0.98	2.18
CP/PD	2.90	3.61	5.57
CD/PD	3.37	2.15	5.52
Control	0.86	0.40	1.26

CP = Cassava Peel; CD = Cow Dung; PD = Poultry Dropping

Table 3b: Correlation Coefficients (R) of maize performance with selected soil properties under different amendments (average values of two croppings)

		Soil properties			
Amendments	Parameters	pH	Total carbon	Available phosphorus	Total nitrogen
CP	Plant height (cm)	0.5*	0.7*	0.4*	0.8**
	Fresh seed yield (g pot^{-1})	0.4*	0.5*	0.4*	0.4*
	Dry matter (g pot^{-1})	0.5**	0.8*	0.5*	0.7**
CD	Plant height (cm)	0.5*	0.9*	0.5*	0.6*
	Fresh seed yield (g pot^{-1})	0.5**	0.6**	0.5**	0.5**
	Dry matter (g pot^{-1})	0.7*	0.8*	0.6*	0.6*
PD	Plant height (cm)	0.8**	0.4*	0.8*	0.9**
	Fresh seed yield (g pot^{-1})	0.7**	0.5*	0.8**	0.8**
	Dry matter (g pot^{-1})	0.8**	0.4*	0.7*	0.9**
Control	Plant height (cm)	0.2^{NS}	0.5*	0.2^{NS}	0.4^{NS}
	Fresh seed yield (g pot^{-1})	0.1^{NS}	0.4^{NS}	0.3^{NS}	0.2^{NS}
	Dry matter (g pot^{-1})	0.4*	0.4^{NS}	0.2^{NS}	0.2^{NS}

**Significant $p<0.01$; *Significant $p<0.05$; NS: Not Significant; CP = Cassava Peel, CD = Cow Dung; PD = Poultry Dropping

Effects of Soil Amendments on Maize Performance

Table 3a shows the yield variations among soil treatments in two cropping seasons. There was increased yield when PD was combined with CP or CD than where amendments were applied singly. This shows positive interaction between amendments. However, PD showed higher total yield in both the first and second cropping seasons, although all the amendments gave higher yield during the second cropping. This could be attributed to less rapid mineralization of amendments in the first cropping season. Progressive decline in total yield was observed in the control pot, indicating absence of any fertility regeneration material in the experiment.

Soil amendments correlated positively and significantly with performance of maize (*Zea mays* var. western yellow) at $p \leq 0.05$ using plant height, fresh seed yield and dry matter yield as growth and yield characteristics (Table 3b). These results are consistent with the findings of Mbagwu *et al.* (2001) when degraded Ultisol was amended with these organic manures. These correlations varied among amendments in line with the findings of Reeves and Van Kessel (2002) that manure composition differs according to diet. Calderon *et al.* (2004) in his incubation studies observed that some manures act as net suppliers of nitrogen while others may result in net nitrogen immobilization. Of all amendments, weakest correlations were observed between growth and yield characteristics of maize and soil properties under the CD. Dairy manure has been described as a complex mixture of materials with varied mineralization kinetics ranging from relatively resistant lignin to readily available ammonium and volatile fatty acids (Van Kessel *et al*., 2000).

Total yield (Table 3a) was found to reflect uptake of N.P and K (Table 4) with PD showing the best effect on maize performance followed up by CP. However, a combination CP and PD resulted to highest grain yield (5.57 g per pot) though with less uptake (Table 4). Improved performance of maize on soils amended with PD was reported by Oguike and Mbagwu (2001).

Post-planting Soil Properties

Soils amended with combination of CD and PD gave very high residual nitrogen (Table 5). This confirms the earlier observation by Van Kessel *et al.* (2000) concerning net immobilization of nutrients by dairy manure and these temporarily unavailable nutrients were possibly released after the second cropping. It implies that CD has a longer enhancement effect on productivity of these soils. But PD gave better residual effect on soil phosphorus and potassium. Soil pH increased tremendously in all the organically-amended soils at the end of the second cropping, especially when CD was combined with PD. This agrees with the earlier report of Spaccini *et al.* (2002) that organic amendments improved soil physical and chemical fertility of degraded soils. However, Okpara and Mbagwu (2003) reported that the effects of cattle dung and swine wastes were more significant at initial cropping.

Table 4: Effect of amendments on N, P, K concentration (g kg^{-1}) and uptake (mg $plant^{-1}$) of maize tops

	Concentration						Uptake								
	First cropping			Second cropping			First cropping			Second cropping			Total		
Amendments	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
CP	10.2	0.80	50.00	10.0	1.3	31.60	10.79	0.84	59.08	19.29	2.52	105.55	30.08	3.36	164.63
CD	8.8	0.97	42.00	9.0	1.6	22.70	13.12	1.42	62.83	12.45	2.21	31.35	25.57	3.63	94.18
PD	25.0	1.80	75.00	9.4	1.8	53.00	40.64	2.82	122.28	30.18	5.78	167.05	70.82	8.60	289.33
CP/CD	7.6	0.97	56.00	7.7	1.6	47.00	9.10	1.12	66.92	7.51	1.57	46.07	16.61	2.69	113.00
CP/PD	13.3	1.60	65.00	9.4	1.6	32.30	39.64	4.74	193.00	24.51	4.17	86.30	64.15	8.91	277.27
CD/PD	16.9	1.60	52.30	8.4	1.9	20.30	57.12	5.39	176.52	18.04	4.08	43.68	75.16	9.47	222.01
Control	18.9	1.30	28.00	8.0	0.8	19.30	16.10	1.12	26.01	3.20	0.32	7.00	19.30	1.44	31.73

CP = Cassava Peel; CD = Cow Dung; PD = Poultry Dropping; N = Nitrogen; P = Phosphorus, K = Potassium

Table 5: Effect of amendments on residual N, P, K and pH in the soil after two croppings

Amendments	N(g kg^{-1})	P (mg kg^{-1})	K (g kg^{-1})	pH (KCl)
CP	3.00	12.33	20.70	4.60
CD	4.90	18.00	12.70	4.90
PD	4.20	176.67	24.30	5.30
CP/CD	3.80	14.00	15.30	4.80
CP/PD	4.20	146.67	15.00	5.10
CD/PD	5.00	153.33	13.00	5.40
Control	0.80	3.67	0.73	3.90

CP = Cassava Peel; CD = Cow Dung; PD = Poultry Dropping

CONCLUSIONS

Soils of the study site are highly degraded giving the low nutrient status and strong acidity. Organic amendments of CP, CD and PD and their combinations enhanced total yield of maize whose productivity was least under control experiment. There were significant positive correlations between growth and yield parameters of maize and selected soil properties, especially as amended by CP, CD and PD.

High uptake of nutrients from PD-amended soils resulted to highest yield when amendments were singly applied. These organic amendments had sustainable impact on the use of soils in subsequent immediate cropping season when no amendment was added.

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