CHANGES IN SOME PHYSICAL PROPERTIES OF A DEGRADED ULTISOL TREATED WITH POULTRY MANURE

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Abstract
Application of organic materials is important in ameliorating degradedsoil physical properties for enhanced crop production. Poultry manure (PM) at the rates of 0,5,10 and 15t ha^{-1}was used to study the effects of application of organic materials on some soil physical properties of an Ultisol in Umudike, southeastern Nigeria. Auger and core samples (0 -20 cm) collected from Michael Okpara University of Agriculture, Umudike farm, sown with sole maize (SM), sole okra (SO) and maize-okra intercrop (MO), were used for the determination of some soil physical parameters and organic matter (OM). The auger samples were used for particle size distribution analysis and OM whereas the core samples were used to determine saturated hydraulic conductivity (K_{sat}), moisture retained at field capacity (FC), permanent wilting point (PWP) and bulk density (Bd). The experiment was designed as a split plot in a randomized complete block replicated three times. The PM rates were the sub-plot treatments while the cropping systems (CS) were the main plot treatments. Data generated were subjected to analysis of variance (ANOVA) and the differences between treatment means were detected using Fisher's least significant difference at 5% probability level ($FLSD_{0.05}$). Regression and correlation were performed to detect the extent of relationship among soil properties. The texture of the soil was sandy loam. Compared to the control, there were significant ($P \leq 0.05$) improvements in soil properties due to PM application. However, with regard to FC, there was no significant difference among the CS: MO (52.42%), SM(52.36%) and SO (52.52%) whereas at 5t ha^{-1} (51.08%), 10 t ha^{-1}(53.25%) and 15 t ha^{-1} (57.45%) of PM, significant improvements above the control (47.95%) were observed. Bulk density reduced from 1.82 Mg m^{-3} at control to 1.08 Mg m^{-3} at 15 t ha^{-1} reflecting a 40.7% improvement. Hydraulic conductivity (K_{sat}) at 5 t ha^{-1} (0.0061 mm sec^{-1}) was not significantly different from control (0.0057 mm sec^{-1}) corresponding to the low Pt at 5 t ha^{-1} (38.11 m^3/m^3) which was also statistically similar to the control. Regression analysis (R^2 = 0.653) indicated that OM accounted for 65% increase in AWC. Also, AWC contributed 8.2 (R^2 = 0.082) and 17.9% (R^2 = 0.179) to FMC and FOP weight variations, respectively. Correlation of $K_{sat}$and AWC showed a significant ($P \leq 0.01$) positive relationship. These results suggested that PM above 5 t ha^{-1} will result to improvements in soil physical properties as well as enhancement in productivity of Ultisol in Umudike environment.

Keywords: Physical properties, poultry manure, cropping system, Ultisol.

Introduction

With the depletion of OM through intensification of agriculture, tropical soils have become structurally fragile. The soils are exposed to harsh climatic conditions exemplified by torrential rainfall. This leads to erosion that results in rapid deterioration of their physical and chemical properties.

The low OM content of soils leads to high bulk density, low total porosity, reduced water infiltration and transmission rates, low water retention and available water capacities (Mbah and Mbagwu, 2003). Intensification of agriculture, characterized by continuous cultivation, does not allow the build-up of OM. Therefore, the soils require external inputs to replenish depleted OM for improved soil physical properties. Hence, this study with objective as the assessment of influence of PM on water retaining and conducting characteristics, bulk density and total porosity of an Ultisol. Specific objectives were: to evaluate the variations in field capacity(FC), permanent wilting point (PWP), bulk density (Bd) and saturated hydraulic conductivity ($K_{(sat)}$)of soil due to PM application and to determine the relationship between $K_{(sat)}$and AWC of soil treated with PM.

Materials and methods

Site description

The study site was Michael Okpara University of Agriculture, Umudike farm located within latitude 7^{o}33^{1}N and longitude 5^{o}29^1 E with an altitude of 122 m above sea level (NRCRI, 2007). The climate is tropical with wet and dry seasons. Wet season starts from March and ends in October with peaks in June and September. There is a short break in August. Mean annual rainfall ranges from 2100 to 2300 mm (NRCRI, 2007).Dry season sets in from November spanning through February.Maximum and minimum monthly mean temperatures are 32^o and 23^{o}C, respectively.The monthly relative humidity varies from 51% to 87% during the wet season (NRCRI, 2007). The vegetation type is of humid tropical.

Experimental design

The design was a split plot in a randomized complete block (RCBD) with different rates of PM (0, 5, 10 and 15 t ha^{-1}) as the sub plot treatment while cropping system [sole maize (SM), sole okra (SO) and maize – okra intercrop (MO)] was the main plot treatment. The treatments were replicated three times.

Each plot size was 2.4 x 5 m. Maize (Orba super 2) and okra (V-35) used as test crops were obtained from National Agricultural Seed Council while PM was sourced from Michael Okpara University of Agriculture, Umudike poultry farm. The PM was incorporated into the soil.

Soil sampling and laboratory analysis

Auger and core samplers were used to collect soil samples from the experimental plots at 0 – 20 cm depth. Auger samples were taken randomly from different spots within a plot and bulked to form composite samples while triplicate core samples were collected from each plot.

The bulked soil samples were air-dried and passed through a 2 mm sieve size for the determination of particle size distribution (Gee and Bauder, 1986) and OM (Nelson and Sommers, 1996). The core samples were saturated in water and used to determine saturated hydraulic conductivity (K_{sat}) (Stolte, 1997), field capacity (FC), permanent wilting point (PWP) (Mbagwu, 1991) and bulk density (Bd) (Anderson and Ingram, 1993).

Available water content (AWC) was deduced as the difference between moisture retained at FC and PWP. Total porosity (P_t) was computed from Bd value assuming a particle density (Pd) of 2.65 Mg m^{-3} as follows:

$$P_t = 1 - \left[\left(Bd / Pd \right) x\ 100 \right]$$

(Anderson and Ingram, 1993)

Data analysis

Data generated were analysed as split-plot in a randomized complete block design (RCBD). Analysis of variance (ANOVA) was performed and means were separated using Fisher's least significant difference (FLSD) at 5% probability level. Regression and correlation were used to determine relationship amongst soil properties and yield parameters.

Results and Discussion

Physical properties of soil studied

Some of the physical properties of soil studied are shown in Table 1. The soil is sandy loam in texture with values of the physical properties indicating degradation. The soil therefore required inputs of organic materials since inorganic fertilizers do not easily ameliorate degraded physical properties of soils. The PM used in the study improved the physical properties of the soil.

Table 1. Some properties of soil studied.

Soil properties	Values
Sand g/kg	658
Silt g/kg	198
Clay g/kg	144
Texture	Sandy loam
FC (m^3/m^3)	0.484
PWP (m^3/m^3)	0.169
AWC (m^3/m^3)	0.315
Bd (Mgm^{-3})	1.900
P_t(m^3/m^3)	0.304
K_{sat} $mmsec^{-1}$	0.006
OM g/kg	18

FC = Field capacity, PWP = permanent wilting point, AWC = available water content, Bd bulk density, Pt = total porosity, K_{sat} = saturated hydraulic conductivity, OM = organic matter.

Water retaining characteristics

Table 2 shows the FC, PWP and AWC of soil treated with PM. There was significant ($P \leq 0.05$) increase in water retention with increasing PM application rate. In each of the cropping systems (CS), plots treated with PM performed significantly better than control with the 15 t ha^{-1} rate having the highest values. Although differences were observed among the CS, they were statistically similar. The increase in moisture retained at FC, PWP and the AWC, with respect to the control, was a manifestation of the affinity of OM for water (Oguike and Mbagwu, 2009;

Vengadaramana and Jashothan, 2012). Organic matter of the soil improved due to PM application (Table 4) and is known to enhance soil aggregation thereby improving water retention capacity of soils (Leon *et al.,* 2009;Eche*et al.,* 2013). The regression model shown in Table 5 indicated that OM accounted for 65% increase in available water content suggesting that the PM improved soil moisture content possibly due to its colloidal and hydrophilic nature (Adeleye*et al.,* 2010). This observation agreed with the findings of Mbah and Mbagwu (2006) on the effect of animal waste on physico-chemical properties of a dystricleptosol and maize yield in southeastern Nigeria. Enhancements in soil water retention observed in this study were also probably due to structural improvement (Adesodun*et al.,* 2005; Aluko and Oyedele, 2005) exemplified in increased total porosity (Table 3). This implied that irrespective of differences in CS, PM applicationhad similar effect on their water retention characteristics (Ojeniyi*et al*., 2013).

Table 2. Moisture retaining characteristics of soil treated with poultry manure.

CS	PM (t ha^{-1})														
	FC (m^3/m^3)					**PWP** (m^3/m^3)					**AWC** (m^3/m^3)				
	0	**5**	**10**	**15**	**Mean**	**0**	**5**	**10**	**15**	**Mean**	**0**	**5**	**10**	**15**	**Mean**
MO	0.4797	0.5186	0.5295	0.5692	0.5242	0.1775	0.1953	0.1955	0.1953	0.1909	0.3021	0.3232	0.3340	0.3739	0.3333
SM	0.4839	0.5114	0.5337	0.5655	0.5236	0.1651	0.1733	0.1775	0.1845	0.1751	0.3188	0.3377	0.3563	0.3811	0.3484
SO	0.4752	0.5025	0.5343	0.5886	0.5252	0.1620	0.1749	0.1921	0.1954	0.1811	0.3132	0.3276	0.3422	0.3933	0.3441
Mean	0.4795	0.5108	0.5325	0.5745		0.1682	0.1812	0.1884	0.1917		0.3113	0.3295	0.3441	0.3828	
$LSD_{(0.05)}$ system	0.0446					0.0221					0.0291				
$LSD_{(0.05)}$ manure	0.0176					0.0086					0.0150				
$LSD_{(0.05)}$ interaction	0.0457					0.0225					0.0322				

CS = cropping system, MO = maize – okra intercrop, SM = sole maize, SO = sole okra, FC = field capacity, PWP = permanent wilting point, AWC = available water content, $LSD_{(0.05)}$ = least significant difference at 5% probability level.

Table 3. Bulk density and moisture conducting characteristics of soil treated with poultry manure.

CS	PM (t ha^{-1})														
	Bd (Mgm^{-3})					**P_t**(m^3/m^3)					**K_{sat} (mm sec^{-1})**				
	0	**5**	**10**	**15**	**Mean**	**0**	**5**	**10**	**15**	**Mean**	**0**	**5**	**10**	**15**	**Mean**
MO	1.79	1.64	1.44	1.23	1.53	0.3245	0.3811	0.4566	0.5358	0.4245	0.0056	0.0062	0.0068	0.0074	0.0065
SM	1.76	1.59	1.30	0.92	1.39	0.3358	0.4000	0.5094	0.6528	0.4745	0.0058	0.0065	0.0075	0.0083	0.0070
SO	1.80	1.75	1.34	1.09	1.52	0.2868	0.3396	0.4943	0.5887	0.4274	0.0056	0.0055	0.0055	0.0078	0.0064
Mean	1.82	1.66	1.36	1.08		0.3157	0.3736	0.4868	0.5924		0.0057	0.0061	0.0066	0.0078	
$LSD_{(0.05)}$ system	0.21					0.0783					0.0010				
$LSD_{(0.05)}$ manure	0.19					0.0706					0.0006				
$LSD_{(0.05)}$ interaction	0.32					0.1199					0.0012				

Bd = Bulk density, P_t = total porosity, K_{sat} = saturated hydraulic conductivity. CS, MO, SM, SO and $LSD_{(0.05)}$ are as indicated in Table 2.

Bulk density (Bd), total porosity and water conducting characteristics

There was a steady decline in Bd as the rate of PM increased from 0 to 15t ha^{-1}(Table 3). Although, there was a decrease in Bd from 0 to 5 t ha^{-1}, it was not significant ($P < 0.05$). However, there was significant difference between the control and 10 and 15 t ha^{-1} in all CS reflecting a 40.7% improvement at 15t ha^{-1}. This was as a result of the increased OM content of the soil (Table 4). This observation is consistent with the reports of Adesodun*et al*., (2005), Alukoand Oyedele (2005) and Adeleye*et al*., (2010).

Table 4. Organic matter (OM) of soil treated with poultry manure.

CS	PM (t ha^{-3})				
	OM g/kg				
	0	**5**	**10**	**15**	**Mean**
MO	19.3	21.3	25.0	28.5	23.5
SM	18.0	24.9	27.1	31.2	25.3
SO	18.5	23.0	25.0	30.4	24.2
Mean	18.6	23.1	25.7	30.0	
$LSD_{(0.05)}$ system	4.6				
$LSD_{(0.05)}$ manure	1.6				
$LSD_{(0.05)}$ interaction	4.6				

OM = organic matter, CS, MO, SM, CO and LSD are as indicated in Table 2.

Total porosity (P_t) increased in the PM treated plots relative to the control. The increase from control to 5 t ha^{-1} was not significant. However, significant differences were observed at 10 and 15 t ha^{-1} with regard to the control. The PM treatment did not influence the CS since no significant difference was observed among them. This observation confirmed the report of Adeleye*et al*. (2010) that the improvement in soil P_t due to increased rate of PM may be due to improved soil aggregate stability brought about by the improved soil OM.

The value of K_{sat} was significantly higher at 15 t ha^{-1} when compared to the control. Although, the 5 and 10 t ha^{-1} were better than the control, they were not significantly different. This observation suggested that higher rates of at least 15 t ha^{-1} of PM application wasrequired to significantly increase K_{sat}. This further corroborates the earlier observation of Oguike*et al*. (2006) who reported that incorporation of organic manure significantly increased K_{sat} and that the magnitude depended on the application rate. Improvement in K_{sat} with increasing PM treatment will result to increased water transmission (Mbah*et al.*, 2011).

There was a highly significant ($P \leq 0.01$) negative correlation between Bd and K_{sat} (r = -0.862) (Table 6). This trend, showing an inverse relationship between Bd and K_{sat} (Oguike and Henshaw, 2013), indicated that a reduction in Bd will result to an increase in K_{sat} (Agbede*et al*., 2008; Ojeniyi*et al.*, 2013).

Table 5. Correlation of Bd, K_{sat} and AWC

	Bd	**K_{sat}**	**AWC**
Bd	1	-0.862**	-0.609**
K_{sat}	-0.862**	1	0.692**
AWC	-0.609**	0.692**	1

** significant at 0.01% probability level (2 tailed)

Bd, K_{sat} are as indicated in Table 3, AWC is as indicated in Table 2.

Percent increase of fresh maize coband fresh okra podweights above thecontrol

The reduced Bd and increased P_t may have increased crop root penetration while the improved K_{sat} may have increased water transmission (Mbah*et al.*, 2011) thereby resulting in the observed percentage increase of fresh maize cob (FMC) and fresh okra pod (FOP) weights above the control (Table 6).

Table 6. Percent increase of fresh maize cob (FMC) and fresh okra pod (FOP) weights above control.

CS	PM ($t\ ha^{-1}$)							
	0	5	10	15	0	5	10	15
	FMC %				FOP %			
MO	-	40	57	22	-	72	152	80
SM	-	52	67	29	-	-	-	-
SO	-	-	-	-	-	32	149	115
Mean	-	47	63	26	-	48	150	100

CS, MO, SM, SO are as indicated in Table 2.

The regression between FMC and FOP weights and AWC (Table 7) suggested that the AWC accounted for 8% FMC and 18% FOP weight variations, respectively.

Table 7.Regression of FMC and FOP weights and AWC.

	Model	R	R_{square}	Adjusted R_{square}	Std. error of estimate
FMC	1	0.286	0.082	0.040	0.52492
FOP	1	0.423	0.179	0.142	1.69181

FMC = fresh maize cob weight, FOP = fresh okra pod weight, AWC is as indicated in Table 2.

Conclusion

Results from this study showed that PM enhanced the physical properties and OM of the soil studied. The use of PM on the Ultisol is considered desirable because it ensured availability of soil moisture through enhanced structural parameters (Bd and Pt) and OM status.

Based on the findings, application of PM above 5t $ha^{-1}$is suitable for ameliorating degraded physical conditions of Ultisol in southeastern Nigeria as it appeared responsible for the increases in FMC and FOP weights.

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