SOIL CHEMICAL BEHAVIOURS AND MAIZE YIELD UNDER DIFFERENT LEVELS OF OIL PALM HUSK MULCH IN AN ULTISOL OF OFOROLA, OWERRI, IMO STATE.

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ABSTRACT
The study centered on evaluating the effects of different levels of oil palm husk on chemical properties of the soil and yield of maize in an Ultisol of Oforola, Imo State. Oil palm husks were collected from an oil palm mill at Obosima, Owerri West Local Government Area, Imo State and transported to Federal College of Land Resources Technology Demonstration Farm, Oforola Owerri West Local Government Area of Imo State for use as surface mulch. The site for the experiment was cleared and laid out in a Randomized Complete Block Design with four treatments replicated four times. The treatment matrices includes four blocks comprising of 0 t/ha, 12 t/ha, 18 t/ha and 24 t/ha of the oil palm husk mulch in each replication. Soil samples were collected before and after application of oil palm husk and analyzed in Soil Science Laboratory of Federal College of Land Resources Technology, Owerri, Imo State. Data collected were analyzed using Genstat Statistical Package. The results showed that the application of oil palm husk at various levels increased the pH of the soil samples. The pH values of the soils after application of the oil palm husk were significantly ($P \leq 0.05$) different in all the plots. Application of 18 t/ha and 24 t/ha oil palm husk treatment increased the total nitrogen content of the soil. The 0 t/ha treatment did not change the total nitrogen content of the soil. Total nitrogen values reduced significantly ($p \leq 0.05$) in 12 t/ha treatment. The application of oil palm husk mulch increased the available phosphorus content of the soil except for 12 t/ha, which reduced the mean phosphorus content. The mean available phosphorus content of all the treatments were significantly ($P \leq 0.05$) different. The exchangeable potassium, cation exchange capacity and the soil organic carbon content of the soils increased as more units of oil palm husk were added. The mean exchangeable potassium values, soil organic carbon contents and cation exchange capacity values for all the treatments were significantly ($P \leq 0.05$) different. The study has also shown that the application of oil palm husk at 12 t/ha significantly gave the highest ear height (48.57cm) and grain yield (1270 k/ha) at 5% confidence level. Based on the findings of the research, it is recommended that the oil palm husks from oil mill plants be used for proper soil amendment and soil fertility improvement in the study area as shown in this study.
Keywords: effects, different levels, oil palm husk, Ultisol, chemical properties.

INTRODUCTION

The world population is increasing day by day, which is likely a serious threat to food security. This can be overcome by enhancing production of major crops like maize. Maize (*Zea mays* L.) is the third most important cereal crop in the world after wheat and rice with respect to area and productivity (Acharya and Sharma, 2004). Maize is used as fasten food in many countries. It belongs to *Gramineae* family. As maize is the highest yielding cereal crop in the world, it is of considerable importance for countries like Nigeria, where rapidly increasing population has already ran short of existing food supplies.

The practice of spreading plant residue or any other material like oil palm husk on the soil surface to reduce water evaporation losses and add quality to the soil is called mulching. The type of material used as mulch determines its impact on soil physical and chemical properties, and crop yield (Awodun and Ojeniyi, 2009; Enyioko *et al.*, 2017). This is due to differences in biochemical quality of plant materials. The key factors determining quality of the mulching materials are the nutrient value, texture, rate of decomposition, availability, cost, growth rate and vegetative matter turn over. The nutritional effect of mulches on plants depends on residue quality. High quality materials improve plant nutrition by releasing nutrients. Low quality residues have relatively weak direct nutritional effect.

The oil palm husk is used mainly as mulch (Hamdan *et al*, 2008). Placed around young palms, oil palm husk helps to control weeds, prevent erosion and maintain soil moisture. Mulching using oil palm husk is a traditional practice in maize cultivation aimed at controlling heat scorching and soil temperature and also improves soil physical and chemical properties.

Appropriate tillage and mulch practices using oil palm husk are used to conserve soil moisture and increase the yield of crops. Rathore *et al.* (2008) reported that

more water was conserved in the soil profile during the early growth period with oil palm husk mulch than without it. In essence, mulching with oil palm husk is an effective method of manipulating crop growing environment to increase yield and improve product quality by controlling weed growth, reducing soil temperature, conserving soil moisture, reducing soil erosion, improving soil structure, improving soil chemical properties and enhancing organic matter content of the soil (Opara-Nadi, 2003).

Use of oil palm husk in mulching is widely practiced in Imo State for improvement of many soil aspect as support soil moisture retention ability, prevent wind erosion, control of weeds, nutrients return and soil structure improvement. Keeping this in view, this study was undertaken to assess the effect of oil palm husk mulch on soil chemical properties and growth of maize. The objectives of the study were to determine the effect of oil palm husk mulch on soil chemical properties; ascertain the best levels of oil palm husk mulch that affects soil chemical properties optimally and proffer advice to farmers on the best levels of application to optimize maize yield in the study area.

MATERIALS AND METHODS

Study Area

The research was carried out in the Research and Demonstration Farm of the Federal College of Land Resources Technology, Oforola in Owerri West Local Government Area of Imo State. The area lies between latitude 5^0 14 and 6^0 31^l North, and longitude 7^o 34^l and 6^o 15^1 East (Uwakwe, 2012).

Oforola lies within the low land, humid tropical ecosystem of South Eastern Nigeria. The annual rainfall in Oforola ranges from 1,599 – 2,000 mm. The minimum and maximum temperature ranges are 20^0C and 31^0C respectively (Uwakwe, 2012). The soils of Oforola are porous, weakly structured, well drained in such a way that runoff water disperses 30 minutes after a typical rainfall storm (Ufot, 2012). The weather condition during the rainy season is cold, while hot and warm during the dry season. The area witnesses a rainy season from the month of April to October and usually interrupted by a short dry weather in the month of August, while the dry season of harmattan starts from November to January of the following year.

Vegetation

The vegetation of the area is controlled by geologic factors of topography, relief and lithology as well as other anthropogenic factors (Ufot, 2012). The vegetation ranges from light rainforest to derived savannah. The area supports extensive man-made vegetation community which comprises mainly cashew orchards and oil palm trees. Human activities such as bush burning, agriculture and construction works have greatly modified the natural vegetation in the area and contributed to the gully erosion problem that is prominent (Uwakwe, 2012).

Oil Palm Husk Collection

Oil palm husk was collected from an oil palm mill at Obosima, Ohaji/Egbema Local Government Area, Imo State and transported to FECOLART Research and Demonstration Farm, Oforola, Owerri West Local Government Area.

Site Preparation and Experimental Design

The site for the experiment was cleared and laid out in a Randomized Complete Block Design (RCBD) with four treatments and replicated four times (4 X 4 replications). The oil palm husk was applied and incubated for two weeks before planting of the maize was done. The variety of maize planted was *Suwan* – 1.Weeding was done manually once a month. The treatment matrix included four blocks of 0 t/ha, 12 t/ha, 18 t/ha and 24 t/ha of the oil palm husk mulch in each replication.

SOIL PARAMETERS ANALYSED

The soil samples were analyzed for the following parameters:

Total Nitrogen

The nitrogen was determined by the Kjeldahl digestion and distillation procedure. 0.2 g of soil was weighed into a Kjeldahl digestion flask and 5 ml distilled water added. After 30 minutes, a tablet of selenium and 5 ml of concentrated H_2SO_4 were added to the soil and the flask placed on a Kjeldahl digestion apparatus and heated initially gently and later vigorously for 3 hours. The flask was removed after a clear mixture was obtained and then allowed to cool. 40 ml of distilled water was added to the digested material and transferred into 100 ml distillation tube.

Phosphorus

Phosphorus was extracted with a HCl: NH_4 mixture, the Bray's No. 1 extract. Phosphorus was determined using a spectrophometer by the blue ammonium molybdate method with ascorbic acid as reducing agent. 5 g soil was weighed into 100 ml extraction bottle and 35 ml of extracting solution of Bray's No. 1 was added. The bottle was shaken for 10 minutes after which the content was filtered. The resulting clear solution was collected into 100 ml volumetric flask. 5 ml of the supernatant solution was pipetted into 25 ml test tube and 10 ml colouring reagent was added as well as a pinch of ascorbic acid and then mixed very

well. The mixture was allowed to stand for 15 minutes to develop a blue colour to its maximum. The colour was measured photometrically using a spectronic 210 spectrophotometer at 66 nm wavelength. Available phosphorus was extrapolated from the absorbance reading.

Available Potassium

Available potassium extracted using the Bray's No. 1 solution was determined directly using the Gallenkamp flame analyzer. Available potassium concentration was determined from the standard curve. Potassium standard solutions were prepared with the following concentrations: 0, 10, 30, and 50μg K per litre of solution. The emission values were read on the flame analyzer. A standard curve was obtained by plotting emission values against the respective concentration.

Soil pH

Soil pH was measured in a 1:1 soil water ratio using a glass electrode pH meter, 25 g of soil was weighed into a 50 ml polythene beaker and 25 ml of distilled water was added to the soil. The soil-water solution was stirred thoroughly and allowed to stand for 20 minutes. After calibrating the pH meter, the pH value was recorded.

Soil Organic Carbon

Soil organic carbon was determined by the modified Walkley-Black method as described by Nelson and Sommers (1996). The procedure involves a wet combination of the organic matter with a mixture of potassium dichromate and sulphuric acid. After the reaction, the excess dichromate was titrated against ferrous sulphate. 1.0 g of air-dried soil was weighed into a clean and dry 250 ml Erlenmeyer flask. 20 ml of concentrated sulphuric acid (H_2SO_4) was dispersed rapidly into the soil suspension and swirled vigorously for 1 minute and allowed to stand on a porcelain sheet for 30 minutes. 100 ml of distilled water was added and mixed well. 10 ml of orthophosphoric acid and 1 ml of diphenylamine indicator was added and titrated by adding 1.0 M ferrous sulphate until the solution turned dark green at end-point from an initial purple colour. The titration was completed by adding $FeSO_4$ drop-wise to attain a stable end-point. The volume of $FeSO_4$ solution used was recorded and percentage carbon calculated.

RESULTS AND DISCUSSION

Chemical properties of the soils before application of oil palm husk

The chemical properties of the soils before application of oil palm husk are shown in Table 1. The Table shows that the mean pH of the soils was 3.7 and ranged from 3.21 in plot meant for 0 t/ha to 4.07 in plot meant for 24 t/ha. The mean total nitrogen, available phosphorus, soil organic carbon, exchangeable potassium, organic matter and CEC of the soils were generally low. The mean total Nitrogen was 0.14% and ranged from 0.08% in plot meant for 18 t/ha mulch treatment to 0.23 % in plot meant for 12 t/ha mulch treatment. Mean Available phosphorus (0.203mg/kg) ranged from 0.16mg/kg in plot meant for 18 t/ha to 0.27 mg/kg in plot meant for 24 t/ha mulch treatment. Mean Soil organic carbon (0.92%) ranged from 0.69% in soil meant for 24 t/ha mulch treatment to 1.06% in plot meant for 0 t/ha mulch treatment. Mean exchangeable Potassium (1.37Cmol (+)/k) ranged from 1.12 Cmol(+)/kg in plot mean for 0 t/ha mulch treatment to 1.62 Cmol(+)/kg for plot mean for 12 t/ha mulch treatment.

Soil organic matter values of the experimental site ranged from 1.19% to 1.83% with a mean value of 1.58%. The mean cation exchange capacity which is the sum total of exchangeable cations that the studied soil could absorb before the treatment's application was 3.97Cmol (+)/kg with a range in value of 3.21 – 4.61 Cmol(+)/kg.

From the above, it has been observed that the soils of the study area are low in nutrients. These findings are in line with the findings of Onyekwere (2015). He observed general low nutrient content of soils in certain parts of Owerri West Local Government Area of Imo State. The possible reason for this could be because of the high sand content of the area reported by Ufot (2012). Sandy soil had been reported to hold lesser nutrients and encourage leaching of nutrients. The nutrients status of these soils therefore, calls for dare need for evaluating various cheap soil amendments that can be taken to improve the soil fertility status of the study area.

TABLE 1: CHEMICAL PROPERTIES OF SOILS BEFORE APPLICATION OF OIL PALM HUSK

Treatment (OPH) t/ha	pH	Total Nitrogen (%)	Available Phosphorus (m/kg)	Soil Organic Carbon (%)	Exchangeable Potassium (Cmol(+)/kg)	Organic matter (%)	CEC (Cmol(+)/kg)
0 t/ha	3.21	0.09	0.17	1.06	1.12	1.83	3.21
12 t/ha	3.58	0.23	0.21	0.97	1.62	1.67	3.58
18 t/ha	3.81	0.08	0.16	0.95	1.54	1.64	4.46
24 t/ha	4.07	0.15	0.27	0.69	1.20	1.19	4.61
Mean Value	3.7	0.14	0.203	0.92	1.37	1.58	3.97

Effects of oil palm husk on chemical properties of soil in the study area

The results obtained for the mean chemical properties of soils after application of oil palm husk are shown in Table 2

Soil pH

The mean pH of the soil after application of oil palm husk ranged from 4.36 in 0 t/ha treatment of mulch to 5.49 in 24 t/ha treatment. This showed that soil pH increased as more unit of oil palm husk was applied to a plot (Table 2). Application of oil palm husk increased the pH of the soil in the study area above the value of 3.7 observed in the soils before application as shown in Table 1.

The pH values of the soils after application of the oil palm husk were significantly ($P \leq 0.05$) different in all the plots. Elevated soil pH as observed in this study could have resulted from the leaching of basic cations from decomposing organic matter as opined by Havlin *et al.*, (2000).

Total Nitrogen

The mean total Nitrogen content was highest (0.16%) on the soil with 24 t/ha oil palm husk mulch application and lowest (0.09%) in soils with 0 t/ha oil palm husk mulch application. The mean total nitrogen content for all the treatments was significantly ($P \leq 0.05$) different (Table 2).

When compared with the results in Table 1, it was observed that 18 t/ha and 24 t/ha oil palm husk treatment increased the total nitrogen content of the soil. The 0 t/ha treatment did not change the total nitrogen values but remained (0.09%). In 12 t/ha treatment, the total nitrogen values reduced from 0.23% (Table 1) as observed before mulch application to 0.10% (Table 2) after mulch application.

Available Phosphorus

The mean phosphorus content for the soils after application of the mulch were 0.22 mg/kg, 0.19mg/kg, 0.32 mg/kg and 0.29 mg/kg for 0 t/ha, 12 t/ha, 18 t/ha and 24 t/ha treatment respectively (Table 2). When compared with the results in Table 1. The application of oil palm husk mulch increased the available phosphorus content of the soil except for plots that received 12 t/ha oil palm husk. 12 t/ha treatment reduced the mean phosphorus content from 0.21 Cmol(+)/kg (Table 1) observed in the soil before application of oil palm husk to 0.19 Cmol(+)/kg (Table 2) observed after application of oil palm husk. The mean phosphorus content of all the treatments were significantly ($P \leq 0.05$) different. 24 t/ha treatment had the highest mean phosphorus content while the treatment of 12 t/ha had the lowest available phosphorus value.

As reported by Opara-Nadi (2003), available phosphorus was significantly affected by mulching. Aulkah *et al.*, (2003) posited that the increase in available phosphorus in mulched plots could be attributed to the increase in organic matter, since Gupta (2003) had mentioned that the importance of maintaining organic matter could affect the maintenance of organic phosphorus.

Soil Organic Carbon

The mean soil organic carbon recorded after the application of oil palm husk was highest in 24 t/ha oil palm husk treatment (1.79%) and lowest for 0 t/ha

(1.05%). The mean soil organic carbon for all the treatments were significantly (P≤0.05) different.
When compared with the results of Table 1, it was observed that the soil organic carbon content increased as a result of application of oil palm husk. There was reduction in soil organic carbon content in the 0 t/ha treatment from 1.06% (observed before mulch treatment) to 1.05% (observed after mulch treatment).
Iken and Amusa (2004) posited that mulching helps in organic amendment and consequently adds organic carbon to soils.

Exchangeable Potassium
The mean exchangeable potassium values for 0 t/ha, 12 t/ha, 18 t/ha and 24 t/ha were 1.81, 2.01, 2.03 and 2.20 Cmol(+)/kg respectively. It was highest for 24 t/ha mulch treatment (2.20 Cmol(+)/kg) and lowest for 0 t/ha treatment. The mean exchangeable cation values for the treatments were significantly (P≤0.05) different. When compared with the results of Table 4.1, it was observed that the exchangeable potassium values increased as more units of oil palm husk were added.

Soil Organic Matter
The mean organic matter content observed in 0 t/ha, 12 t/ha, 18 t/ha and 24 t/ha were 1.83%, 1.93%, 2.22% and 3.09% respectively (Table 4.2). The order of increase in Soil organic matter is 24 t/ha>18 t/ha>12 t/ha>0 t/ha. The soil organic matter content in all the spacing treatments were significantly (P≤0.05) different. When compared with Table 4.1, it was observed that the application of oil palm husk increased the soil organic matter content above what was observed before its application except for 0 t/ha where there was a reduction in soil organic matter.

Cation Exchange Capacity (CEC)
The mean CEC values of the soils in the study area ranged from 3.67 Cmol(+)/kg in 0 t/ha oil palm husk treatment to 4.95Cmol(+)/k in 24t/ha oil palm husk treatment (Table 4.2). The order of increase in CEC was 24 t/ha>18 t/ha>12 t/ha>0 t/ha.

TABLE 2 MEAN CHEMICAL PROPERTIES OF SOIL AFTER APPLICATION OF OIL PALM HUSK

Treatment (OPH) t/ha	pH	Total Nitrogen (%)	Available Phosphorus (mg/kg)	Soil Organic Carbon (%)	Potassium (Cmol(+)/kg)	Organic matter (%)	CEC (Cmol(+)/kg)
0t/ha	4.36	0.09	0.22	1.05	1.81	1.81	3.67
12t/ha	4.40	0.10	0.19	1.12	2.01	1.93	4.19
18tha	5.13	0.11	0.32	1.29	2.03	2.22	4.48
24t/ha	5.49	0.16	0.29	1.79	2.20	3.07	4.95
LSD	0.13*	NS*	0.013*	0.051*	0.06*	0.088*	0.127*

OPH = Oil Palm Husk
***** LSD at 5% level of significance

Effects of Oil Palm Husk Mulch on Maize Growth and Yield Parameters
The results on the mean effect of oil palm husk mulch on maize growth and yield parameters are as shown in Table 3.

Grain Weight
The results shows that treatment of 0 t/ha gave the highest (106.47) grain weight while the 12 t/ha treatment gave the lowest (102.75g) grain weight (Table 3). The order of increase in grain weight is 0 t/ha (106.47g) >18 t/ha (105.75g) > 24 t/ha (104.49g) > 12 t/ha (102.75g). The grain weight values for all the treatments were significantly (P≤0.05) different.

Ear Height
The ear height values for 0 t/ha, 12 t/ha, 18 t/ha and 24 t/ha were 28.99 cm, 48.57 cm, 35.5 cm and 39.37 cm respectively (Table 4.3). The results showed that the highest mean ear height (48.57 cm) was recorded for 12 t/ha treatment while the lowest (28.99 cm) was recorded for 0 t/ha treatment (Table 3). The results

have shown that oil palm husk mulching significantly increased ear height of maize. Optimum ear height (48.57 cm) was obtained with 12 t/ha oil palm husk mulch. There was no significant difference in the ear height due to 18 t/ha treatment and 24 t/ha treatment. The ear height values for 0 t/ha and 12 t/ha treatment were significantly ($P \leq 0.05$) different.

Grain Yield

The results obtained show that the mean grain yield were 497 kg/ha, 1270 kg/ha, 763 kg/ha and 907 kg/ha for 0, 12, 18 and 24 t/ha OPH treatment respectively. There was no significant difference in the grain yield due to 18 t/ha and 24 t/ha treatment. There was significant ($P \leq 0.05$) in the grain yield of 0 t/ha and 12 t/ha treatment. Significantly highest grain yield (1270 kg/ha) was obtained from plot that received 12 t/ha oil palm husk.

Table 3: Yield results of maize on oil palm husk mulched plots after 8 weeks of planting

Treatment	1000 grain weight (g)	Ear height (cm)	Grain yield (kg/ha)
0t/ha	106.47	28.99	497.0
12t/ha	102.75	48.57	1270.0
18t/ha	105.19	35.72	763.0
24t/ha	104.49	39.37	907.0
LSD (0.05)	1.02**	5.40**	212.8**

** = Significant at 1% probability level.

CONCLUSION AND RECOMMENDATION

The study centered on evaluating the effects of different levels of oil palm husk on chemical properties of the soil and yield of maize in an Utisol of Oforola, Imo State.

The study has shown that the application of oil palm husk at various levels increased the pH, total nitrogen, available phosphorus, exchangeable potassium, organic matter and CEC but reduced the soil organic carbon of the soil significantly. The study shows that the addition of more oil palm husk led to a increase in the chemical properties earlier mentioned except for soil organic carbon.

The study also, showed that the application of oil palm husk at 12 t/ha significantly gave the highest ear height and grain yield.

Recommendations

Based on the findings of the research, it is recommended that:

1. The environmental pollution due to indiscriminate dumping of oil palm husk in oil palm milling areas should be brought to a stop and the oil palm husks used for proper soil amendment and soil fertility improvement in the study area as shown in this study.
2. Extension services should be undertaken to inform farmers on the potency of oil palm husk in improving soil fertility.

REFERENCES

Acharya, C.L. and P.D. Sharma, (2004). Tillage and mulch effects on soil physical environment, root growth, nutrient uptake and yield of maize and wheat on an Alfisol in north-west India. *Soil Till. Res.*, 4: 291–302

Aulkah, Diaz-Zorita, M., J.H. Grove, L. Murdock, J. Herbeck and E. (2000) Perfect, Soil structural disturbance effects on crop yields and soil properties in a no-till production system. *Agron. J.*, 96: 1651–1659

Awodun, F. and Ojeniyi, D. (2009). Effect of tillage and mulching on yield of corn in the submontaneous rainfed region of Punjab, India. *Int. J. Agric. Biol.*, 6: 126–128

Enyioko, C. O., Akande, S. O.and Nwokocha, C. C. (2017). Physical Properties and Yield of Maize Using Oil Palm Husk on Soils of Owerri Area, Imo State, Nigeria. Int'l Journal of Agric. And Rural Dev. Volume 20(1): 2998- 3003, 2017

Gupta, A. (2003) Crop residue and tillage effects on carbon sequestration in a Luvisol in central Ohio. *Soil Till. Res*., 52: 73–77

Hamdan, S. Bonari, E., M. Mazzoncini, N. Silvestri, M. Pagliai, M. Barbafieri, M. Borin and M. Sattin, (2008). Effects of different soil tillage systems on soil physical characteristics and maize yield. In: *Proc. 3rd Cong. Europ. Soc. Agron., Padova University, Abano-Padova, Italy, 18-22 September 1994*, pp: 454–455

Havlin, S. Buresh, R.J., E.R. Austin and E.T. Craswell, (2000). Analytical methods in N-15 research. *Fert. Res.* 3: 37–62

Iken N. and Amusa, (2004). Maize growth, response to deep tillage, straw mulching and farmyard manure in coarse textured soils of N.W. Nigeria. *Soil Use Manag.*, 10: 15–20

Nelson, A. and Sommers, S. (1996). *Official Methods of Analysis of the Association of Official Analytical Chemists International*, 16th edn., vol. 972. AOAC International, Arlington, VA. p. 43.

Onyekwere, S. (2015). The potential of siam weed (*Chromolaena odorata*) as a source of organic matter for soils in the humid tropics. In *Soil organic matter dynamics and sustainability of tropical Agriculture*. (K. Mulongoy, R. Merckx, eds), pp. 89–99. Proceedings of an International Symposium Leuven Belgium, 4–6 November, 1993, John Wiley and Sons Ltd. Chichester, England.

Opara-Nadi, O. (2003). *Methods of Analysis for Soils, Plants and Water*. University Of California, Berkeley, CA, USA

Rathore D., Bremner, J.M. and Mulvancy, C.S. (2008). Nitrogen Total. *In:* Page, A.L. (ed.), *Methods of Soil Analysis, Agronomy No. Part 2: Chemical and microbiological properties*, 2nd edition, pp: 595–624. American Society Agronomy, Madison, WI, USA

Ufot, D. (2012). Soil physical and chemical in Soils Of South Eastern Nigeria in Nigeria. *Afr. Soils* 28: 21–22.

Uwakwe, S. (2012). Soil physical and chemical properties in Southeastern Nigeria (*Dioscorea rotundata*) production in southeastern Nigeria. In Proceedings of the 6th Symp. Int. Soc. Trop. Root