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Restoration of Productivity of Degraded Soil With Organic Wastes Amendment in Abakaliki, Southeastern Nigeria

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ABSTRACT

Abakaliki area of Southeastern Nigeria is characterised by slash and burn as well as continuous cultivation practice of farming which is degradative to soil productivity. In order to arrest this condition, this study was carried out on restoration of productivity of degraded soil using organic wastes at Teaching and Research Farm of Faculty of Agriculture and Natural Resources Management, Ebonyi State University, Abakaliki for three seasons. A land area equivalent to 0.02 ha was used for the experiment. Randomized complete block design was used to layout the field. Four treatments of 20 th^{-1} each equivalent to 8 kg/plot of burnt rice mill waste (BRMW), unburnt rice mill waste (URMW), saw dust (SD) and control (C) were respectively replicated five times to give twenty experimental plots in the study. Maize (*Zea mays* L.) variety suwan-I-SR-hybrid was used as test crop. Results showed that plots amended with organic wastes had significantly ($P<0.05$) higher studied soil properties than control for three seasons and as well as in plot amended with BRMW relative to URMW and SD for the period. Available P, nitrogen, organic carbon and pH were 11-12%, 9-6%, 5-3%. 6-2% and 13-13%, 12- 7%, 7-4%, 7- 4% and 1,6, 3, 2% and 5, 8, 5, 6% higher in plot amended with BRMW when compared to those receiving amendment of URMW and SD in 2013, 2014and 2015 cropping seasons. Plots amended with organic wastes had significantly ($P<0.05$) higher grain yields of maize for 2013, 2014 and residual season. Grain yield of maize was higher by 8, 1 and 3% in BRMW in 2013 season relative to yields obtained in 2013, 2014 and 2015 study years. Organic wastes amendment is recommended for restoration of productivity of degraded soil in Abakaliki. It is therefore concluded that burnt rice mill waste should be used in preference to other agro wastes for higher productivity of a degraded soil and for sustainability in the study area.

KEYWORDS: Amendment, Degraded, Organic wastes, Productivity, Restoration, Soil

INTRODUCTION

Soil physicochemical properties such as bulk density, water retention and supply, total porosity, texture, structure and pH as well as nutrient storage including crop yield are important indices for evaluating soil productivity [1]. Physicochemical degradation of soil often results in loss of inherent productivity giving rise to its inability to sustain crop yield [2, 3]. Sometimes as is the case in Abakaliki, southeastern Nigeria, degradation of soil occur due to inappropriate soil use as is obtained in farm practices such as continuous cultivation [4] as well as slash and burn method [5, 6, 3] and high input of inorganic fertilizer [7].

Abakaliki is criss-crossed with numerous rice and saw milling industries which generate high magnitude of wastes on daily basis. These wastes constitute nuisance to the environment and man due to lack of their conversion to valuable use [8, 9]. The value of a waste in terms of its use for amendment depends on the ability to restore lost productivity of soil. Several authors [10, 9, 11] corroborated that rice husk dust has high specific

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surface area, organic carbon content and other valuable inorganic materials that could be used as soil amendment as it could improve and sustain both immediate and long-term productivity of a degraded soil [12]. Cereal straws and sawdust have high organic stability that could be used to restore and/or reclaim marginal soils [13].

Since agricultural production in the study area is largely rural based, it is imperative to adopt low-input system that relies partly on nutrient recycling and the maintenance of soil fertility through biological process [10, 14] for enhanced sustenance of soil productivity. [15] (2012) attributed rapid productivity decline to problems of conventional farming practices such as continuous cropping and lack of fallowing, overgrazing, deforestation and intensive cultivation which are common indices in developing countries. To reverse this trend, [7] (2015) advocated for proper soil management strategies for enhanced productivity restoration. Consequently, there is apparent need for alternative food production systems that is productive and devoid of environmental hazards. This system is the use of rice mill wastes and sawdust waste in soil amendment. The objective of this study was to evaluate restorative ability of rice mill wastes and sawdust on productivity of degraded soil using maize as a test crop.

MATERIALS AND METHOD

2.1 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 06^0 $4^/$ N and longitude 08^0 $65^/$ E in the derived savannah zone of the southeast agroecological area of Nigeria. The rainfall pattern is bimodal (April-July and September –November), with a short dry spell in August normally referred to as "August break". The total annual rainfall in the area ranges from 1500 to 2000 mm, with a mean of 1800 mm. At the onset of rainfall, it is torrential and violent, sometimes lasting for one to two hours [14]. The area is characterized by high temperatures with minimum mean daily temperature of 27^oC and maximum daily temperature of 31^Oc throughout the year. Humidity is high (80%) with lowest (60%) levels occurring during the dry season between December to April, before the rainy season begins. Geologically, the area is underlain by sedimentary rocks derived from successive marine deposits of the cretaceous and tertiary periods. According to the Federal Department of Agricultural and Land Resources [16], Abakaliki Agricultural zone lies within 'Asu river group' and consists of Olive brown sandy shales, fine-grained sandstones and mudstones. The soil is shallow with unconsolidated parent material (shale residuum) within 1m of the soil surface. It belongs to the order ultisol and is classified as Typic Haplustult [16].

2.2 Experimental Design and Treatment Application:

A land area equivalent to 0.02 ha was used for the experiment. Randomized complete block design was used in laying out the field. The beds measured 2 m x 2 m with 0.5 m spaces. The replications were set apart with 1 m alley. The treatments were replicated four times to give a total of twenty (20) plots in the study. The treatments consisted of control (C), burnt rice mill waste (BRMW) at 20 t ha^{-1} equivalent to 8 kg/plot, unburnt rice mill waste (URMW) at 20 t ha^{-1} equivalent to 8 kg/plot and Sawdust (SD) 20 t ha^{-1} equivalent to 8 kg/plot. The treatments namely BRMW, URMW and SD were sourced from the agro-rice mill industry and timber shade market, Abakaliki, respectively. These organic wastes were spread on the plots and incorporated into the soil during seedbed preparation using traditional hoe. The beds were allowed to age for two weeks after incorporation of treatments before planting the test crop. The field was cleared and debris removed.

Maize seed *Zea mays* L. (suwan-I-SR-hybrid variety) sourced from Ebonyi State Agricultural Development Programme (EBADEP) was planted (2 seeds per hole) at 5 cm depth and spacing distance of 25 x 75 cm. Two weeks after emergence (WAE), the plants were thinned down to one plant per hole while lost stands were replaced. Weak plants were rogued 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 tested in the third year of study without fresh application to treatments.

2.3 Agronomic Data:

The cobs were harvested at plant maturity. This was when the husks were dried. The cobs were dehusked and further dried before shelling and grain yield determined at 14% moisture content.

2.4 Soil Sampling:

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

2.5 Laboratory determinations:

Dry bulk density and total porosity were determined as described by Obi (2000). Total porosity was derived from measurement of dry bulk density (P_b) and soil particle density (P_s) assumed to be 2.65 Mgm^{-3}.

$$\text{Thus, } S_t = \left(1 - \frac{P_b}{P_s}\right) \times \frac{100}{1} \ldots \quad (1)$$

where

St = Total porosity

P_b = Bulk density

P_s = Average density of soil assumed to be 2.6gcm^{-3}

Particle Size distribution was determined by the hydrometer method as described by Gee and Or (2002). The result was reported in grammes per kilogramme Aggregate stability and mean weight diameter were determined using distribution of aggregates as estimated by the wet sieving technique described by [17] (1986). In this procedure, 50g of the < 4.76 mm aggregates were placed on the topmost of a nest of sieves of diameters, 2, 1, 0.5 and 0.25 mm. The samples were pre-soaked in distilled water for 10 minutes before oscillating vertically in water 20 times (along 4 cm amplitude). The resistant aggregates on each sieve were dried at 105 ^oC for 24 hours, and weighed. The mass of <0.25 mm fraction was obtained by difference between the initial sample weight and the sum of sample weights collected on the 2, 1, 0.5 and 0.25 mm sieve nests. The percent water-stable aggregates (WSA) on each sieve were determined, thus:

$$WSA = \left(\frac{M_a + S - M_s}{Mt - M_s}\right) \times \frac{100}{1} \ldots \quad (2)$$

where;

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

Ms = The Mass of the sand fraction alone (g)

Mt = The total mass of the sieved soil (g)

All soil samples that fell within 4.76 and 0.25 mm were used to express WSA >0.25 mm as the index of stability. Mean Weight Diameter of aggregates was evaluated using the expression

$$MWD = \sum_{i=1}^{n} x_i W_i \quad (3)$$

where;

MWD = Is the mean weight diameter of water-stable aggregates

X_i= The mean diameter of each size fraction (mm) and,

W_i= The proportion of the total sample weight (%SA) in the corresponding size fraction, after deducting the weight of stone (upon dispersion and passing through the same sieve). Higher values of MWD indicate the dominance of the less erodible, large aggregates of the soil.

The pH of the soil was determined in duplicates both in distilled water and in 0.1N KCL solution, using a soil/water solution ratio of 1:2.5. After stirring for 30 minutes, the pH values were read off using a Beckman zerometric pH meter. Total nitrogen was determined using the micro-Kjeldhal distillation. The ammonia from the digestion was distilled with 45% Na0H into 2.5% boric acid and determined by titrating with 0.05N KCL.

Available phosphorus determination was by the Bray-2 method as described by [18] (1982). The available phosphorus was read off from the standard curve obtained from optical density using a colorimeter. Organic carbon was evaluated using the method described by [19] (1982). The percentage organic matter was calculated by multiplying the value for organic carbon by the "Van Bemmeler factor" of 1.724, which is based on the assumption that soil organic matter (SOM) contained 58% carbon. Exchangeable bases of Calcium (Ca) and Magnesium (Mg) were determined by titration method [20]. Sodium (Na) and Potassium (K) were extracted with 1N ammonium acetate solution (NH_4OAC) and determined using flame photometer. Cation exchange capacity was determined by ammonium acetate (NH_4OAC) displacement method. Base saturation was calculated by dividing total exchangeable bases (TEB) with cation exchange capacity value and multiplying by 100. The expression is thus:

$$\%BS = \frac{TEB}{CEC} \times \frac{100}{1} \ldots \quad (4)$$

2.6 Organic wastes:

The burnt rice mill waste (BRMW), unburnt rice mill waste (URMW) and sawdust (SD) organic wastes were analyzed for sodium (Na), Potassium (K), calcium (Ca), Magnesium (Mg), Nitrogen (N), Phosphorus (P), Organic carbon (OC) and C:N ratio using [21] (1983) method.

2.7 Data analysis:

The data collected from this experiment were subjected to Statistical Analysis System [22] method. Significant treatment effect was reported at 5% probability level.

RESULTS AND DISCUSSION

3.1 Properties of the Soil at initiation of the study:

Table 1 shows some properties of soil at the initiation of the study. The particle size distribution analysis indicates that the textural class is sandy loam. The pH in KCL was 5.1 indicating that the soil was slightly acidic according to the rating of [23]. The percentage organic matter and total N were 3.17 and 0.16 and rated low [24]. The soil exchange complex was dominated by calcium and magnesium (5.20 and 3.80 cmolkg^{-1}), respectively. Low values of 0.17 and 0.18 cmolkg^{-1} [25] were recorded for sodium and potassium, respectively. The available phosphorus was low with value of 4.70 Mgkg^{-1} [26]. The soil was moderate (68.0%) in base saturation [25] confirming its slightly acidic nature. Exchangeable acidity (EA) was 0.7 cmolkg^{-1}. The soil cation exchange capacity (CEC) and effective cation exchange capacity (ECEC) were 10.3 and 7.97 cmolkg^{-1}, respectively and rated low [25, 26].

Table 1: Some properties of the Soil at the initiation of the study

Soil Properties	Unit	Values
Sand	gkg^{-1}	660
Silt	gkg^{-1}	210
Clay	gkg^{-1}	130
Textural class		Sandy loam
pH kcl		5.1
OC	%	1.84
OM	%	3.17
N	%	0.16
Na	cmolkg^{-1}	0.17
K	cmolkg^{-1}	0.18
Ca	cmolkg^{-1}	5.20
Mg	cmolkg^{-1}	3.80
Available P	Mgkg^{-1}	4.70
Base saturation	%	68.0
CEC	cmolkg^{-1}	10.3
EA	cmolkg^{-1}	0.7
ECEC	cmolkg^{-1}	7.97

OC- organic carbon, OM-organic matter, CEC-cation exchange capacity, N-nitrogen, EA-exchangeable acidity, ECEC-effective cation exchange capacity

3.2 Nutrient Composition of Amendments:

The nutrient compositions of organic wastes applied to the soil are presented in Table 3. The nutrient contents of the organic wastes were generally low. Exchangeable cations were low in burnt rice mill waste (BRMW), saw dust (SD) and unburnt (fresh) rice mill waste (URMW) compared to the soil (Table 3) according to the ratings of [27, 26]. The percentage organic carbon and total N ranged from 6.92 to 16.39 and 0.28 to 0.48 in the organic wastes and rated high [24]. Similarly, available phosphorus ranged from3.00 to 14.00 mgkg^{-1} in the organic wastes and rated low according to [24, 26]. The C:N ratios were 23, 32 and 34 for BRMW, SD and URMW wastes, respectively.

Table 2: Some properties of Organic wastes

Treatment	Parameter	Unit	Value
BRMW	Na	$cmolkg^{-1}$	0.04
	K	$cmolkg^{-1}$	0.06
	Ca	$cmolkg^{-1}$	1.17
	Mg	$cmolkg^{-1}$	0.27
	OC	%	6.92
	N	%	0.30
	P	$mgkg^{-1}$	14.00
	C:N		23
SD	Na	$cmolkg^{-1}$	0.07
	K	$cmolkg^{-1}$	0.13
	Ca	$cmolkg^{-1}$	0.30
	Mg	$cmolkg^{-1}$	0.10
	OC	%	8.99
	N	%	0.28
	P	$mgkg^{-1}$	3.00
	C:N		32
URMW	Na	$cmolkg^{-1}$	0.07
	K	$cmolkg^{-1}$	0.24
	Ca	$cmolkg^{-1}$	0.50
	Mg	$cmolkg^{-1}$	0.12
	OC	%	16.39
	N	%	0.48
	P	$mgkg^{-1}$	7.00
	C:N		34

BRMW-burnt rice mill waste, SD-sawdust, URMW-unburnt rice mill waste, OC-organic carbon, C:N-carbon nitrogen ratio

3.3 Soil Physical Properties:

Table 3 shows effect of organic wastes amendment on restoration of some physical properties of soil for three cropping seasons. Bulk densities of control were significantly ($P<0.05$) higher than in the plots amended with organic wastes for two seasons and in residual studies, respectively. Furthermore, bulk density was lower in plot receiving burnt rice mill waste (BRMW) when compared to those of unburnt rice mill waste (URMW) and sawdust amended plots in 2013 and 2014 cropping seasons as well as in residual year. Amendment of BRMW on soil reduced bulk density by 5 and 8% for 2013 and 2014 seasons and 8% in residual cropping season. Total porosities were respectively significantly ($P<0.05$) higher in plots amended with organic wastes compared to ones obtained in control for two years (2013-2014) and in residual season. Inverse relationship existed between bulk densities and total porosities. Hence, total porosities followed the trend of values observed in bulk densities for the different treatments for the cropping seasons. Aggregate stability was significantly ($P<0.05$) higher in plots amended with organic wastes in first cropping season and in residual study relative to control. The aggregate stability values in BRMW amended plots were respectively higher by 9 and 6% when compared to control for 2013 and 2014 seasons and 13% higher in 2015 study year compared to control.

Similarly, mean weight diameter (MWD) was significantly ($P<0.05$) higher in organic wastes amended plots than in control for two cropping seasons and in residual study. Highest values of MWD were obtained in BRMW amended plot for three cropping seasons compared to those recorded for URMW and SD amended plots. These were respectively 1-13%, 10-14% and 11-29% higher in MWD in BRMW amended plot when compared to values obtained in 2013 and 2014 as well as 2015 for URMW and SD amended plots. Water retention obtained in organic wastes amended plots was significantly ($P<0.05$) higher compared to control for two seasons of amendment and during residual season, respectively. Amount of water retained in soil was higher in plot amended with BRMW for two cropping seasons and then in residual season compared to one retained under URMW and SD amendment. This accounted for 3-9%, 5-7% and 8-14% increments in water retained in BRMW amended plot compared to those of BRMW and SD amended plots for 2013, 2014 and 2015 cropping seasons.

The significantly lower bulk density recorded in organic wastes amended plots for two years of amendment and in residual season relative to control could be attributed to materials released from the organic wastes which increased the volume of soil thereby reducing its bulk density. This finding is supported by the report of [8] that rice husk dust increased its volume and reduced the density compared to control. On the other hand, increase in bulk density after cropping season is in line with the observations of [28] (2009); [29] (2003) that continuous cropping as well as trafficking during field operations including other natural forces like alternate wetting and drying circles caused large effective stress which led to increase in soil bulk density. Significantly lower bulk density observed in plots treated with BRMW compared to URMW and SD suggests that the organic waste was more effective and efficient in bulk density reduction. This could be that it released more valuable materials that increased bulk volume of the soil than other organic wastes. Significantly lower bulk densities in organic wastes amended plots in residual season could be attributed to long residual effect of the organic wastes. The bulk densities of the plots amended with organic wastes were within non-limiting values for root penetration and proliferation [30, 31].

Significantly higher improvements recorded in total porosity, aggregate stability, mean weight diameter (MWD) and water retention (WR) in amended plots relative to control could be attributed to positive effect of organic wastes amendment on the soil. The organic wastes loosened the soil thereby opening the pores. Furthermore, the organic wastes stabilized the soil aggregates and this resulted to increased water storage pores. The significant increase in total porosity of soil amended with organic wastes is in agreement with the reports of [32] (2010); [33] (2008). Amendment of rice mill wastes and sawdust is ameliorative measure on soil according to [11] (2000) and [5] (2001). [33] (2008) attributed significant improvement in aggregate stability of organic wastes amended soil to binding effect of organic components of the materials. [34] (2000) noted that significant MWD in organic wastes amended plots increased soil productivity due to increased water storage pores.

Degradation in soil physical properties after first cropping season could be linked to continuous cultivation. This observation is in line with the report of [28] (2009) that continuous cropping led to decrease in pore volume and loss of stabilization. This was corroborated by [4] (2007) who equally observed that continuous cultivation reduced water storage pores and water available to crops. Non significant effect of organic wastes amendment on aggregate stability in second cropping season could be due to sampling error. However, the aggregate stability values in the season are above 60% recommended as ideal to enhance soil productivity [30]. Similarly, significantly higher improvements in soil physical properties in plots amended with organic wastes relative to control in residual season implies that the amendments could restore and sustain soil productivity owing from their long residual effect. This finding agrees with the report of [35](2004) and [28] (2009) that organic wastes amendment is ameliorative and hence could sustain soil productivity due to their long-residual effect.

Table 3: Effect of organic wastes amendment on some physical properties of soil

				Bulk Density (Mgm^{-3})					Total Porosity (%)			Aggregate Stability (%)			
	MWD (%)				WR(%)										
Treatment	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
Control	1.61	1.69	1.69	39.34	37.16	37.16	65.8	66.0	48.5	2.67	2.67	26.4	23.04	20.90	20.90
BRMW	1.54	1.56	1.56	42.07	41.23	41.23	72.0	70.3	55.4	3.22	3.16	3.16	28.41	26.88	26.88
URMW	1.58	1.59	1.59	40.56	40.09	40.09	70.9	69.7	56.8	2.86	2.86	2.80	27.66	25.66	24.65
SD	1.59	1.59	1.59	40.19	39.91	39.91	70.2	69.5	49.2	2.80	2.71	2.25	25.95	25.10	23.10
FLSD 90.050	0.02	0.02	0.02	0.92	1.54	1.54	2.9	NS	3.0	0.15	0.41	0.41	1.74	1.73	1.72

BRMW- Partial burnt rice mill waste, URMW- Fresh rice mill waste, SD- Sawdust, MWD- Mean diameter, WR- Water retention

3.4 Soil chemical properties:

3.4.1 Available P, total N, Organic carbon and Soil pH:

Effect of organic wastes amendment on restoration of soil chemical properties is shown in Table 4. Results indicate that plots amended with organic wastes had significantly ($P<0.05$) higher available phosphorus, N, organic carbon and pH respectively for two cropping seasons and in residual season than control. The plot amended with burnt rice mill waste (BRMW) had significantly ($P<0.05$) higher available phosphorus, N, organic carbon and pH compared to values obtained in unburnt rice mill waste (URMW) and sawdust (SD) amended plots for two seasons and during residual study. The respective increments of available P, N, organic carbon and pH in BRMW were 11-12%, 9-6%, 5-3%, 6-2% and 13-13%, 12-7%, 7-4%, 7-4% when compared to the values obtained for URMW and SD amended plots respectively for 2013 and 2014 cropping seasons. Similarly, available P, N, organic carbon and pH were respectively higher by 1, 6, 3, 2% and 5, 8, 5, 6% in BRMW than the values recorded for URMW and SD in 2015 cropping season.

The significantly higher available P, N, organic carbon and pH in plots amended with organic wastes relative to control for 2013 and 2014 seasons and 2015 cropping season is attributable to mineralized materials into the soil by the wastes. In other words, available P, N, organic carbon and pH were boosted due to organic wastes amendment. On the other hand, available P, N, organic carbon and pH are sequestered in the organic wastes and were released to soil during their decomposition. This finding is supported by the observation of [5, 8] that available P, N, OC and pH of organic wastes amended plots significantly increased relative to control. In addition, [10] (2011); [32] (2010) noted that incorporation of organic wastes into the soil significantly improved available P, N, organic carbon and pH. This played restorative role in the degraded soil and hence its productivity. Although, pH increased it was still strongly acidic after first cropping season following amendment of organic wastes. This agrees with the report of [5] (2001); [35] (2004) that amendment of soil with URMW and BRMW failed to improve strongly acidic soil and attributed it to organic acids as well as CO_2 produced during the process of organic wastes decomposition.

In their corroborations, [35] (2004) and [3] (2015) noted that there were significantly higher available P, N, organic carbon and pH obtained in plots amended with organic wastes compared to control during residual study implied that the amendment materials imparted on the soil positive residual effect which could sustain productivity.

Generally, there were reduced values of available P, total N, organic carbon and pH across the cropping seasons after first season. This situation could be due to utilization of nutrients [36] by crops on the one hand and continuous cropping [35] on the other. Essentially, continuous cropping if it is not well planned could be strenuous and depletive on soil nutrients. This situation could result to low productivity.

Table 4: Effect of organic wastes amendment on soil chemical properties

Treatment	P(mgkg^{-1})			N(%)			OC(%)			pH(kcl)		
	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
Control	27.16	26.67	26.65	0.79	0.76	0.74	1.23	1.20	1.18	4.7	4.7	4.5
BRMW	56.44	55.26	48.25	1.16	1.07	1.06	1.43	1.35	1.34	5.4	5.1	5.1
URMW	50.10	48.88	47.87	1.06	1.01	1.00	1.36	1.31	1.30	5.1	5.0	5.0
SD	49.38	47.95	45.93	1.02	0.99	0.98	1.33	1.29	1.28	5.0	4.9	4.8
Flsd (0.050	3.19	3.00	3.00	0.11	0.05	0.09	0.01	0.09	0.05	0.2	0.1	0.1

BRMW- Partial burnt rice mill waste, URMW- Fresh rice mill waste, SD- Sawdust, P-phosphorus, OC-organic carbon

3.4.2 Exchangeable Ca, Mg, K, Na and CEC:

Table 5 shows restoration effect of organic wastes amendment on exchangeable Ca, Mg, K, Na and CEC in soil for three cropping seasons. The plots respectively amended with organic wastes had significantly ($P<0.05$) higher Ca, Mg, K, Na and CEC when compared to control for 2013 and 2014 cropping seasons and during residual study. Similarly, the plot amended with burnt rice mill waste (BRMW) had significantly (P<0.050 higher Ca and Na for 2013 and 2014 seasons and then in residual cropping season compared to plots receiving unburnt rice mill waste (URMW) and sawdust (SD) respectively. These represent 6-7%, 3-33% and 3-22%, 21-24% and 11-29%, 6-24% respective increments of Ca and Na in plots amended with BRMW when compared to plots amended with URMW and SD in 2013, 2014 and 2015 seasons. Magnesium was 10 and 9% higher in plot receiving URMW amendment than values obtained in BRMW and SD amended plots in 2013 cropping season. In subsequent season, magnesium increased by 8 and 2% in plot amended with BRMW compared to values for URMW and SD for 2014 and 2015 cropping seasons. Furthermore, CEC value was 7 and 4% higher in plot amended with BRMW relative to values recorded in plots amended with URMW and SD n 2013 cropping season. However, in 2014 cropping season, CEC was 6-3% and 5-3% higher in SD amended plot when compared to plots amended with URMW and BRMW in 2014 and 2015 cropping seasons.

The significantly higher exchangeable Ca, Mg, K, Na and CEC in plots receiving organic wastes treatment relative to control implies that these cations sequestered in the organic wastes were mineralized into the soil during organic wastes decomposition. In other words, the availability of these cations in soil boosted cation exchange complex of soil in plots amended with organic wastes which restored soil productivity. [14] (2002) reported increased exchangeable cations of Ca, Mg, K and Na in soil following *gliricidia* leaves amendment. Higher exchangeable Ca, Mg, K and Na in BRMW amended plot relative to URMW and SD amended plots could be attributed to higher specific surface area which increased microbial action which led to higher release of these cations than in the control. This is in line with [37] (1998) findings that specific surface area of materials increased microbial activity and consequent release of nutrients which increased soil productivity.

Low values of K and Na compared to Ca and Mg in the soil is due to nutrient immobilization which resulted to formation of complexes after degradation and uptake by crops [38]. The exchangeable Ca, Mg and K are of high to medium ratings [24] while Na is low [24] benchmark for tropical soils. Significantly improved CEC in amended soil could also be attributed to significantly increase exchangeable cations, OC and N content due to organic wastes amendment (Tables 4-5). High CEC in soil is healthy to sustained productivity of soil. This is because CEC is one of the soil quality indicators [30].

Significant increase in exchangeable Ca, Mg, K, Na and CEC in residual season suggests that organic wastes amendment of soil has residual positive effect and could restore and sustain soil productivity. This could be one of the advantages of organic farming in contrast to inorganic fertilization. Several authors such as [35] (2004); [10] (2011) had earlier reported that organic wastes amendment impacted positive residual effect on soil. The authors further noted that with proper and careful management the organic wastes amendment could have long-residual effect on sustained soil productivity.

Table 5: Effect of organic wastes amendment on exchangeable cations and CEC

Treatment	Ca (Cmolkg^{-1})			Mg			K			Na			CEC		
	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
Control	3.78	3.32	3.32	2.27	2.23	2.23	0.83	0.72	0.72	0.19	0.18	0.17	8.11	7.93	7.93
BRMW	5.47	5.28	5.28	2.82	2.97	2.97	1.28	1.30	1.30	0.34	0.35	0.33	10.78	10.19	10.19
URMW	5.15	5.10	5.10	3.12	2.74	2.74	1.16	1.26	1.26	0.27	0.31	0.31	10.00	9.93	9.93
SD	5.16	5.10	4.10	2.84	2.92	2.90	1.24	1.23	1.23	0.26	0.25	0.25	10.39	10.52	10.50
FLSD (0.05)	0.55	0.43	0.43	0.43	0.30	2.92	0.40	0.09	0.09	0.02	0.02	0.02	0.79	0.49	0.49

BRMW- Partial burnt rice mill waste, URMW-Fresh rice mill waste, SD-sawdust, CEC-Cation exchangeable capacity

3.5 Grain yield of maize:

Table 6 shows effect of organic wastes amendment on grain yield of maize for three cropping seasons. The results indicated that plots amended with organic wastes had significantly ($P<0.05$) higher grain yields of maize for 2013 and 2014 cropping seasons and during residual study. The plot amended with BRMW had higher grain yield of maize in first cropping season when compared to yields in other organic wastes amended plots and control for 2013 and 2014 seasons as well as in residual study. The grain yield of maize was higher by 8,1and 3% in plots amended with BRMW compared to control, plots receiving URMW and SD amendments in first cropping season. For 2014 cropping season, grain yields of maize in plots amended with URMW and SD were higher by 11 and 2% when compared to control and plot amended with BRMW. The trend of grain yields of maize obtained in 2014 cropping season was replicated in residual season. Generally, grain yields of maize were lower after first cropping season and lowest yields were obtained in 2015 residual season. The grain yields of maize were comparable in plots amended with organic wastes for the seasons.

The significantly higher grain yields of maize in organic wastes amended plots for the cropping seasons relative to control could be due to restoration in physical and chemical properties of soil (Tables 3-5). [14] (2002); [5] (2001); [11] (2000) reported similar findings of significant increase in yields of maize in organic wastes amended plots relative to control. Furthermore, [11] (2000) particularly noted that reduction in bulk density increased water transmisivity, root penetration and cumulative feeding area of crops which translated to better yields in organic wastes amended plots.

The failure to sustain the increase of grain yield of maize recorded in first cropping season in second and residual season could be attributed to low nutrient reserves (Tables 4 and 5) and then continuous cropping [28]. The authors also pointed out that continuous cropping without application of amendments failed to sustain grain yield of maize during their residual study. The superior grain yield of maize obtained in plot amended with BRMW in first cropping season relative to plots amended with URMW and SD could be linked to better physicochemical properties and higher release of nutrients that resulted to higher yield (Table 3-5). Comparatively, BRMW amendment could have the comparative advantage to restore and sustain soil productivity more than URMW and SD. Nevertheless, the grain yields of maize in amended plots are comparable to average global maize yields of 2.5 t ha^{-1} [39] and medium to high values [40] as obtained under temperate and tropical climates, respectively. The trend of grain yields of maize in the amendments is BRMW> URMW> SD>C.

Table 6: Effect of amendments on grain yield of maize

Treatment	Grain yield of maize (t ha^{-1}) 2013	2014	2015
Control	2.10	2.00	2.00
BRMW	2.28	2.25	2.24
URMW	2.26	2.25	2.24
SD	2.22	2.21	2.20
FLSD (0.05)	0.07	0.11	0.09

BRMW- Partial burnt rice mill waste, URMW- Fresh rice mill waste, SD- sawdust, t ha^{-1}-tons per hectare

Conclusion:

The results from this study have shown that use of partially burnt rice mill waste (BRMW) and unburnt rice mill waste (URMW) as well as sawdust (SD) as soil amendment could not only play restorative role on soil properties but sustain its productivity. This implies that soil productivity arising from slash and burn and continuous cultivation practice could be reversed through conservation approach and use of agro-wastes amendment in Abakaliki agro-ecological environment. These organic wastes significantly loosened soil compaction and density by increasing its volume and the porosity. Water retention as well as structural stabilization were significantly enhanced. Available phosphorus, N, Organic carbon, pH, exchangeable cations and Cation exchange capacity were significantly restored in soil due to organic wastes amendment. The positive impact was significant residual effect of treatments and increase in grain yields of maize. Generally, agro-wastes could be recommended for restoration of degraded soil but BRMW which had superior performance in terms of restored soil properties and grain yield of maize when compared to other wastes amendment is more preferable. It is concluded that further research be carried out in this regard to authenticate and validate the results in future. This research is hoped to widen the horizon of rice mill wastes and sawdust utilization in the study area since the wastes are not channelled to any viable use. Rather are abandoned, constitute nuisance and environmental pollution due to largely ignorance of their potential agricultural use.

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