Effect of Agricultural Waste Products on Physico-chemical Properties of Coastal Plain Sands in Akwa Ibom State, Nigeria

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Abstract

A study was conducted to assess the effect of agricultural waste (AgW), namely, palm oil mill effluent (POME), cassava mill effluent (CME) and poultry manure (PoM) and time of application on the physico-chemical properties of coastal plainsoils in Uyo, Akwa Ibom State. There were eight (8) treatments: Control, POME, CME, PoM, POME+CME, POME+PoM, CME+PoM, and POME+CME+PoM, applied at start of study (ST0), one week (ST1) and two weeks after (ST2). The study was a completely randomized design with three replications. Soil samples were collected before and after experiment for analysis of physico-chemical properties. Results show that soil pH obtained before experiment was very strongly acid (pH of 4.27) and slightly acidic after experiment due to the amendments (pH >6.0). Soil organic carbon and organic matter increased in amended soil compared to control at ST0. Total nitrogen content in the soil also increased due to AgW compared to the control. Available P increased ($p<0.05$) due to AgW, especially CME+POME+PoM (55.24 mg/kg) and ST0 (69.04 mg/kg). Total exchangeable bases were generally increased especially in plots that received POME+CME+PoM (12.34 cmol/kg) and at ST0 (13.99 cmol/kg). Effective cation exchange capacity was moderately high ($p<0.05$) in soil treated with POME+CME+PoM (13.60 cmol/kg) with a base saturation of 90.74% and ST0 (15.80 cmol/kg) with 88.54%. The concentrations of Cu, Fe, Mn and Zn increased ($p<0.05$) in the soil treated with POME+PoM and POME+CME+PoM. Thus, significant improvement in soil fertility may be achieved by adopting POME+CME+PoM in the Uyo area of Akwa Ibom State.

Keywords: soil fertility, agricultural wastes, palm oil mill effluent, cassava mill effluent, poultry manure

Introduction

The fertility status of the coastal plain sands in rain-forest zone of south-eastern Nigeria is generally low, adversely affecting crop production, except where fertility management is the practice, by the use of fertility replenishing materials, such as organic source and or their products can therefore be used as organic soil amendments of diverse forms to overcome the challenges of low fertility status of most soils of the tropics and improve agricultural production in the region. Owing to the coarse nature of their texture (Obalum and Obi, 2014), coupled with the prevailing tropical climate, implies that the soil resources for agriculture in this region are highly leached of base-forming nutrients, rendering them acidic. The low soil fertility and the adverse impact on food production is characteristic of agriculture in southern Nigeria (Obalum *etal.*, 2011; Uzoh *et al.*, 2015; Adubasim *et al.*, 2017).

The use of organic amendments has been proposed to improve the quality of these soils (Unagwu, 2019), including their soil organic carbon (SOC), aggregate stability and nitrogen N content (Ogunezi *et al.*, 2019; Umeugokwe *et al.*, 2021). Organic amendments have also been used to enhance the yields of particularly vegetable crops in these soils (Nwite *et al.* 2012, 2013; Ogunezi *et al.*, 2019). Iren *et al.* (2015a) have reported a positive effect of organic manures on the sustained production of waterleaf. Other reports (Iren *et al.*, 2011; John *et al.*, 2013; Iren *et al.*, 2015b) showed that soils amended with animal manures significantly improved soil productivity and the yield of crops. It has also been pointed out by Ayeni and Adetunji (2010) that organic fertilizers improve soil CEC, nutrient assay, soil structure, base saturation and bulk density.

Agricultural wastes and their products are unwanted or insoluble materials produced wholly from agricultural operations, that is, the growing of crops and raising of animals for the primary purpose of making a profit for a livelihood. Agricultural wastes and their utility therefore varies. Some products of agricultural waste are palm oil mill effluent (POME), cassava mill effluent (CME) and poultry manure (PoM) which affect many soil properties and processes, often one effect leading up to another, so that a complex chain of multiple pros and cons result from the addition of these waste products to soils (Hartley, 2004). Thus, organic soil amendments can greatly enhance soil quality by improving soil structure, nutrient availability and water holding capacity, reduce soil erosion and promote microbial activity. This study was conducted to evaluate the effect of some agricultural waste products on some physico-chemical properties of the coastal plain sands in Akwa Ibom State.

Methods and Materials

Description of the study area: The study was conducted on the Coastal Plain Sands at Usukara-Offot in Uyo Local Government Area, Akwa Ibom State, Nigeria, situated at latitude $5^0$17′ and $5^0$27′N, longitude $7^0$27′ and $7^0$58′E, and on an altitude of 38.1 m above sea level (Udoh *et al.*, 2008). The Coastal Plain Sands represents about 75% of the land mass of the State and sandwiched between the Beach Ridge Sands (20%) along the coastal area and the Sandstone and Shale (5%) parent materials in the northern part of the State.

The area is in the tropical rainforest zone with an annual rainfall of about 2,500 mm. The rainfall pattern is bimodal, with long (March-July) and short (September-November) rainy seasons separated by a short dry spell of uncertain length usually during the month of August. The mean relative humidity is 78% and the atmospheric temperature is 30^0C. The mean sunshine annually is 1,450 hours (Ikeh *et al.*, 2012).

The coastal plain sands or soils are highly weathered and dominated by low activity clay minerals (Ojanuga *et al.*, 1981; Petters *et al.,* 1989a). They are coarse-textured, deeply permeable, have low content of organic matter, base saturation and water storage capacity, and are highly susceptible to accelerated erosion (Enwezor *et al.,* 1981; Petters *et al.,* 1989a and b; Ogban and Ekerette, 2001).

Field studies and sample preparation: A reconnaissance was undertaken to select a farmland at Nsukara-Offot in Uyo. Soil samples were collected from the top 15 cm depth of an adjacent area, mixed and 25 kg soil packed into cement bags. Two sub-samples were taken for particle-size and chemical analyses at the Research Laboratory of the Department of Soil Science and Land Resources Management, University of Uyo, Uyo (see Table 1). Similarly, the AgW products, palm oil mill effluent (POME) and cassava mill effluent (CME) were obtained from Domita Farms at Nsukara Offot, Uyo, while poultry manure (PoM) was from the Department of Animal Science (Poultry Unit), University of Uyo, Uyo, and were subjected to routine analysis at the Research Laboratory of the Department of Soil Science and Land Resources Management, University of Uyo, Uyo.

The study was a potted experiment with three times of application (3 levels) of three types (3 levels) of agricultural waste

(AgW).The POME and CME were applied at the rate of 2 l/25 kg soil (2x10^3 l/ha), while PoM was applied at the rate of 1 kg/25 kg soil (10 tons/ha) and thoroughly mixed. The experimental site was cleared of vegetation and the experimental bags laid out in a spacing of 0.50 x 0.50 m^2in three rows of plots of 2 x 1.5 m^2.The three (3) levels of time were: (i) commencement of study (ST0), (ii) one week after commencement of study (ST1), and (iii) two weeks after commencement of study (ST2). The AgW treatments were: (i) Control, (ii) POME, (iii) CME, and (iv) PoM, and their combinations: (v) (POME)+CME), (vi) (POME)+ (PoM), (vii) (CME)+(PoM), and (viii) (POME)+(CME)+(PoM). There were, therefore, eight treatments, including combinations of the AgW, applied at ST0, ST1 and ST2. That is, a set of the bags/plots received the treatments at ST0, the next at ST1, and the third at ST2, respectively. The experiment was a completely randomized design (CRD) in three replications, which were allowed undisturbed for three months, long enough for the treatments to possibly impart the soil, at which soil samples were collected for laboratory analysis, as was done prior to commencement of study.

Laboratory analyses

The soil samples prior to and after the application of AgW were processed and analyzed for particle size fractions by the Bouyoucos hydrometer method (Gee and Or 2002), using calgon (sodium hexametaphosphate) solution as the dispersing agent.

Soil pH was determined in 1:2.5 soil to water and 0.1N KCl suspension and read with a glass electrode pH meter (Udo *etal.,* 2009), electrical conductivity was determined using the conductivity bridge by inserting a sensing conductivity electrode into the soil water ratio of 1:2.5. Soil organic carbon was determined by using the wet oxidation method of Walkley and Black (Nelson and Sommers, 1996) and thereafter, organic matter was derived by multiplying the value of organic carbon by a factor of 1.724 (Van Bremmelen factor). Total nitrogen was determined by the micro-Kjeldahl digestion and distillation method (Udo *et al.*, 2009). Available P was extracted by the Bray P1 method of Murphy and Riley (1962). Exchangeable bases (Ca, Mg, K, and Na) were extracted with IM NHOAC (pH = 7). The Ca and Mg were determined by EDTA titration while K and Na were determined by flame photometry. Exchangeable acidity was determined with IM KCl (Udo *et al.,* 2009). Effective cation exchange capacity (ECEC) was determined by the IITA summation method (IITA, 1979) by summing up the ex-changeable cations (TEB) and exchangeable acidity.

Concentrations of extractable heavy metals, copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) were determined on the Atomic Absorption Spectrophotometer, and the concentrations compared with the FAO/WHO safety limits for heavy metals in soils and sediments.

The POME, CME and PoM were analyzed for pH, electrical conductivity, soil organic carbon, available phosphorus, calcium, magnesium, potassium, sodium, zinc, copper iron and manganese. They were also analyzed for physical parameters such as salinity, total dissolve solids (TDS), total solids (TS), and total suspended solids (TSS), as well as biochemical parameters such as biological oxygen demand (BOD), chemical oxygen demand (COD) and dissolved oxygen (DO) using FEPA (1991), APHA (2011), Ademoroti (1996) and Agbenin (1995).

Statistical analysis: The data obtained were subjected to descriptive analysis of mean and coefficient of variation using the scheme by Wilding (1985), which is: < 15% = low variation; 15-35% = moderate variation; >35% = high variation. The data were also subjected to the one-way analysis of variance (ANOVA), and compared the results by computing the least significant difference (LSD) at 5% probability level.

Results and Discussion

Physico-chemical properties of soil before application of AgW products

The data of the physico-chemical properties of soil prior to the application of the agricultural waste products are shown in Table 1. The results indicate that the sand fraction constitute over 80% of the textural particles. The soils are coarse-textured within the depth of sampling giving a dominant textural class of sandy loam, with implications for rapid rainwater infiltration and low available water storage capacity. Consequently, the soil would benefit from soil management practices that improve soil water storage. Similar results were obtained for the soils of Akwa Ibom State (Essien and Eteng, 2016). Such soils also lack adsorption capacity for basic plant nutrients and water. This pattern is characteristics of the acid sands soils of the south-eastern Nigeria (Enwezor *et al.*, 1990).

The soil is very strongly acid, with a pH of 4.27 (Table 1). The soil is low in virtually all analyzed soil chemical properties, namely, SOM, Total N, Available P, and the major and minor nutrient elements, indicating the poor fertility status of the coastal plain sands and the need for nutrient replenishment to sustain crop production on the soils.

Physical and biochemical properties of the AgW products before application

The physical and biochemical properties of the AgW products before application are shown in Table 2. The results show that pH in H_2O ranged from very strongly acid (CME and POME) to alkaline (PoM), while in KCl it ranged from strongly acid (CME and POME) to alkaline (PoM). That is, pH in both H_2O and KCl was generally higher than in soil before commencement of the study. The implication is that the application of the AgW products would ameliorate in the sense of raising the pH value from being very strongly acid to perhaps moderately acid and suitable for the crops grown on the soils.

The SOC and SOM contents as well as the nutritive elements were generally high, indicating that each of the AgW products had the potential for nutrient replenishment and improvement of the productive capacity of the acid sands.

Effect of agricultural waste products and time of amendment on soil particle-size distribution

The data of the main and the interaction effect of the AgW products, POME, CME and PoM, on particle size distribution is shown in Table 3. The results show that all treatments significantly ($p< 0.05$) affected the soil separates, sand silt and clay, modifying soil texture from loamy sand (Table 1) to sandy loam (Table 3). That is, the treatments caused significant decreases (about 2.02%) in the content of the sand fraction, which also resulted in significant increases (about 10.71% and 9.43% respectively) in the contents of silt and clay, compared to the control. The result is contrary to the generally held view that the textural fractions or soil separates are basic and inherent unalterable soil properties, and is why they are basic parameters in soil survey and classification. However, the results indicates that the predominantly quartz material is weatherable, aided by the AgW products, and therefore a potential material for the management and conservation of the coastal plain sands. The results also show that the variation in the main and interaction effects of the treatments was low for sand (CV = 2.80%) and clay (CV = 13.10%) and moderately low for silt (CV = 26.50%) (Wilding, 1985), which indicates the uniformity in the intrinsic nature of the coastal plain sands. The order of the differences were, main effect: sand = CME>POME>PoM; silt = PoM>CME>POME; clay = POME>PoM>CME, and interaction effect: sand = CME+PoM > POME+PoM > POME+CME > POME+CME+PoM.

Similarly, results of particle size analysis averaged over main and interaction effects, indicated significant ($p< 0.05$) increases in sand and silt and decreases in clay when AgW products were applied at ST0, and decreases in sand and clay, and increases in silt with ST2, than ST1; the synthesis of the silt separate significantly benefited the most from the application of the AgW products. The generally low to moderate variability in the main and interaction effects of the AgW products indicated that they have similar potential impact on particle size fractions when applied singly or in combination, and irrespective of the time of application. The trend in the time of application was: sand = ST0>ST1>ST2; silt = ST2>ST0>ST1; clay = ST1>ST0>ST2.

Main and interaction effect of AgW products on chemical characteristics of coastal plain soils

The results of the main and interaction effects of the application of AgW products on the soil are shown in Table 4. The pH (H_2O and KCl) of the main and interaction effects of the AgW products were generally significantly ($p<0.05$) higher than the control or soil before the application of POME, CME and PoM (Tables 1 and 3). However, soil pH, averaged over main and interaction effects, was high and moderately variable but not significantly affected by time of application (Table 4). The generally high pH observed in this study agrees with the findings of Ebhoaye and Dada (2004), who found an increase in soil pH after treatment with the CME which is at the critical level for good plant growth in this area. The pH values of polluted soils within this range and even above it indicates nutrient availability and micro floral activities to support plant growth (Agbede, 2009 and Akpan *et al.*, 2011). Similar observation has also been made by

Enwezor *et al.* (1990). Chude *et al.* (2004) and Udoh *et al.* (2013) reported that most crops grow at a pH of 6.4 to 7.0 and soil pH is one of the principal factors affecting nutrient availability to plants. Therefore, the availability of the plant nutrients in soils is affected by the impacted soil pH (alkaline) changes. At pH values higher than 7.5 toxic levels of the major plant nutrients (nitrogen, potassium and phosphorus) may become present in the soil (Ogban *et al.*, 1999, 2011; Akpan-Idiok, 2012).

The electrical conductivity in dS/m was generally low whether in treatments of main effect, interaction effect or time that the AgW products were applied, and indicates that the soils were non-saline. Organic carbon (SOC) content ranged from 0.39-1.21 g/kg with a mean of 0.99 g/kg. The level of SOC was rated high as most values were higher than 15 g/kg estimated for soils in south-eastern Nigeria (Enwezor et al., 1990; Ogban *et al.*, 1999, 2011). The SOC accumulation was higher, particularly, more so in soils that received the organic waste than in non-treated soils. Total nitrogen varied between 0.75 and 1.17 g/kg with a mean value of 1.01 g/kg, and was rated medium when compared with the range of 2

-5 g/kg for productive soils (Enwezor et al., 1990; Ogban *et al.*, 1999, 2011; Akpan-Idiok, 2012).

Available P varied from 46.51 to 55.24 mg/kg with a mean of 46.72 mg/kg in treated soils. This range of values is high exceeding 15 mg/kg regarded as optimum for productive soils (Akpan-Idiok, 2012). Available P was higher in treated soils than the control soil. This may probably be due to the cyanogenic compounds from the POME and CME which led to high organic P inputs in the soils. Individually, the AgW products had no effect on available P. Similarly, the significant inputs of avail. P to the soil were from the interaction effects of POME + CME, POME + PoM and POME+CME+PoM, while CME+PoM depressed the input of avail.P or fixed P in the soil compared to the control and may not be suitable for the soil. Also, the AgW products were significantly ($p<0.05$) more effective in terms of replenishing P at ST0 and ST1, compared with ST2. In general, the low variability in differences in avail. P inputs to the soil indicated that the AgW products are suitable soil amendments for the acid sands.

Exchangeable Ca varied from 6.08-7.29 cmol/kg with a mean of 6.22 cmol/kg, while exchangeable Mg ranged from 3.68-4.0 cmol/kg with a mean of 4. 07 cmol/kg, due to the main and interaction effects of the AgW products. Similarly, exchangeable K varied between 0.063 and 0.0163 cmol/kg with mean of 0.091 cmol/kg and, exchangeable Na ranged between 0.032 and 0.076 cmol/kg with a mean 0.041 cmol/kg. Among Ca, Mg, K and Na (Table 4), the products, especially POME+CME+PoM, compared to the control, were generally a good source of the plant nutrient elements in the soil, as could also be inferred from their low to moderate variability (Table 4). This finding showed that, the exchangeable cations were generally moderate to high in the amended soils than in the non-treated (initial) soils, and when compared with the acceptable limits of individual basic cations for crop production in the south-south ecological zone.

The main and interaction effects of the AgW on total exchangeable acidity (TEA) was significant for CME, POME+CME and CME+PoM, and moderately variable (CV ≦35%), compared with the control (Table 4). The effect of time of application on TEA was not significant but equally moderately variable (Table 4). The main and interaction effects of the waste products on total exchangeable bases (TEB) were not significantly different which could be inferred from the low variation among the results (Table 4). However, when applied at ST1 and ST0, compared to ST2, the AgW significantly ($p<0.05$) increased the TEB content of the acid soil. However, the average values of the results obtained from this study were higher than the results by Chude *et al.* (2004) and Udoh *et al.* (2013) for productive soils of the south-south ecological zone, which also received agricultural waste amendments. Increases in ECEC correspondingly increases the availability of plant nutrients and improve the conditions for the activities of micro-organisms in the soil.

The main effect of the soil amendments percent base saturation (%BS) was significantly ($p<0.05$) greater in PoM and POME than CME; POME and PoM were similar, indicating that CME was a poor carrier of the exchangeable bases. Similarly, the interaction effect the different soil amendments on %BS was significantly ($p<0.05$) greater in POME+CME+PoM than POME+CME and POME+PoM; POME+CME and POME+PoM were similar (Table 4). The higher value of %BS observed in the mixtures that contained PoM indicated that PoM was a potential carrier of the exchangeable bases which could be applied as a sole amendment or combined with POME and CME, or other poor quality nutrient carriers to improve the fertility status of the highly weathered and leached acid sands of the tropical humid southern Nigeria. Studies by Ohimain *et al.* (2012) indicated that combined amendments of compost and biochar enhanced soil quality, increased plant growth, provided positive synergistic effect on soil nutrient contents under field conditions, resulted in reduction of fertilizer input, improved nutrient use efficiency, stabilized soil structure, and improved water retention capacity. Generally, however, their CV was low, that is, that they made similar contributions to the base status of the soil. Similarly, the %BS was significantly ($p<0.05$) greater in soil that received the waste products at ST2 and ST0 than ST1, even though their CV was low.

Main and Interaction effect of AgW products on micronutrient contents of the soil

The influence of the main and interaction of AgW products on micronutrient (Cu, Fe, Mn, and Zn) concentrations in the soil are shown in Table 5. The concentration of micronutrients in the amended soil was by several order of magnitude significantly ($p<0.05$) greater than in the untreated soil. POME, CME and PoM were generally rich in micronutrients, but their combinations, especially, POME+PoM and POME+CME+PoM were more efficient in improving the concentrations of all four micronutrients in the coastal plain sands. Respectively, the highest ($p<0.05$) concentrations of Cu, Fe, Mn and Zn were obtained from the soil amended with POME+PoM (36.61 mg/kg), CME+PoM (54.58 mg/kg), CME+PoM (46.89 mg/kg) and POME+PoM (68.12 mg/kg). Overall, Fe and Zn had higher mean soil concentrations than Cu and Mn, but their abundance was in the order: Fe^{3+}> Zn^{2+}> Mn^{2+}> Cu^{2+}. The concentrations of all four micronutrients were moderately variable, ranging from Zn (19.0%), through Fe (20.1%), Cu (28.6%) to Mn (31.5%).

Concerning the time of application, the effect of the amendments on the concentration of the micronutrients was significantly ($p<0.05$) greater at ST0 than ST1 and ST2: ST1 and ST2 were not significantly different (Table 5). That is, the maximum concentrations of Cu, Fe, Mn, and Zn, respectively, 36.18, 39.05, 45.81, and 49.49 mg/kg, which were in the order: Zn^{2+}>Mn^{2+}> Fe^{3+}> Cu^{2+}, were obtained 1WBP, and could be exploited to maximize the availability of Cu, Fe, Mn and Zn in the soil for optimum increases in crop production. The variation in the micronutrient status of the soil through the time of application was similar to the effect of the amendments. Generally, the micronutrient concentrations in the soils were above the critical values for plant growth (Oviasogie and Ofomaja, 2007).

Conclusion

This study assessed the effect of agricultural waste products and time of amendment on the physico-chemical properties of the coastal plain sands in Uyo, Akwa Ibom State. The agricultural waste significantly ($p<0.05$) improved the physico-chemical properties and thus the fertility status of the soil whether applied as sole treatment or in combination. In particular, the combination of palm oil mill effluent and poultry manure (POME+CME+PoM) had the most effect of improving the chemical fertility status of the soil than the other soil amendments, and therefore, recommended for improvement in the productive capacity of the soil and increases in crop productivity in the area of the coastal plain sands in Akwa Ibom State.

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Table 1: Physico-chemical properties of the soil prior to start of the study

Soil properties	Value	Rating
Sand (g/kg)	817	
Silt (g/kg)	69	
Clay (g/kg)	114	
Texture	loamy sand	
pH (KCl)	4.27	very strongly acid
EC (dS/m)	0.11	very Low
SOC (g/kg)	11.34	Low
SOM (g/kg)	19.56	Low
Total N (g/kg)	11.43	Low
Av. P (mg/kg)	15.52	Low
K (cmol/kg)	0.08	Low
Ca (cmol/kg)	2.52	Low
Mg (cmol/kg)	2.91	Low
Na (cmol/kg)	0.02	Low
TEB (cmol/kg)	5.53	Low
TEA (cmol/kg)	1.23	Low
ECEC (cmol/kg)	11.31	very low
BS (%)	64.39	moderate
Zn^{+2} (mg/kg)	1.52	Low
Cu^{+2} (mg/kg)	2.76	Low
Mn^{+4} (mg/kg)	3.22	Low
Fe^{+3} (mg/kg)	5.04	Low

Table 2: Physical and biochemical properties of agricultural waste products before application to soil

Soil property	POME	CME	PoM
pH (H_2O)	4.82	3.94	8.45
pH (KCl)	5.74	4.34	7.82
EC (dS/m)	1.96	2.12	2.72
SOC (g/kg)	18.91	17.94	27.44
SOM (g/kg)	32.60	30.93	49.31
Av. P (mg/kg)	141.92	97.76	110.02
Ca (cmol/kg)	10.21	37.40	56.21
Mg (cmol/kg)	35.62	16.83	11.09
Na (cmol/kg)	78.66	39.91	50.93
K (cmol/kg)	13.41	16.35	18.66
Zn (cmol/kg)	23.64	36.88	21.48
Cu (cmol/kg)	34.04	41.04	5.14
Fe (cmol/kg)	27.48	51.75	49.84
Mn (cmol/kg)	33.01	55.22	58.66
Salinity (ppm)	11.96	5.99	-
Temp ^{0}C	28.04	27.69	-
BOD (mg/l)	27.43	56.45	-
COD (mg/l)	34.72	27.86	-
DO (mg/l)	5.42	3.59	-
TDS (mg/l)	17.44	7.66`	-
Total hardness	88.21	62.31	-
TS (mg/l)	236.33	473.67	-
TSS (mg/l)	142.39	721	-

POME = palm oil mill effluent; CME = cassava mill effluent; PoM = poultry manure; EC = electrical conductivity; SOC = soil organic carbon; SOM = soil organic matter; Av. P = available phosphorus; Ca = calcium; Mg = magnesium; K = potassium; Na = sodium; Zn = zinc; Cu = copper; Fe = iron; Mn = manganese; BOD = biological oxygen demand; COD = chemical oxygen demand; DO = dissolved oxygen; TDS = Total dissolve solids; TS = total solids; TSS = total suspended solids.

Table 3: Effect of agricultural waste and time of application on particle-size distribution

Treatments	Sand	Silt	Clay	Texture
	←	%	→	
Agricultural waste products				
Control	839	56	106	sandy loam
POME	821	57	122	sandy loam
CME	826	62	112	sandy loam
PoM	815	68	116	sandy loam
POME+CME	822	63	115	sandy loam
POME+PoM	823	59	119	sandy loam
CME+PoM	828	59	113	sandy loam
POME+CME+PoM	805	67	127	sandy loam
Mean	822	62	116	sandy loam
LSD(0.05)	2.20	1.54	1.45	
CV%	2.80	26.50	13.10	
Time of application				
ST0	827	58	115	sandy loam
ST1	825	56	120	sandy loam
ST2	815	71	114	sandy loam
Mean	822	61	117	sandy loam
LSD(0.05)	1.35	0.95	0.89	
CV%	2.80	26.50	13.10	

CME = cassava mill effluent; POME = palm oil mill effluent; PoM = poultry manure; CME+PoM = cassava mill effluent + poultry manure; POME+PM = palm oil mill effluent + poultry manure; CME+POME = cassava mill effluent + palm oil mill effluent CME+POME+PM = Cassava Mill Effluent + Palm Oil Mill Effluent + Poultry Manure; ST0 = commencement of study; ST1 = one week after commencement; ST2 = two weeks after commencement of study

Table 4: Effect of agricultural waste and time of application on soil chemical properties

Treatment	pH		EC	SOC	SOM	TN	Av P	Exchangeable Cations				TEB	TEA	ECEC	BS
								Ca	Mg	K	Na				
	KCl	H_2O	dS/m	← g/kg →			mg/kg	← cmol/kg →							%
Control	4.24	4.61	0.11	3.90	6.72	0.75	45.51	6.08	3.86	0.063	0.032	10.08	1.77	11.24	83.64
POME	6.28	6.94	0.11	10.1	18.0	1.02	48.45	6.36	4.62	0.135	0.034	11.15	1.67	12.82	85.18
CME	5.38	6.17	0.13	11.4	19.2	1.03	51.13	6.87	4.02	0.074	0.037	11.01	2.89	13.09	76.91
PoM	6.34	6.84	0.19	11.3	19.1	0.94	45.84	5.90	3.68	0.067	0.037	9.68	1.40	11.08	86.22
POME+CME	5.39	6.09	0.12	9.80	17.0	1.01	50.55	5.05	4.43	0.059	0.032	9.57	2.48	13.04	80.25
POME+PoM	6.88	6.76	0.23	10.3	17.4	1.08	54.15	6.46	4.26	0.114	0.037	10.87	1.65	12.53	85.44
CME+PoM	5.71	5.66	0.18	10.2	18.2	1.01	34.05	6.52	3.76	0.136	0.040	10.45	2.26	12.71	81.18
CME+POME+PoM	6.31	6.52	0.14	12.1	21.1	1.17	55.24	7.29	4.90	0.076	0.076	12.34	1.30	13.60	90.74
Mean	5.82	6.28	0.13	9.9	18.8	1.01	46.12	6.22	4.07	0.089	0.040	10.42	1. 93	12.34	83.45
LSD(0.05)	0.39	0.28	0.12	0.28	0.46	0.42	14.80	1.10	0.79	0.110	0.037	2.04	0.64	1.58	5.60
CV%	6.60	5.40	0.95	30.0	25.6	43.5	6.90	18.7	15.2	11.90	37.40	8.20	35.0	13.50	7.10
ST0	6.35	6.38	0.16	11.1	20.2	0.96	69.04	9.30	4.57	0.078	0.041	13.99	1.81	15.80	88.54
ST1	6.23	6.30	0.13	9.40	18.7	1.04	54.09	5.58	4.86	0.087	0.057	10.58	1.93	12.51	84.74
ST2	6.18	6.16	0.11	9.30	17.3	1.03	38.53	3.77	2.77	0.103	0.023	6.67	2.04	8.69	77.18
Mean	0.39	0.28	0.12	9.90	18.8	1.01	46.12	6.22	4.07	0.089	0.040	10.42	1.93	12.34	83.45
LSD(0.05)		0.20	0.07	0.17	0.28	0.26	11.9	0.68	0.49	0.062	0.023	1.26	0.39	0.97	3.43
CV%	6.60	5.40	0.95	30.0	25.60	43.5	6.90	18.7	15.2	11.9	37.4	8.2	35.0	13.50	7.10

Table 5: Effect of agricultural wastes and time of application on available micronutrients

Treatment	Micronutrients (mg/kg)			
	Copper (Cu)	Iron (Fe)	Manganese (Mn)	Zinc (Zn)
Control	12.12	27.35	19.70	25.15
POME	26.05	45.53	30.96	40.69
CME	25.23	41.94	20.44	34.67
PoM	21.31	46.57	34.44	38.88
POME+CME	23.29	42.65	22.09	36.25
POME+PoM	36.61	49.79	26.05	68.12
CME+PoM	29.19	54.58	46.89	30.65
POME+CME+PoM	33.75	45.64	42.00	46.14
Mean	25.94	44.26	30.42	40.07
LSD(0.05)	6.22	6.35	6.34	5.74
CV%	28.6	20.1	31.5	19.0
Time of application				
ST0	36.18	41.05	29.81	41.49
ST1	15.99	30.94	16.60	26.91
ST2	16.66	27.62	17.17	27.07
Mean	25.22	41.96	30.82	40.07
LSD(0.05)	3.81	3.89	3.88	3.52
CV%	28.6	20.1	31.5	19.0

CME = cassava mill effluent; POME = palm oil mill effluent; PoM = poultry manure; CME+PM = cassava mill effluent + poultry manure; POME+PM = palm oil mill effluent + poultry manure; CME+POME = cassava mill effluent + palm oil mill effluent; CME+POME+PM = cassava mill effluent + palm oil mill effluent + poultry Manure; ST0 = one week before planting; ST1 = day of planting; ST2 = one week after planting