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Research Article

Studies on Mineralization Rate Constants, Half Lives of Organic Wastes and Its Effect on Productivity of *Typic haplustult* in Abakaliki, Southeastern Nigeria

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ABSTRACT

Studies on mineralization rate constants, half lives of organic wastes and its effect on productivity of a *Typic Haplustult was carried out* for three cropping seasons. The field was laid out in a Randomized Complete Block Design on a 0.021 ha of land with four treatments which consisted of control (no application of organic wastes), burnt rice mill waste (BRMW), unburnt rice mill waste (URMW) and sawdust (SD) each applied at 20 t ha^{-1} equivalent to 8 kg /plot and replicated five times to give a total of twenty experimental plots. The treatments were applied for two consecutive seasons while there was no application on third season. A Swan - 1-SR-hybrid of maize (*Zea mays L.*) was used as a test crop. The results of the study showed that mean mineralization rate constants of 0.0498, 0.0487, 0.0471 and 0.0226 K/ day for BRMW, URMW, SD and C occurred at 15, 14, 15 and 32 days of treatment application. The bulk densities of organic wastes amended plots were significantly ($P<0.05$) lower than those of control, respectively. The total porosity, aggregate stability and gravimetric moisture content (GMC) of organic wastes amended plots were significantly ($P<0.05$) higher than those of the control. Total porosity and GMC were 4, 3, 3% and 9, 7, 14% higher in BRMW amendment than SD amended ones for three cropping seasons. Similarly, significantly ($P<0.05$) higher available P, total N, OC, pH, exchangeable Ca and Mg were obtained under organic wastes amendment relative to control, respectively for three cropping seasons. Available P, total N, OC and pH were 11 - 8%, 12 - 8%, 7 - 50% and 7 - 6% higher in 2012 and 2014 cropping seasons in BRMW amended plots when compared with SD amended ones. The grain yield of maize was significantly ($P<0.05$) higher under organic wastes amendment than control. The grain yields of maize obtained under BRMW amended plots were 3, 2 and 2% higher than those from SD amendment for 2012, 2013 and 2014 cropping seasons. Thus mineralization rate constants and half lives of the amendments enhanced productivity of the soil. It is recommended that organic wastes amendment, particularly BRMW should be explored for soil productivity sustainability.

Key words: Effect, half-lives, Mineralization Rate Constants, Organic wastes, Productivity, *Typic Haplustult*

INTRODUCTION

Mineralization is a process of the release of minerals into readily available forms into the soil. Nutrients utilized by crop plants are generally released during organic wastes decomposition. Essentially, decomposition and mineralization of nutrients is affected by moisture content, temperature, pH, aeration, available nutrients, C/N ratio and lignin content of the wastes (Par and Papendick, 1987). The process of organic wastes decomposition leads to synthesis of humus and colloidal materials which play significant role in ion-exchange processes as well as buffer capacity particularly in acid soils of the tropics characterized by high sesquioxides content (Pain and Phipps, 2000).

Enzyme mediated process in soil cause transformation of organic wastes (Brady and Weil, 2002). The initial phase of microbial attack is characterized by rapid loss of readily decomposable organic substances which is usually immobilized as part of microbial cells (Lickas and Penny, 2000). The amount of substrate carbon utilized for cell synthesis would normally vary from 10-79% (Pierce *et al.,* 1997), whereas the other by-products include CO_2-NH_3-H_2S, organic acid and incomplete oxidized substances. Organic wastes possess unique properties with regard to mineralization rate and potentia

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to release nutrients due to microbial attack. For instance uncomposited animal manure, green manure and activated sewage sludge are subject to rapid microbial decomposition in fertile soils (Hornick and Parr, 1987). On the other hand, cereal straw, composite animal manure and sewage sludge would be more resistant to microbial attack and as a result release their nutrients rather relatively slower.

Generally, the benefits of organic wastes addition to soil and their subsequent transformation are the provision of macro-elements such as N,P,O, C and K in more readily available forms. The cation exchange capacity (CEC), base saturation and pH of the soil are enhanced. (Mbagwu and Piccolo, 1990). The biological, physical and chemical conditions of the soil are maintained in a balanced condition (Pain and Phipps, 2000). Furthermore, soil texture, structure, bulk density, total porosity, water storage and retention and aeration (Allison, 2001) are improved by organic wastes amendment. These culminate into increased soil productivity with consequent higher crop yield.

Abakaliki area is largely dominated by quartz, Kaolinite, low activity clay and sequoxides so much that farmers depend on soil fertility status for improved yields. Soil productivity depends heavily on improvements on soil physical properties and readily available nutrients to cater for the needs of crops. It is against this background that it has become imperative to explore ways of ensuring sustainable soil productivity. Even though, organic wastes amendment has been extensively studied in research, there is paucity of information on mineralization rate constants and half-lives of wastes used to amend the soil in the literature. The objectives of this study were to study mineralization rate constants as well as half- lives of organic wastes used to amend soil and its effect on soil productivity in Abakaliki, Southeastern Nigeria.

MATERIALS AND METHODS

Experimental site

The study was carried out at the Faculty of Agriculture and Natural Resources Management Teaching and Research Farm, 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". Total annual rainfall in the area ranges from 1700 to 2000 mm with a mean of 1,800 mm. At the onset of rainfall, it is torrential and violent, sometimes lasting for one to two hours (Okonkwo and Ogu, 2002). Early rains are characterized by thunder storms and heavy lightening. The area has high temperatures with minimum mean daily temperature of 27^0C and maximum mean daily temperature of 31^0C throughout the year. The relative humidity is high (80%) with lowest (60%) levels occurring during the dry season between December to April before the rainy season begins (ODNRI, 1989). 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 Land Resources (FDALR, 1985), 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 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 regrowth, and scanty economic tress. The site has history of previous cultivation of yam (*Dioscorea spp*) and cassava *(Manihot spp).* There is growth of native vegetation such as *Aspilia africana, Panicum maximum* and *Imperata cylindrica*. These were cleared manually using matchet and hoe. The debris left after clearing was removed before seedbed preparation.

Field methods

Field design/Layout and treatment application

An area of land that measured 28 x 15 m approximately 0.021 ha was used for the study. The land was demarcated into plots and replicates. The plots were laid out in Randomized Complete Block Design (RCBD). Each plot measured 2 m x 2 m with a plot alley of 0.5 m spacing. The five replicates were separated by 1m spaces. The treatments consisted of: Control (C), no application of organic wastes, burnt rice mil waste (BRMW) 20tha^{-1} equivalent to 8 kg/plot, unburnt rice mill waste (URMW) 20tha^{-1} equivalent to 8kg/plot and sawdust (SD) 20tha^{-1} equivalent to 8kg/plot.

The treatments, burnt rice mill waste, fresh or unburnt rice mill waste and sawdust were sourced from the Agro-rice Mill Industry and Timber Shade Market, Abakaliki, respectively. These organic wastes were spread evenly on the plots and later 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 treatments were replicated five times to give a total of twenty experimental plots in the study.

Maize seed (Suwan-1-SR-hybrid variety) sourced from Ebonyi State Agricultural Development Programme (EBADEP) was planted at a seed rate of 2 seeds per hole at 5 cm depth and spacing distance of 25x75cm. Two weeks after emergence of seedlings (WAE), the maize plants were thinned down to one per hole while lost stands were replaced by re-planting. This gave a total plant population of approximately 53,000 stands per hectare. There was application of NPK 20:10: 10 fertilizer at 400 kg ha^{-1} to all the plots two weeks after plant emergence in order to boost decomposition. The fertilizer was banded and placed 5cm away from the maize plants. 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 of treatments.

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.

Soil sampling

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

Laboratory determination

Physical properties

Dry bulk density was determined as described by Blake and Hartge (1986). Soil total porosity determination was done using the procedure described by Obi (2000). Particle size distribution was determined by the hydrometer method as described by Gee and Or (2002). The result was reported as percentage sand, silt, clay and texture, respectively. Aggregate stability and mean weight diameter were respectively estimated by wet sieving technique described by Kemper and Rosenau (1986). The percentage water stable aggregates (WSA) on each sieve were determined as follows:

$$\text{WSA} = \left(\frac{\text{Ma+S-Ms}}{\text{Mt-Ms}}\right) \text{x } 100 \quad \text{-------------} (1)$$

Where

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

Ms = Mass of the sand fraction alone (g)

Mt = 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. Whereas Mean weight diameter was evaluated as:

$$\text{MWD} = \sum_{i=1}^{n} \text{Xi Wi} \quad \text{-----------------------------} (2)$$

Where

MWD = Mean weight diameter of aggregates

Xi = Mean diameter of each size fraction (mm)

Wi = Proportion of total sample weight (%SA) in the corresponding size fraction after deducting the weight of stone after passing through the sieve.

Soil moisture retention was extracted using hanging water column technique as described by Obi (2000). Saturated hydraulic conductivity (Ks) was determined by the constant head core method expressed as:

$$\text{Ks} = \frac{\text{Q}}{\text{At}} \text{ x } \frac{\Delta \text{H}}{\text{L}} \quad \text{------------} (3)$$

Where

Ks = Saturated hydraulic conductivity

Q = Mean volume of water conducted

At = Cross sectional area of core x Time

L = Soil sample

ΔH = Hydraulic head change

Chemical properties

The pH of the soil was determined in duplicates both in distilled water and in 0.1 N KCL solution using a soil/water ratio of 1:2.5. After stirring for 30 minutes, the pH values were read off using a Beckman Zeromatic pH meter (Peech, 1965).Total nitrogen determination was done using the micro-kjeldhal distillation method of Bremner (1996). The ammonia from the digestion was distilled with 45% NaOH into 2.5% boric acid and determined by titrating with 0.05 NKCL. Available phosphorus was extracted with the Bray-2 method as described by Page *et al.* (1982). The available phosphorus was read off from the standard curve obtained from optical density using a colorimeter. The organic carbon determination was done through the method described by Nelson and Sommers (1982). The percentage organic matter was calculated by multiplying the value of organic carbon by the "Van Bemmeler Factor" of 1.724 which is based on the assumption that soil organic matter (SOM) contains 58%C (Allison, 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. Cation exchange capacity (CEC) determination was done using ammonium acetate (NH_4OAC) displacement (Jackson, 1958) method. Base saturation (%BS) was calculated by dividing total exchangeable bases (TEB) with cation exchange capacity (CEC) value and multiplied by 100. The expression is:

$$\% \text{ BS} = \text{TEB / CEC x } 100 \quad \text{---------------------------------} (4)$$

Where

% BS = Percentage base saturation

% TEB = Total exchangeable bases (cmolkg^{-1})

CEC = Cation exchange capacity (cmolkg^{-1})

The nutrient composition of the organic wastes was extracted using Juo (1983) method. Mineralization rate constant was calculated after determining residual organic matter of the organic wastes. Mineralization rate was then calculated using the equation proposed by Gilmour *et al.* (1977) as follows:

$$\text{K} = \{(2.303/ (t_2 - t_1)\} \log (C_1/ C_2) \quad \text{-----------------------} (5)$$

Where

K = Organic carbon mineralization rate constant / day

C_1 = amount of organic carbon in the soil (g) at beginning of the experiment (t_1)

C_2 = residual amount of organic carbon (t_1) at the end of study (t_2) with t_1 and t_2 expressed in days. Half – life (T_{50}) of the organic wastes was determined using the equation:-

$$T_{50} \quad \frac{\text{In (0.50)}}{\text{K}} = \frac{0.693}{\text{K}} \quad \text{----------------------} (6)$$

Where

T_{50} =Half – life i.e. the time it took to mineralization 50% of the wastes (day)

K = Organic carbon mineralization rate (day)

Data analysis

The data collected from this experiment were subjected to statistical Analysis System (SAS, 1985) method. Significant treatment effect was reported at 5% probability level.

RESULTS AND DISCUSSION

Properties of the Soil at Initiation of the Study

Table 1 shows some properties of soil at the initiation of study. The particle size distribution analysis indicates that sand fraction was higher compared to silt and clay fractions, respectively. The textural class was sandy loam. The pH in KCL was 5.1 and this indicates that the soil was strongly acidic according to USDA – SCS (1974) rating. The percentage organic carbon (1.84%) and organic matter (3.17%) were low (Enwezor *et al.*, 1981). The percentage nitrogen (0.16%) was low (Asadu and Nweke, 1999). The soil exchange complex was dominated by calcium and magnesium. Similarly, sodium and potassium (0.17 – 0.18 cmolkg^{-1}) were low (Asadu and Nweke, 1999). The available phosphorus recorded low (Landon, 1991) value of 4.70 mgkg $^{-1}$. The base saturation was 68% and this indicates that the soil was slightly acidic. Cation exchange capacity was 10.3 cmolkg $^{-1}$ and according to Asadu and Nweke (1991) is low.

Nutrient composition of organic wastes

The nutrient composition of organic wastes used for soil amendment is shown in Table2. The nutrient contents of the organic wastes were generally low. Exchangeable cations were low in the organic wastes as recommended by (Howeler, 1996; Landon 1991). The perentage organic carbon and total Nitrogen ranged from 6.92 to 16. 39% and 0.12 to 0.30% in the organic wastes and are rated high (Landon, 1991) but that of nitrogen is low.

Available phosphorus ranged from 3.00 to 7.00 mgkg^{-1} in the organic wastes and according to Enwezor *et al.* (1989) and Landon (1991) is low, respectively. The C: N ratio of the organic wastes were 23, 34 and 32 for burnt rice mill waste, unburnt rice mill waste and saw dust, respectively.

Mineralization rate constants and half- lives of organic wastes

Table 3 shows mineralization rate constants and half – lives for the different organic wastes used for soil amendment. The mean mineralization rate constant was higher in burnt rice mill waste compared to control, unburnt rice mill waste and saw dust for the three cropping seasons, respectively. Similarly, higher mineralization rate constants were obtained for unburnt rice mill waste and saw dust than control for the three seasons. The mean mineralization rate constant value for burnt rice mill waste was higher by 55, 2 and 50% when compared with control, unburnt rice mill waste and saw dust mineralization rate constants, respectively, Generally, decomposition of organic wastes proceeded at a faster rate during the early stages and subsequently declined. Mineralization rate constant was higher in second cropping season relative to first and third cropping seasons probably because of higher microbial activity due to their having been accustomed with the wastes.

The mean half life value was 14 days indicating that it was the number of the days it took for 50% of unburnt rice mill waste to be decomposed and mineralized in comparison to burnt rice mill waste, saw dust and control, respectively. Although, half lives values slightly varied among the organic wastes, they were generally lower than control for the three cropping seasons. It took less number of days for the organic wastes to be decomposed in second season compared to first and third cropping seasons.

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

Soil Properties	Unit	Values
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
Organic matter	%	3.17
Nitrogen	%	0.16
Sodium	cmolkg^{-1}	0.17
Potassium	cmolkg^{-1}	0. 18
Calcium	cmolkg^{-1}	5.20
Magnesium	cmolkg^{-1}	3.80
Available phosphorus	mgkg^{-1}	4.70
Base Saturation	%	68.0
Cation exchange capacity	cmolkg^{-1}	10.3

Table 2: Nutrient composition of organic wastes

Treatment	Parameter	Unit	Value
Burnt Rice mill waste	Na	cmolkg^{-1}	0.04
	K	cmolkg^{-1}	0.66
	Ca	cmolkg^{-1}	0.22
	Mg	cmolkg^{-1}	0.20
	Organic Carbon	%	0.92
	Nitrogen	%	0.30
	Available Phosphorus	mgkg^{-1}	14.00
	C : N	23	
Unburnt rice mill waste	Na	cmolkg^{-1}	0.07
	K	cmolkg^{-1}	0.12
	Ca	cmolkg^{-1}	0.50
	Mg	cmolkg^{-1}	0.23
	Organic Carbon	%	16.39
	Nitrogen	%	0.48
	Available Phosphorus	mgkg^{-1}	7.00
	C : N	34	
Saw dust	Na	cmolkg^{-1}	0.06
	K	cmolkg^{-1}	0.13
	Ca	cmolkg^{-1}	0.18
	Mg	cmolkg^{-1}	0.10
	Organic carbon	%	18.99
	Nitrogen	%	0.28
	Available Phosphorus	mgkg^{-1}	3.00
	C : N		32.00

The low mineralization rate constant obtained in the control compared to organic wastes amended plots is in line with the report of Okonkwo *et al.* (2011) that mineralization rate was higher in organic waste amended soil relative to control. Furthermore, low mineralization rate constant could be attributed to low nitrogen content. This was corroborated by several researchers (LaRue, 1977; Macura and Kune, 1976 and Amadi *et al*., 1996) who noted limitation imposed on mineralization rate by low N and P contents of organic wastes due to low microbial action. The faster mineralization rate in second season could be due to adaptability of micro organisms as well as readily available carbon and nitrogen. Similar observation was made by Mbah and Mbagwu (2003) in their studies of organic wastes decomposition.

The faster decomposition during early stages could be as a result of increased microbial activity due to ready available carbon. Higher mineralization rate constant in

Table 4: Selected Soil Physical Properties

Treatment	BD (Mgm^{-3})			TP (%)			AS (%)			GMC (%)		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
Control	1.61	1.69	1.69	39.34	37.16	37.16	65.8	66.0	48.5	23.04	20.90	20.90
BRMW	1.54	1.56	1.56	42.07	41.23	41.24	72.0	55.4	55.4	26.88	26.88	24.65
URMW	1.58	1.59	1.59	40.56	40.09	40.09	70.9	69.7	56.8	27.66	25.66	23.10
SD	1.59	1.59	1.59	40.19	39.91	39.91	70.2	69.5	49.2	25.95	25.95	25.10
FLSD (0.05)	0.02	0.02	0.02	0.92	1.45	1. 54	2.9	NS	3.0	1.74	1.73	1.72

BD – Bulk density, TP – Total porosity, AS – Aggregate stability, GMC – Gravimetric moisture content, BRMW-Burnt rice mill waste, URMW- unburnt rice mill waste

burnt rice mill waste compared to other wastes is as a result of low C: N ratio which provided increased surface area. Biswas and Mukherjee (2008) pointed out that C: N ratio was of great importance in the decomposition and mineralization of organic wastes. They further stated that low C: N enhanced decomposition of organic wastes. The less number of days it took for 50% of unburnt rice mill waste to be decomposed in second cropping season and generally lesser mean value of days could be attributed to higher microbial action on the wastes. This observation is supported by higher nitrogen and available phosphorus contents of the waste (Table 2). Hornick and Parr (1987) noted that organic wastes, which were decomposed rapidly tended to release their nutrients easily while those that were resistant to microbial attack released their nutrients slowly (Ofori and Santana, 1990).

Physical properties of soil

Table 5 shows physical properties of soil as influenced by mineralization rate constants and half lives of organic wastes amendment. Significantly ($P<0.05$) higher bulk density was obtained in control compared to plots amended with different organic wastes in the three cropping seasons. The bulk densities ranged from 1.54 – 1.61Mgm^{-3}, 1.56- 1.69Mgm^{-3} and 1.56 – 1.69Mgm^{-3} for 2012, 2013 and 2014 seasons. The bulk densities of unburnt rice mill waste and saw dust amended plots were significantly ($P< 0.05$) higher relative to those of burnt rice mill waste across the cropping seasons. The bulk densities generally increased after first cropping season in the soil.

Significantly lower total porosities were obtained in control plots compared to plots amended with the different organic wastes across the three cropping seasons. The total porosities ranged from 39. 34 – 42. 07%, 37.16 – 41. 23% and 37.16-41. 23% respectively for 2012, 2013 and 2014 study seasons. Burnt rice mill waste amendment had significantly ($P < 0.05$) higher total porosity relative to unburnt rice mill waste and saw dust amended plots. There was reduction in total porosity after first season. The aggregate stability of control was significantly ($P< 0.05$) lower when compared with plots amended with the different organic wastes in 2012 and 2014 except saw dust treated plots in the residual season. The aggregate stability ranged from 65.8 -72.0 mm, 66.0 -70.3 mm and 48.5-56.8 mm respectively for the study seasons. The aggregate stability values generally decreased after first cropping season. The gravimetric moisture content (GMC) ranged from 23.04-28.4%, 20.90-26.88% and 20.90 – 26.88% across the cropping seasons. The GMC for burnt rice mill waste, unburnt rice mill waste and saw dust treated plots was significantly ($P < 0.05$) higher than those of the control for the cropping seasons. Similarly, significantly ($P<0.05$) higher GMC was obtained under burnt rice mill waste amendment relative to unburnt rice mill waste and saw dust amended plots.

The significantly lower bulk density in plots where organic wastes were treated is attributable to increased mineralization of higher organic carbon and other nutrients from the wastes. This increased the bulk volume of the soil which resulted to low bulk densities. Whereas, increased bulk densities after first cropping season could be as a result of realignment of soil particles due to continuous cultivation which led to decreased volume and hence compaction. Anikwe *et al.* (2003) observed that bulk density increased due to continuous cultivation and trafficking during field operations and other natural forces. This was corroborated by Mbah (2004) that soil bulk density increased after tillage. The bulk densities were within non-limiting values for root penetration and proliferation (Grossman and Berdanier 1982). The positive impact of mineralization of higher organic carbon on bulk density was reflected in significantly higher total porosity in plots amended with organic wastes. The pore spaces in the soil were opened up due to organic wastes mineralization. Several researchers (Adeleye *et al.,* 2010; Asadu *et al.,* 2008 and Anikwe, 2000) reported significant increase in soil total porosity of organic wastes amended soil. According to Anikwe *et al.* (2007), high bulk density decreases soil pore volume and water available to crops. Furthermore, significantly increased aggregate stability in organic wastes amended plots relative to control could be as a result of higher mineralization of materials by the wastes into the soil that resulted to binding affect on smaller aggregates into large ones. Mbagwu *et al.* (1991) noted that organic matter from mineralization of organic wastes bound smaller aggregates into larger ones which were important in the formation and stabilization of soil aggregates. This was supported by Asadu *et al.* (2008) finding that mineralization from organic wastes amendment helped to stabilize soil particles into aggregates. Significant gravimetric moisture content (GMC) in plots amended with organic wastes was due to higher total porosity and lower bulk density (Table 5). Obi and Asiegbu (1980) and Nnabude and Mbagwu (2001) attributed increased GMC in soil amended with organic wastes to their releases which created more storage pores.

Soil chemical properties

Selected soil chemical properties as influenced by mineralization rate constants and half lives of different organic wastes are shown in Table 5. The result indicates that available P, total N, soil OC and pH were significantly ($P<0.05$) higher in plots amended with different organic wastes than control for the three cropping seasons. Similarly, significantly ($P<0.05$) higher

Table 5: Studied soil chemical properties cmolkg^{-1}

Trt.	P (mgkg^{-1})			N (%)			OC (%)			pH (KcL)			Ca			Mg		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
C.	27.16	25.57	26.65	0.79	0.76	0.74	1.23	1.20	1.18	4.7	4.7	4.5	3.78	3.32	3.32	2.27	2.23	2.23
BRMW	55.44	48.26	48.25	1.16	1.07	1.06	1.43	1.35	1.34	5.4	5.1	5.1	5.47	5.28	5.28	2.82	2.97	2.97
URMU	50.10	47.88	47.87	1.06	1.01	1.00	1.36	1.31	1.30	5.1	5.0	5.0	5.15	5.10	5.10	3.12	2.74	2.74
SD	49.38	55.95	45.93	1.02	0.99	0.98	1.33	1.29	1.28	5.0	4.9	4.8	5.16	5.10	4.10	2.84	2.92	2.90
LS(0.05)	3.19	3.10	3.00	0.11	0.05	0.09	0.01	0.09	0.05	0.2	0.1	0.1	0.55	0.43	0.43	0.43	0.30	0.30

C – Control, BRMW – Burnt rice mill waste, URMW – Unburnt rice mill waste, SD – Saw dust.

Table 6: Grain yield of maize (t ha^{-1})

Treatment	Study Years		
	2012	2013	2014
Control	2.10	2.00	2.00
Burnt rice mill waste	2.28	2.25	2.24
Unburnt rice mill waste	2.26	2.25	2.24
Saw dust	2.22	2.21	2.20
LSD (0.05)	0.07	0.11	0.09

available P, total N, soil OC and pH were obtained under burnt rice mill waste treated plots when compared to unburnt rice mill waste and saw dust amended ones for the study seasons. On the other hand, significantly ($P<0.05$) higher pH was recorded in unburnt rice mill waste amended plots compared to saw dust treated one for the three cropping seasons. Furthermore, exchangeable calcium (Ca) and Magnesium (Mg) were significantly ($P<0.05$) higher in plots amended with different organic wastes than the control for the three cropping seasons. Exchangeable Ca of burnt rice mill waste and unburnt rice mill waste amended plots was significantly ($P<0.05$) higher than the saw dust amended one in 2014 cropping season. The values of other studied chemical properties varied among the different organic wastes treatments. The studied chemical properties values were generally lower after first cropping season.

The significantly higher available P, total N, soil OC, pH, exchangeable Ca and Mg indicate that these nutrients were sequestered in the organic wastes and were mineralized into the soil during their decomposition. This is consistent with the findings of Nwite *et al.* (2005) and Nnabude and Mbagwu (2001) that available P, total N, OC and pH of organic wastes amended soil increased significantly. Okonkwo *et al.* (2011) corroborated increase in organic carbon due to mineralization arising from incorporation of organic wastes.

The positive contributions through mineralization of the added organic wastes improved the soil fertility status. Although, pH increased, it was still strongly acidic after first cropping season following amendment of organic wastes. This is supported by observation of Nnabude and Mbagwu (2001) that amendment of organic wastes in soil failed to improve strongly acidic soil and attributed it to organic acids as well as $C0_2$ produced during the processes of organic wastes decomposition. Mbah (2004) also noted low pH in organic wastes amended soil. The significant increase in exchangeable Ca and Mg is in line with report of okonkwo and Ogu (2002) that the nutrients were increased due to organic wastes amendment. The superior performance of burnt rice mill waste in terms of mineralization of higher nutrients into the soil could be attributed to its low C: N ratio value (Table 2) which influenced its surface area for microbial action more than other organic wastes.

Grain yield of maize

Grain yield of maize as influenced by mineralization rate constants and half lives for three cropping seasons is shown in Table 6. The grain yield of maize ranged from 2.10–2.28 t ha^{-1}, 2.00–2.25 t ha^{-1} and 2.00–2.24 t ha^{-1}, respectively for 2012, 2013 and 2014 cropping seasons. The grain yield of maize was significantly ($P<0.05$) higher in plots amended with different organic wastes than the control ones for the three seasons. There was no significant ($P>0.05$) difference in grain yields of maize among the different organic wastes amendments for the study seasons. Nevertheless, the grain yields of maize in burnt rice mill waste and unburnt rice mill waste amended plots were higher than those of saw dust treated plots for the season. Furthermore, grain yield of maize was generally higher in first cropping season and decreased subsequently in other years. The grain yields of maize generally followed the trend of mineralization rate constants of the amended organic wastes.

The significant increase in grain yield of maize in plots treated with different organic wastes relative to control could be due to mineralization from the wastes which created favorable conditions for improved physical and chemical properties of soil (Tables 4 and 5). Similar result of significant increase in grain yield of maize in organic wastes amended plots relative to control was reported by Okonkwo and Ogu (2002), Nnabude and Mbagwu (2001) and Anikwe (2000). Anikwe (2000) and Nnabude and Mbagwu (1999) particularly observed that reduction in bulk density in plots amended with organic wastes increased water transmissivity, root proliferation and cumulative feeding area of the crops, all of which translated to better yield. The failure to sustain the increase of grain yield of maize obtained in burnt rice mill waste amended plot and generally of the organic wastes treated plots after first cropping season could be attributed to low nutrient reserve (Table 5) as well as continuous cropping. The grain yields of maize in organic wastes amended plots are comparable to average global maize yields of 2.5 t ha^{-1} (Harper, 1999) and medium to high values according to ratings of (NPAFS, 2010) for average maize yields in southeastern Nigeria.

Conclusion

The results of this study have shown that mineralization rate constants and half lives of different organic wastes used for soil amendment had positive and significant impact on physicochemical properties of soil and generally its productivity. Mineralization rate constants and half lives of organic wastes influenced degree of positive improvements in soil productivity. The cumulative influence of the mineralization rate constants and half lives of the organic wastes translated to higher yield of maize obtained under different amendments. The higher mineralization rate constant of burnt rice mill waste amendment accounted for a better improved physicochemical soil properties which gave higher grain yield of maize in first cropping season although comparable to the ones from URMW amended plots in 2013 and 2014 seasons. Incorporation of organic wastes is therefore recommended for sound and effective soil management for sustainable productivity.

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