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RESIDUAL EFFECT OF ORGANIC WASTES ON PRODUCTIVITY OF AN ULTISOL IN ABAKALIKI, SOUTH EASTERN NIGERIA

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ABSTRACT: *An experiment was carried out to study residual effect of organic wastes amendment on productivity of an ultisol.The field was laid out in a Randomized Complete Block Design with four treatments of 20 t ha^{-1} equivalent to 8kg/plot of burnt rice mill waste (BRMW), unburnt rice mill waste (URMW), sawdust (SD) and control which were replicated five times to give a total of twenty experimental units. The treatments were applied in 2006 and 2007 cropping seasons and residual effect studied in the third season. A hybrid of maize (Oba super II hybrid) variety was used as a test crop. Data obtained were subjected to analysis of variance (ANOVA) while means were separated with Fisher's Least Significant Difference. The results showed that the textural class remained sandy loam. Hydraulic conductivity of organic wastes amended soil was significantly (P<0.05) higher when compared to control. While bulk density of SD amended plot was 7% lower, total porosity and hydraulic conductivity in same treatment were higher by 16 and 6% when compared to control, respectively. Total porosity, hydraulic conductivity. Available phosphorus and CEC of organic wastes amended soil were significantly (P<0.05) higher than control. Grain yield of maize was higher in BRHD, URHD and SD amended plots by 5, 9 and 13% respectively than control. Residual effect of organic wastes improved the productivity of ultisol more than control, and thus, could be recommended for sustainable soil productivity in Abakaliki agroecological farming system.*

KEYWORDS: Abakaliki, Residual effect, Organic wastes, Productivity, Ultisol

INTRODUCTION

Organic wastes play a key role in sustaining soil productivity especially in the tropics where soil fertility undergoes a rapid decline when land is cleared and cultivated (Lal and Kang, 1982). Essentially, these organic wastes when added to the soil usually have residual effects since they decay and remain in the soil (Lickas and Penny, 2000), although become reduced in amount as crops are continuously grown on it. Furthermore, the organic wastes are normally converted from their organic forms to inorganic forms assimilable to crops and hence remain in stable forms in the soil (Brady and Weil, 2002).

Use of organic wastes to regenerate soil is receiving attention and the current focus in soil productivity restoration (Nagarejah *et al*., 1990). For instance, USDA (1980) noted that organic wastes were the primary source of mineral elements for farmers in developing countries such as Nigeria. Amendment with organic wastes improves general soil characteristics including physical, chemical and biological properties of soil (Hughes, 2004). Improvements in soil friability due to organic wastes incorporation counter balance losses of organic matter during cultivation (John *et al*., 2006) and thus not only serve as a conservative approach but ensure sustainable soil productivity.

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According to Pain and Philips (2000), effect of organic wastes remains in the soil maintain its fertility through positive impacts on soil properties. Remains of organic wastes in soil modify physical conditions such as aeration propensity, friability, colour, porosity, bulk density, plant available water content (Epstein, 2004) thereby enhancing soil productivity. Decomposed organic wastes improve and supply N, P,S, organic carbon, exchangeable cations of Ca, Mg and K to the soil (Allison, 2001).

In Abakaliki agroecology, farmers practice the art of incorporating organic wastes such as wastes, tuber peels and ordinary cut grasses, herbs and shrubs into the soil. They sometimes add these wastes while cultivating the soil but subsequently discontinue leaving cultivation to go on. There is paucity of information on residual effect of organic wastes amendment in the area. This study is to provide information through documentation of residual effect of organic wastes amendment on soil productivity. The objective of this work was to study residual effect of organic wastes amendment on the productivity of an ultisol at Abakaliki Southeastern, Nigeria.

MATERIALS AND METHODS

Experimental Site

The study was carried out at the Teaching and Research Farm of Faculty of Agriculture and Natural Resources Management, Ebonyi State University, Abakaliki. The area is located by Latitude 06^o4^1N and Longitude 08^o65^1E in the derived savannah of southeast agro-ecological zone. The area experiences bimodal pattern of rainfall which is spread from April-July and September-November with a short dry spell in August often called "August break". The annual rainfall ranges from 1700-2000 mm with mean annual rainfall of 1800 mm. The minimum and maximum temperatures are 27^oC and 31^oC. The relative humidity at dry season is 60% but increases to 80% during rainy season (ODNRI, 1989). The soil is derived from coastal sedimentary deposits from cretaceous and tertiary periods. The soil is unconsolidated up to 1m depth of the soil surface. According to Federal Department of Agricultural Land Resources (FDALR, 1985), Abakaliki agricultural zone lies within the "Asu River" and is associated with olive brown sandy shales, fine grained sand stone and mud stones and belongs to the order ultisol classified as *typic haplustult* (FDALR, 1985).

Field Design/Layout

A land area of approximately 0.016ha was used for the experiment. Randomized Complete Block Design (RCBD) was used in laying out the field. Each plot measured 2 m x 2 m with a space of 0.5 m within the plots. The blocks were separated with 1m alley.

Treatment Application

The treatments were Burnt Rice Husk Dust (BRHD), Unburnt Rice Husk Dust (URHD) and Saw Dust (SD) each applied at rate of 20 t ha^{-1} equivalent to 8 kg/plot, respectively and control making it five in all. These agro-wastes were collected at Abakaliki Agro-rice Mill and Timber Mill Industries. The wastes were spread on the beds and later incorporated into the soil with hoe during soil tillage. The treatments were replicated five times to give a total of twenty experimental plots in all. The incorporation was done consecutively for 2006 and 2007 cropping seasons before residual study in 2008 season.

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Planting

Oba super II hybrid of maize (*Zea mays L.*) was used as a test crop. The maize seed was sourced from Ebonyi State Agricultural Development Programme (EBADEP), Onuebonyi Izzi, Abakaliki. The maize was planted a seed rate of two seeds per hole at 2 cm depth and at planting distance of 25 cmx75 cm. Two weeks after germination (WAG), the seedlings were thinned down to one per hole. Weak ones and those which failed to germinate were replaced. This gave approximately 53, 000 plant population per hectare. Weeding was done biweekly and manually using hand hoe till harvest of the crop.

Soil Sampling

Auger soil samples were collected at 0-20 cm depth from the field before incorporation of organic wastes for pre-planting analysis. The samples were composited before routine laboratory study. Core and Auger samples were further collected during residual study for post-harvest soil analysis.

Agronomic Data

Maize cobs were harvested after the husk had dried. The cobs were harvested, dehusked, shelled and seeds further dried to constant weight. This was used to determine grain yield of maize at 14% moisture content.

Laboratory Determination

Core and auger samples were used to determine some soil physical properties. Bulk density was determined using the method described by Blake and Hartge (1986). Total porosity determination was done according to the method described by Obi (2000). Saturated hydraulic conductivity was determined by the method described by Klute (1986). Particle size distribution determination was done using Gee and Or (2002) method. Mean weight diameter was evaluated using Van Bavel (1950) procedure as follows:

$$MWD = \sum_{i=i}^{n} x_i W_i \ldots\ldots 1$$

where

MWD = Mean weight diameter

X_i = Mean diameter of each size fraction (mm)

W_i = Proportion of the total sample weight(mm)

Aggregate stability of both water stable aggregates and micro-aggregates determination were carried out using the method of Kemper and Roseanu (1986). This was done as follows:

$$AS\% = \frac{Ma+S-Ms}{Mt-Ms} \times \frac{100}{1}$$

where

As% = Percentage stable aggregate at <0.25 and 4.76mm

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Ma+S = Mass of the resistant aggregates + stone (g)

Ms = Mass of stone faction alone (g)

Mt = total mass of the sieved soil (g)

Auger samples were air-dried, crushed and sieved with 2 mm sieve. Soil pH was determined in 1:2.5 soil/water solution ratio. The pH values were read off with zeromatic pH meter (Peech, 1965). Total nitrogen determination was done using semi-micro-kjeldahl procedure as described by Bremner and Mulancy 1996). Organic carbon was determined as described by Nelson and Sommers (1982). Exchangeable cations of Ca, Mg, K and Na were extracted with 1N ammonium acetate (NH_4OAC) solution and their amounts in filtrate determined using Perkin Elmer atomic absorption spectrophotometer (Tel and Rao, 1982). Available phosphorus was extracted with Bray-2 as described in Page *et al*.(1982). Exchangeable acidity was determined by titration method of Juo (1979). Cation exchange capacity (CEC) determination was in 1N ammonium acetate (NH_4OAC) solution.

Data Analysis

The data obtained from this study were analyzed using analysis of variance (ANOVA) for Randomized Complete Block Design. Means were separated by Fisher's Least Significant Difference (F-LSD) according to Steel and Torrie (1980). Significance was reported at 5% probability level.

Results and Discussions

Initial properties of soil before study are presented in Table 1. Particle size distribution indicates that sand fraction dominated other fractions. The textural class was sandy loam. The soil pH was strongly acidic (USDA-SCS, 1974) with a value of 5.5. Organic carbon value was 2.2% and rated as moderately high (Landon, 1991). The total nitrogen was very low according to the rating of Federal Ministry of Agriculture and Rural Development (FMARD, 2002) for tropical soils. Exchangeable Ca and Mg had 4.5 and 3.0 cmolkg^{-1} values and dominated potassium and sodium in the exchange complex. Available phosphorus with the value of 40.00 mgkg^{-1} was rated as high (FMARD, 2002). Cation exchange capacity was very low (Asadu and Nweke, 1999). Exchangeable acidity was 0.68 cmolkg^{-1}. This shows that the soil was moderately fertile and simulates most of the conditions of soils in Abakaliki agroecological zone.

Table 1. Soil Properties before Initiation of Study

Soil Properties	Values
Sand (gkg^{-1})	570
Silt (gkg^{-1})	250
Clay (gkg^{-1})	180
Textural class	sandy loam
pH in kcl	5.5

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Organic carbon (%)	2.2
Total nitrogen (%)	0.24
Calcium ($cmolkg^{-1}$)	4.5
Magnesium ($cmolkg^{-1}$)	3.0
Potassium ($cmolkg^{-1}$)	0.32
Sodium ($cmolkg^{-1}$)	0.15
Available phosphorus ($mgkg^{-1}$)	40.00
Cation exchange capacity ($cmolkg^{-1}$)	15.5
Exchangeable acidity ($cmolkg^{-1}$)	0.68

Residual effect on physical properties of soil

Table 2 shows residual effect on physical properties of soil. The result showed that particle size distribution generally varied among the treatments with sand fraction dominating over other fractions. However, the texture remained sandy loam during the residual study. The result further showed that the treatments had significantly ($P<0.05$) higher residual effect on saturated hydraulic conductivity compared to control. The plot amended with sawdust had higher saturated hydraulic conductivity when compared with those amended with burnt rice husk dust and unburnt rice husk dust, respectively. There were no significant ($P<0.05$) differences between control and organic wastes amendment on bulk density, total porosity, mean weight diameter (MWD) and aggregate stability. Plots receiving organic wastes amendment had lower bulk densities when compared to control. The plot amended with sawdust had slightly lower bulk density relative to those amended with burnt rice husk dust and unburnt rice husk dust. Similarly, plots amended with organic wastes respectively had higher total porosities relative to control. The mean weight diameter and aggregate stability values of organic wastes amended plots were lower when compared to control ones. However, plots amended with burnt rice husk dust had higher MWD and aggregate stability values relative to those amended with sawdust and unburnt rice husk dust.

The low variations in particle size distribution of soil before and during residual studies could be attributed to low residual effect on particle size distribution. In addition, the texture which remained same was due to little or no modification on it by cultural practices. These findings supports Obi (2000) report that texture and by extension particle size distribution were not immutable and changed little with time due to cultivation. The low bulk densities and increase in total porosities in organic wastes amended soil could be attributed to humus formation from the decomposed materials and high organic carbon content in the soil (Table 3). Mbagwu and Piccolo (1990) reported that organic wastes incorporation and their remnants reduced bulk density and increased total porosity of soil. Pain and Phipps (2000) also corroborated that remains of organic wastes amendment increased total porosity. Significantly higher saturated hydraulic conductivity in organic wastes amended plots is attributable to increased total porosities in those plots and reduced bulk densities. Transmission of water or flux is through channels, pores and openings in the soil. However, organic wastes amendment had poor residual effect on MWD and aggregate stability. The poor effect obtained on these soil properties could be attributed to fragile nature and low friability of tropical soils. This observation is in line with the report of Pain and Phipps (2000) that residual effect of organic wastes incorporation reduced aggregate stability due to low organic matter content of soil. Soil organic matter content of tropical soils is low because of high temperatures which cause high and rapid mineralization of it (Asadu, 1990). This presents a serious challenge to farmers not only in Nigeria but in the whole of West Africa

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sub-region.

Table 2: Residual effect of organic wastes amendment on soil physical properties

Treatments	BD(gcm^{-3})	TP(%)	HC(cmh^{-1})	MWD(%)	AS(%)	Sand ← gkg^{-1}	Silt →	Clay	Texture
Control	1.49	78	163	2.9	67.1	570	250	180	SL
BRHD	1.42	87	170	2.7	55.4	570	250	170	SL
URHD	1.40	90	171	2.5	52.2	570	250	180	SL
SD	1.39	91	174	2.4	52.1	560	260	180	SL
FLSD (P<0.05)	NS	NS	2.3	NS	NS				

BD-Bulk density, TP-total Porosity, HC-Hydraulic conductivity, MWD-Mean weight diameter, AS-Aggregate stability, SL-Sandy loam, BRHD-Burnt rice husk dust, URHD-Unburnt rice husk dust, SD-sawdust.

Residual Effect on Chemical Properties of Soil

Residual effect of organic wastes amendment on soil chemical properties is shown in Table 3. The result shows significantly (P<0.05) higher residual effect on available phosphorus relative to control. Available phosphorus of sawdust amended plot was 21% higher than burnt rice husk dust amended one. Similarly, cation exchange capacity of organic wastes amended plots was significantly (P<0.05) higher than control. Furthermore, the cation exchange capacity of sawdust amended plot was significantly (P<0.05) higher than those amended with burnt rice husk dust and unburnt rice husk, respectively. There were no significant (P<0.05) differences in pH, organic carbon, total nitrogen, exchangeable Ca, Mg, K, Na respectively and exchangeable acidity between control and organic wastes amended plots. However, organic wastes amended plots had higher pH, organic carbon, total nitrogen, exchangeable Ca, Mg, K, Na and lower exchangeable acidity than control.

Soil pH of plots amended with unburnt rice husk dust and saw dust was 103% higher than the one amended with burnt rice husk dust. Similarly, organic carbon increased slightly in unburnt rice husk dust and sawdust when compared with the control. Furthermore, total nitrogen of unburnt rice husk dust slightly increased relative to burnt rice husk dust and sawdust amended ones. Exchangeable Ca, Mg, K and Na of organic wastes amended plots were slightly higher than those of control plots. Similarly Ca, K and Na of unburnt rice husk dust and sawdust were respectively higher than those of burnt rice husk dust amended plots. In addition, exchangeable Mg of sawdust amended plot slightly increased over those of unburnt rice husk dust amended ones. Exchangeable Ca and Mg dominated the exchange complex of soil. Exchangeable acidity of organic wastes amended plots was respectively higher than control. Highest exchangeable acidity was recorded in burnt rice husk dust amended plot. Significantly (P<0.05) higher CEC was obtained under residual effect study of organic wastes amendment relative to control. The plot amended with SD had higher CEC compared to those amended with BRHD and URHD, respectively.

The improvements obtained in pH under residual effect of organic wastes amended plots could be due to improved exchangeable Ca and Mg in those plots (Table 3). The finding is

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also supported by observation of Parr and Perpendriock (2005) that residual effect of organic wastes increased soil pH. Similarly, higher percentage of organic carbon and total nitrogen compared to control could be attributed to positive impacts of residual effect on the soil parameters. According to Mcinrosh and Vamey (2007), releases from amended organic wastes move pH from acidic to more basic direction and in that way improve organic carbon content of soil. Furthermore, Sharpley *et al.* (1993) linked increase in total nitrogen under residual effect study to organic matter colloid of incorporated organic wastes which decomposed to mineralize it. The significant residual effect on available phosphorus could be due to positive residual effects on soil pH, organic carbon and total nitrogen (Table 3). Improved soil condition reduced tendency for fixation of available phosphorus hence its significant increase in the soil. Available phosphorus is a component part of crop wastes and they are decomposed to release the nutrient in soil (Sharpley *et al.*, 1993).

High exchangeable cations in amended plots are attributable to residual positive effects of organic wastes. This could be further attributed to higher exchange complex of soil of the cations due to impacts of residual effect relative to control. This finding is supported by the report of Turk and Weildman (2004) that exchangeable bases increased due to residual effect of organic wastes amendment in soil. Perucci (1992) pointed out that exchangeable Mg increased during study of residual effect of organic wastes amendment. The positive residual effect of organic wastes amendment on exchangeable cations could be linked to improved and high available phosphorus, organic carbon, total nitrogen and pH in soil (Table 3). The already improved soil condition reduced exchangeable H^+ and Al^{3+}. This was corroborated by Clark *et al.* (1998) that organic wastes amendment neutralized H^+ and Al^{3+} thereby reducing exchangeable acidity of soil. The significantly higher residual effect on CEC could be attributed to liberation of exchangeable cations contained in the organic wastes incorporated in to the soil and held in organic colloid. This finding is in line with the observation of Lyrich and Bragg (2003) that CEC was significantly higher under residual effect study of organic wastes amendment.

Table 3. Residual Effect of Organic Wastes Amendment on Chemical Properties of Soil

					← cmolkg^{-1} →					
Treatments	**pH(kcl)**	**OC(%)**	**N(%)**	**P(%)**	**Ca**	**Mg**	**K**	**Na**	**EA**	**CEC**
Control	4.1	1.90	0.15	14.3	2.9	2.1	0.21	0.10	0.88	10.23
BRHD	4.6	2.05	0.19	15.7	3.1	2.3	0.28	0.11	0.50	11.26
URHD	5.3	2.12	0.20	21.3	3.4	2.4	0.29	0.12	0.48	11.99
SD	5.3	2.12	0.19	21.6	3.4	2.6	0.29	0.12	0.48	12.36
FLSD (P<0.05)	NS	NS	NS	0.7	NS	NS	NS	NS	NS	0.25

BRHD-Burnt rice husk dust, URHD-Unburnt rice husk dust, SD-Sawdust, EA-Exchangeable acidity, CEC-Cation exchange capacity, OC-Organic carbon

Grain Yield of Maize

Table 4 shows residual effect of organic wastes amendment on grain yield of maize. Residual effect of organic wastes amendment showed higher grain yield of maize compared to control. Grain yield of maize was higher under sawdust amendment when compared to those obtained in unburnt rice husk dust and burnt rice husk dust, respectively. However, there was no

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significant (P<0.05) differences in grain yield of maize between organic wastes amendment and control as well as among the amended plots.

The higher grain yield of maize obtained under residual effect of organic wastes amendment could be attributed to improved physicochemical properties of the soil (Table 2-3). According to Curtis and Post (2004), residual effects of organic wastes amendment gave higher crop yield relative to control. The highest grain yield of maize in sawdust dust amendment could be due to slow and steady release of minerals in sawdust during decomposition compared to other wastes. Furthermore, higher grain yield under SD amended plot is also attributable to its superior performance in terms of physicochemical properties when compared to other organic wastes amended plots and control (Table 3).

Table 4. Residual Effect of Organic wastes Amendment on Grain of Maize

Treatment	Grain Yield of Maize (tha^{-1})
Control	1.9
Burnt rice husk dust	2.0
Unburnt rice husk dust	2.1
Sawdust	2.2
FLSD (P<0.05)	NS

CONCLUSION

The results of this study have shown that residual effects of organic wastes amendment had positive impacts on soil productivity. Residual effects significantly increased saturated hydraulic conductivity, available phosphorus and cation exchange capacity of soil. Generally, residual effect improved all studied physicochemical properties of soil. Furthermore, exchangeable acidity was depressed. Grain yield of maize was higher under residual effect of organic wastes amendment. Essentially, the residual effect of organic wastes amendment on soil productivity could be ranked as SD>URHD>BRHD>C. consequently, farmers are encouraged to adopt the use of organic wastes amendment for their lasting positive impacts in soil productivity and with good management could ensure sustainable soil use.

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