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Soil Science

Productivity of Soil Amended with Rice Mill Wastes and Sawdust in Abakaliki, Nigeria

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Abstract

Rice mill wastes and sawdust were used to amendsoil in Abakaliki Southeast, Nigeria to study its immediate and residualproductivity for three cropping seasons. Randomized Complete Block Design was used in laying out the field with four treatments replicated five times. Results showed that soil texture remained sandy loam after cropping for three seasons. Grain yield of maize was significantly ($P<0.05$) higher in Burnt Rice Mill Waste (BRMW), Unburnt Rice Mill Waste (URMW) and Sawdust (SD) amended plots relative to control for the three seasons. The grain yield of maize in BRMW amended plot was 8, 11 and 11% higher when compared to control for the studied seasons. Total porosity, macro-porosity, micro-porosity and cation exchange capacity (CEC) had $r = 0.90$, $r = 0.86$, $r = 0.74$ and $r=0.80$ with grain yield of maize. There were $r^2 =0.82$ and $r^2 = 0.73$ for total porosity and macro-porosity with grain yield of maize. Organic carbon ($r=0.57$), available phosphorus ($r=0.63$), exchangeable magnesium ($r= 0.59$), base saturation ($r= 0.51$) and aluminum saturation ($r = 0.58$) and micro-porosity ($r^2 = 0.55$), CEC ($r^2 = 0.64$) were significantly related to grain yield of maize. Burnt rice mill waste was more superior to improving soil productivity compared to others.

Highlights

- Compared to control, grain yield of maize was 8, 11 and 11% higher in BRMW in 2010, 2011 and 2012 cropping seasons.
- Total porosity and macro-porosity had respectively $r = 0.90$ and $r^2 = 0.82$, $r = 0.86$ and $r^2 = 0.73$ with grain yield of maize.
- Studied soil physicochemical properties had positive relationship with grain yield of maize.

Keywords: Abakaliki, productivity, rice mill wastes, sawdust, soil properties

The dominant farming system in the Abakaliki agricultural zone of south eastern Nigeria is primarily the slash and burn method. Coupled with the intensive use of the land due to population pressure and absence of any definite management system, the productivity of the soil has been adversely affected (Nnabude and Nbagwu, 2001). The rapid depletion of plant nutrients, low organic matter (< 2.0 according to Enwezor *et al.* 1990) exacerbated by poor physical condition of the soil are major limitations to crop production (Debnath *et al.* 2012) in an area regarded as the food belt of the eastern region (Nnabude and Mbagwu, 2001). Physico-chemical condition of a soil is fundamental to its productivity (Barzeger, 2002; Obi, 2000). Soil properties have high degree of relationship with its productivity and crop yield (Wallace and Wallace 2011; Nnaji, 2009). Unless physic-chemical nature of soil is improved, high plant nutrients use efficiency would be a mirage and the solution could result to poor crop yield (Ezeaku, 2006; Parr *et al.* 2012).

Several studies carried out indicate positive effects of organic wastes on soil productivity (Nwite, 2013; Heluf, 2002; Bell *et al.* 2009). The effect of loading rates of sawdust on plant growth, plant nutrient uptake and chemical properties was reported by Mbagwu and Piccolo (1990). The role of rice mill wastes in reducing bulk density and increasing total porosity has been well reported in literature (Anikwe, 2006; Mbah and Nwite, 2008; Nwite, 2013). Dutarte *et al*. (1993) observed from soils of low activity clay (LAC) which are similar in properly to the one under study that the amount and composition of organic matter influenced the structure of sandy soils in west Africa. Despite the positive effects of these wastes on soil physicochemical properties and productivity, variations still exist in the extent of their effects. Besides, variations arising from the nature of the wastes, it has been recognized (Nnnabude and Mbagwu, 2001) that ability of these wastes in improving productivity is soil-climate and crop- specific and in many cases limited by inadequate availability of such wastes for practical purposes. This scenario is not the same case in the study area since there is abundance of rice mill wastes and sawdust but lacks vital soil information needed for practical utilization (Nnabude and Mbagwu, 2001). The objective of the study was therefore to evaluate the productivity of a degraded soil amended with rice mill wastes and sawdust in Abakaliki, southeastern, Nigerian.

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 site is located by latitude 06°4/N and longitude 08°65/E in the derived savannah zone of the southeast agro ecological area of Nigeria. The rainfall pattern is bimodal ranging from April-July and September-November. There is short spell in August normally referred to as "August break". The total annual rainfall in the area ranges from 1500-2000mm with a mean of 1800mm. At the onset of rainfall, it is torrential and violent, sometimes lasting for one to two hours. It is often characterized by thunderstorm and lightening. The temperatures are 27°C and 31°C for rainy and dry seasons. Humidity is 80% during rainy season but declines to 60% between December and April. Geologically, the area is underlain by sedimentary rocks derived from successive marine deposits of the cretaceous and tertiary periods. Abakaliki agricultural zone lies within "Asu River" group and consists of Olive brown sandy shales (FDALR, 1985), fine grained sandstones and mudstones. The soil is shallow with unconsolidated parent materials (shale residuum) within 1m of the soil surface. It belongs to the order ultisol and is classified as typic haplustult (FDALR, 1985).

The vegetation of the place is primarily derived savannah with bush re-growth and scanty economic trees. The site has history of previous cultivation of yam (*Dioscorea spp*) and cassava (*Manihot spp*). There is growth of native vegetation such as *Tradix spp, Odoratum spp, Aspiliaafricana, Imperata cylindrica, Panicum* maximum, *Pennisetum purpenum, Sporobulus pyramidalis* and other herbs and shrubs. The debris left after clearing was removed before seedbed preparation.

Field methods

An area of land approximately 0.021ha was used for the experiment. The plots were laid out in Randomized Complete Block Design. The plots measured 2 m × 2 m with 0.5 spaces while the replicates were set apart by 1m alley. The treatments were burnt rice mill waste (BRMW), unburnt rice mill waste (URMW)and saw dust (SD) each applied at 20t ha^{-1} equivalent to 8kg/plot and control. These wastes were collected at agro-rice mill and saw mill industries, respectively, weighed and spread on the beds and replicated five times to give a total of twenty experimental units. They were later incorporated into the soil during seedbed preparation. The beds were allowed to age for two weeks after incorporation of treatments before planting the test crop.

Maize seed (Suwan-I-SR-hybrid variety) sourced from Ebonyi State Agricultural Development Programme (EBADEP) was planted two seeds per hole at 5cm depth and at a spacing distance of 25 × 75cm. Two weeks after seedling emergence (WASE), the plants were thinned down to one plant per hole while lost stands were replaced. Weak plants were rouged out and replaced leaving a plant population of approximately 53,000 stands per hectare. Weeds were removed at three-weekly intervals up till harvest. In the second year, the procedure was repeated while residual effect was studied in the third year without fresh application of amendments.

Agronomic data

The cobs were harvested at plant maturity. This was when the husks were dried. The cobs were dehuskedand further dried before shelling. Grain yield was determined at 14% moisture content. Percentage relative yields treatment factor was calculated from amended and control plots by using the formula:

$$TF = \frac{\left[y_a^{-1}\right]}{y_b} \times \frac{100}{1} \qquad (1)$$

Where,

TF = is the treatment factor

Ya = maize grain yield in amended plots

Y_b = maize grain yield in control plots

Agronomic yield data were taken from twelve tagged plots representing 25% of plant population per plot.

Soil sampling

Initial soil samples were collected from 0-20cm depth using auger at different points in the study site before cultivation and application of treatments. The auger samples were composited and used for routine laboratory analysis. Core and auger samples were further collected at 0-20cm depth from each plot at three points i.e. 3 cores and 3 augers after planting for post harvest soil analysis. Core samples were used to determine some physical properties of soil while auger samples were air-dried at room temperature (about 26^{o}C) and passed through a 2mm sieve. These samples were used to determine chemical properties.

Laboratory determinations

Dry soil bulk density was determined as described by Blake and Hartge (1986). Total porosity and pore size distribution were evaluated by Obi (2000) procedure. Particle size distribution was determined by the hydrometer method as described by Gee and Or (2002). Aggregate stability and mean weight diameter were estimated by the wet sieving technique described by Kemper and Rosaneau (1986) and method of Van Bavel as modified by Kemper and Rosaneau (1986). Water retention determination was by the hanging water column technique as described by Obi (2000). Saturated hydraulic conductivity (K_s) was determined by the constant-head soil core method of Obi (2000).

Soil pH was determined in soil/water solution ratio of 1:2.5 and pH value read with pH meter. Total nitrogen determination was done using micro-kjeldhal distillation method of Bremner (1996).

Organic carbon was determined using the method described by Nelson and Sommer (1982). Available phosphorus determination was done using Bray-2 method as described in Page *et al.* (1982). Exchangeable bases of calcium (Ca) and magnesium (Mg) were determined by titration method (Mba, 2004). Sodium (Na) and potassium (K) were extracted with 1N ammonium acetate solution (NH_4OAC) and determined using flame photometer.

Total exchangeable acidity was extracted using titrimetric method with INKCl extract (Mclean, 1982). Cation exchange ablecapacity was determined by ammonium acetate (NH_4OAC) displacement method (Jackson, 1958). Base saturation was calculated as follows:

$$\%BS = \frac{TEB}{CEC} \times \frac{100}{1} \quad (2)$$

where,

%BS - Percent base saturation

TEB - Total exchangeable bases

CEC - Cation exchangeable capacity

Percentage aluminum saturation was obtained by calculation expressed as:

AL^{3+} saturation (%) =

$$\frac{[(\text{Exchangeable } Al^{3+})] \times 100}{TEB} \quad (3)$$

where,

Al^{3+} saturation % = Percentage aluminum saturation

TEB = Total Exchangeable Bases

The organic wastes were analyzed for their nutrients and C: N ratio using Juo (1983) method.

Data analysis

Data collected from this study were subjected to statistical Analysis System (SAS, 1985) method. Correlation and regression analysis were used to determine relationship between some soil properties and grain yield of maize according to Steel and Torrie (1980). Significant treatment effect was reported at 5% probability level.

Results and Discussion

Properties of the soil at initiation of study

Table 1 shows some properties of soil at the initiation of study. The particle size distribution varied but the textural classis sandy loam. The pH in KCL was 5.1 indicating strongly acidic soil condition as rated by Federal Ministry Agriculture and Rural Development (FMARD,2002). The percentage organic carbon and total nitrogen were respectively low (FMARD, 2002 and Asadu and Nweke, 1999).

Available phosphorus was low (Landon, 1991). The soil exchange complex was dominated by calcium and magnesium. The soil cation exchange capacity was low (Asadu and Nweke, 1999). Percent base saturation was very low (Landon, 1991). This shows that the soil used for the experiment is degraded in terms of fertility trend. The soil condition simulates most of the soils under Abakaliki agro-ecology utilized for crop production.

Table 1. Some properties of the soil at initiation of study

Soil properties	Unit	Value
Sand	gkg^{-1}	660
Silt	gkg^{-1}	210
Clay	gkg^{-1}	130
Textural class		Sandy loam
pH in KCL		5.1
Organic carbon	%	1.84
Nitrogen	%	0.16
Available phosphorus	$mgkg^{-1}$	4.70
Calcium	$cmolkg^{-1}$	5.20
Magnesium	$cmolkg^{-1}$	3.80
Potassium	$cmolkg^{-1}$	0.18
Sodium	$cmolkg^{-1}$	0.17
Cation exchange capacity	$cmolkg^{-1}$	10.3
Base saturation	%	6.8

Nutrient composition of rice mill wastes and sawdust

The nutrient composition of rice mill wastes and sawdust used for soil amendment is shown in Table 2. The nutrient contents of the organic wastes were generally low. Exchangeable cations were respectively low in burnt rice mill waste (BRMW), unburnt rice mill waste (URMW) and sawdust (SD) compared to soil (Table 1). The values of exchangeable cations were low in the organic wastes according to Howeler (1996) and Landon (1991) ratings. The percentage organic carbon and total nitrogen ranged from 5.82 to 15.30 and 0.26 to 0.45 in the amendment BRMW, URMW and SD and were rated high (FMAWRD, 2002).Debnath *et al.* (2009) noted that organic carbon was higher in organic wastes. Available phosphorus ranged from 3.00 to 14.00mkg^{-1} in the organic waste and rated low according to Enwezor *et al.* (1990) ad Landon (1991), respectively. The C: N ratios were moderate to high values (Biswas and Merkherjee, 2008)

Table 2. Nutrient composition of rice mill wastes and sawdust

Treatment	Parameter	Unit	Value
Burnt rice husk dust	Na	$cmolkg^{-1}$	0.04
	K	$cmolkg^{-1}$	0.05
	Ca	$cmolkg^{-1}$	1.15
	Mg	$cmolkg^{-1}$	0.25
	Organic carbon	%	5.82
	Nitrogen	%	0.30
	Available phosphorus	$mgkg^{-1}$	14.00
	C:N		22
Unburnt rice husk dust	Na	$cmolkg^{-1}$	0.06
	K	$cmolkg^{-1}$	0.20
	Ca	$cmolkg^{-1}$	0.48
	Mg	$cmolkg^{-1}$	0.10
	Organic carbon	%	15.30
	Nitrogen	%	0.45
	Available phosphorus	$mgkg^{-1}$	6.00
	C:N		32
Sawdust	Na	$cmolkg^{-1}$	0.05
	K	$cmolkg^{-1}$	0.12
	Ca	$cmolkg^{-1}$	0.28
	Mg	$cmolkg^{-1}$	0.09
	Organic carbon	%	7.89
	Nitrogen	%	0.26
	Available phosphorus	$mgkg^{-1}$	3.00
	C:N		30

Changes in particle size distribution following application of rice mill wastes and sawdust

Table 3 shows changes in particle size distribution (PSD) following application of rice mill wastes and sawdust. The results indicate that particle size distribution did not vary appreciably in the soils. Nevertheless, sand was the dominant fraction. The silt fraction seemed to have increased after cultivation and generally across the cropping seasons. The textural class consistently remained sandy loam both after cultivation and for the three study seasons. The high content of sand in the soils seems to be related to the parent material and climate of the region (FDALR, 1985). Sand content of the soils in southeastern region of Nigeria is a characteristic of sand formed on unconsolidated coastal plain and sandstones from "Asu River" (FDALR, 1987). The consistency in texture both at pre-planting and post-planting as well as across the seasons could be attributed to the report of Obi (2000) that texture was a "permanent property" of soil which was not affected by cultivation or other cultural practices. Texture has good relationship with nutrient storage, water retention, porosity (Obi,2000) and specific surface area, soil compatibility and compressibility (Smith *et al.* 1998)which affect inherent productivity of the soil. Debnath *et al.* (2012) reported that texture enhanced moisture availability, adequate soil aeration, root penetration and nutrient supply to plants, all of which increased the productivity of soil. Incidentally, rice mill wastes and sawdust amendment sustained medium texture of soil (Obi, 2000). Sandy loam has great agricultural value for maize production in southeast Nigeria due to its inherent fertility. Increase in clay content (Table 3) in second cropping season is in tandem with the reports of Chen *et al.* (2003); Tiwari and Bajpai (2004) and Talboub *et al.* (2008) due to position. The reverse in amount of clay content in third cropping season could be due to sampling error or continuous cultivation.

Relationships between selected soil properties and grain yield of maize

Table 6 shows relationships between selected soil properties and grain yield of maize as influenced by rice mill wastes and sawdust amendment. The results indicate that the relationships between total porosity, macro-porosity, micro-porosity and cation exchange capacity (CEC) with grain yield of maize were highly ($P<0.01$) significant. The correlation coefficients were r = 0.90, r= 0.86, r = 0.74, and r = 0.80 for total porosity, macro-porosity, micro-porosity, CEC and grain yield of maize, respectively. Similarly, coefficients of determination were r^2 = 0.82 for total porosity and r^2= 0.73 for macro-porosity and grain yield of maize, respectively. Furthermore, percentage organic carbon, available phosphorus, magnesium, base saturation and aluminum saturation with grain yield of maize were significant ($P<0.05$), respectively. Generally, all the selected soil physicochemical properties had positive relationships with grain yield of maize. This implies that the soil physicochemical properties determined grain yield of maize. On the other hand, their degree of relationships with grain yield of maize could be attributed to the influence of rice mill wastes and sawdust used to amend the soil.

The highly significant relationships obtained between total porosity, macro-porosity, micro-porosity, organic carbon and cation exchange capacity with grain yield of maize indicate that these soil properties are productivity indicators. These properties could positively influence nutrient and water availability as well as aeration status of soil .Good aeration in particular leads to easy and hasten mineralization with greater nutrient and water use efficiencies (Kumar and Singh, 2014). Consequently, Brechin and McDonald (1994) noted that judicious management and conservation of soil increased crop yield. This was corroborated by Obi (2000) that total porosity, pore size distribution and generally good soil physical conditions improved soil productivity. According to Asadu and Nweke (1999), organic carbon, available phosphorus and magnesium were major constituents of plant materials. This observation tends to support the significant relationships of these soil properties with maize yield. Positive effect of organic carbon on soil productivity had been reported by Ramesh *et al.* (2008). The significant relationships of percentage base saturation and generally positive relationships between selected soil properties and grain yield of maize implies that they determine soil productivity. Their degrees of relationships are dependent upon the influence of these organic wastes applied on the soil. Conversely, significant relationship obtained between Al^{3+} saturation and grain yield of maize shows that the soil property could influence nutrient availability, soil productivity as well as pH of soil. According to Asadu and Nweke (1999), the pH of a medium is determined by the extent to which the exchange complex is occupied by Mg and other metallic cations.

Table 6. Relationship between soil properties and grain yield of maize

Parameter	N = 64 Regression model	R	r^2
BD vs Grain yield	Y=5.64 × -2.16	0.95**	0.89**
TP vs grain yield	Y=0.07 × -0.85	0.90**	0.82**
AS vs grain yield	Y=1.81 × +0.01	0.34	0.11
MWD vs grain yield	Y=2.66 × -0.21	0.29	0.08
Macrop vs grain yield	Y=0.16 × -0.12	0.80**	0.73**
Microp vs grain yield	Y=0.05 × +0.08	0.74**	0.55**
WR vs grain yield	Y=2.32 × 0.04	0.32	0.10
K_s vs grain yield	Y= 1.66 × -0.06	0.22	0.09
%OC vs grain yield	Y=1.77 × +0.18	0.57*	0.32

Tables 3. Changes in particle size distribution following application of rice mill wastes and sawdust

Treatment	2010 ← Sand	gkg^{-1} Silt →	Texture Clay	2011 ← Sand	gkg^{-1} Silt →	texture Clay	2012 ← Sand	gkg^{-1} Silt →	Clay Texture
Control	660	250	100SL	570	300	130SL	650	210	140SL
BRHD	630	250	120SL	580	290	230SL	620	280	100SL
URHD	640	220	140SL	560	260	180SL	600	270	130SL
SD	650	250	100SL	590	270	140SL	630	250	120SL

BRMW-Burnt rice mill waste, URMW-Unburnt rice mill waste, SD-Sawdust, SL-sandy loam

%N vs grain yield	Y=2.09 × +0.05	0.13	0.02
P vs grain yield	Y=1.78 × +0.01	0.63*	0.39
Ca vs grain yield	Y=1.84 × +0.06	0.33	0.11
K vs grain yield	Y=2.01 × +0.09	0.31	0.09
Mg vs grain yield	Y= 1.55 × +0.25	0.59*	0.35
Na vs grain yield	Y=2.40 × -1.10	0.25	0.06
Bs vs grain yield	Y=1.05 × +0.01	0.51*	0.26
CEC vs grain yield	Y=0.41 × +0.17	0.80**	0.64*
EA vs grain yield	Y=1.39 × -0.68	0.36	0.13
Al^{3+} sat vs grain yield	Y=2.38 × -0.63	0.32	0.10

BD- Bulk density, TP-Total porosity, AS-Aggregate stability, MWD-Mean weight diameter, Macrop-mactoporosity, Microp-microporosity, WR-Water retention, K_s- Saturated hydraulic conductivity, %OC-Percent organic carbon, %N-Percent Total Nitrogen, P-Phosphorus, Ca-calcium, K-Potassium, Mg-magnesium, Na- Sodium, BS-Base Saturation, CEC-Cation exchange capacity, EA-Exchangeable acidity, Al^{3+} sat- Aluminium saturation, r- Correlation coefficient, r^3- Coeiffient of determination, **-Highly significant, *-Significant.

Grain yield of maize

Grain yield of maize following application of rice mill wastes and sawdust is presented in Table 4. The grain yield of maize was significantly (P<0.05) higher in different organic wastes amendment compared to control for 2010 and 2011 amended seasons and during residual study in 2012 cropping season. The grain yield of maize ranged in the treatment from 2.10-2.28 tha^{-1} and 2.00-2.25tha^{-1} for 2010 and 2011 cropping seasons and 2.00-2.24t ha^1 for 2012 season. Even though, grain yield of maize did not significantly vary in the plots receiving organic wastes amendments, the plot amended with burnt rice mill waste had higher grain yield of maize in 2010 and 2011 cropping seasons as well as 2012 season. The trend of increase in grain yield of maize in the treatments is BRHD>URHD>SD>C. The grain yield of maize under burnt rice mill waste amendment was 8, 11 and 11% higher when compared to those of control for the three cropping seasons.

The significant increase in grain yield of maize in rice mill waste and sawdust amended plots relative to control could be attributed to improvements in soil physical and chemical properties (Table 6). Significant increase in crop yields following addition of organic wastes had been reported by Anikwe (2000); Nnabude and Mbagwu (2001); and Adeleye (2011) relative to control. The failure to sustain the increase of grain yield of maize recorded in first season in second and residual cropping seasons could be due to low nutrients reserve (Aulakh *et al.* 2007) as well as continuous cropping. According to Mbah *et al.* (2009), continuous cropping without amendment reduces grain yield of maize. The non significant grain yield of maze in the treatments could be attributed to comparable release of nutrients by the organic wastes. The grain yields of maize in amended plots are comparable to average global maize yield of 2.5t ha^{-1} (Harper, 1999) and medium to high values (NPAFS, 2010) as obtained in Southeastern States of Nigeria.

Table 4. Effect of rice mill wastes and sawdust on grain yield of maize(t ha^{-1})

Treatment	2010	2011	2012
Control	2.10	2.00	2.00
Burnt rice husk dust	2.38	2.25	2.24
Unburnt rice husk dust	2.26	2.25	2.24
Sawdust	2.22	2.21	2.20
FLSD(0.05)	0.07	0.11	0.09

Percentage relative grain yield of maize

Table 5 shows effect of rice mill wastes and sawdust amendment on relative increase of grain yield of maize for three cropping season. The mean grain yields of maize in BRMW, URMW and SD were generally lower when compared to relative increase of grain yields of maize in 2011 and 2012 cropping seasons. The relative increase in grain yields of maize was generally comparable across the cropping seasons.

The generally low relative increase of grain yield of maize could be attributed to comparable yields obtained in the treatments (Table 4). The high percentage of grain yields of maize in BRMW and URMW treated plots in 2011 and 2012 cropping seasons implies that agro-wastes could sustain and increase soil productivity more than sawdust waste. Mbah (2004) noted that wastes that had long residual effect could be used for the reclamation of marginal soil because of their beneficial and long-term effect on sustaining crop yield.

Table 5. Effect of rice mill wastes and sawduston percentage relative yield of maize (%)

Treatment	2010	2011	2012	Mean
Burnt rice husk dust	9	13	12	11
Unburnt rice husk dust	8	13	12	11
Sawdust	6	11	10	9

Conclusion

This study had shown that soil productivity could be improved and sustained through rice mill wastes and sawdust amendment. Amendment of soil with rice mill wastes and sawdust generally indicated great potential to sustain its productivity compared to unamended soil. Grain yields of maize of BRMW, URMW and SD amended soil were higher than control with the plots amended with burnt rice mill waste being higher than those of others amended with unburnt rice mill waste and sawdust, respectively. The relationships between all selected soil properties and grain yields of maize were positive indicating their influence on grain yield of maize and sustenance of soil productivity.

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