Changes in Soil Physical Properties and Growth of Oil Palm Seedlings on a Degraded Ultisol Amended With Composted Oil Palm Bunch Wastes

OVIE .S.
Chemistry Division, Nigerian Institute for Oil Palm Research
P.M.B. 1030, Benin City
Nigeria
oviesteve2013@yahoo.com

UDOH .J.J.
Chemistry Division, Nigerian Institute for Oil Palm Research
P.M.B. 1030, Benin City
Nigeria

EKHORUTOMWEN .O.E.
Plant Pathology Division, Nigerian Institute for Oil Palm Research
P.M.B. 1030, Benin City
Nigeria

ABSTRACT

A pot experiment was conducted at the research and experimental farm of the University of Nigeria, Nsukka, to determine the effect of composted oil palm waste on selected physical properties and growth of oil palm seedlingsraised on a degraded ultisol. Four rates namely,0 g, 100 g, 200 g, 300 g per polybag of the composted oil palm bunch waste were arranged in a completely randomized design with five replications. Core and surface soil samples were collected from the polybagsat 6 and 12 months after planting (MAP) for the determination of selected soil physical properties following standard laboratory methods. Oil palm growth parameters were measured at 5, 8 and 12 MAP.Results revealed that soil bulk density,dispersion ratio, total porosity and aggregate stability significantly differedwith composted oil palm waste addition. The application of 300 g per seedlings of the composted material had lowest ($p<0.05$) effect on soil bulk density, dispersion ratio and highest significant ($p<0.05$) effect on total porosity and aggregate stability throughout the sampling period. The application of composted oil palm waste significantly affected the growth of oil palm seedlings throughout the growth period.The application of 300g per seedlings of the composted material showed highest ($p<0.05$) effect on all growth parameters of oil palm seedlings relative to other rates of amendmentand the control.From the present study,the addition of 300 g compost per polybagwas most effective in improving the soil physical properties and growth of oil palm seedlings raised on the degraded ultisol

INTRODUCTION

Tropical soils are highly susceptible to degradation under continuous cultivation that does not provide adequately for conservation to ensure sustainability. Ultisols, a prominent soil order within the tropics are subject of low productivity and soil degradation and exhibits characteristics that makes its management important. These characteristics include low water holding capacity, poor surface soil stability and relatively high bulk density (Babalola and Obi, 1981). They are also coarse-textured with low organic matter content (Igwe*et al.,* 1995 and Mbagwu*et al.,* 1995). The declining food production and increasing population in the Sub-Saharan African countries poses a serious challenge to farmers and governments (Ahmed, 2000). All these constitute a major developmental constraint to crop production (Kang and Spane, 1986; Adediran*et al.,*1999). The most important goal and challenge in tropical agriculture must be to sustain and, if possible, increase soil fertility and maintain food production for millions of people in an economically, ecologically and socially acceptable way. In order to overcome and restore soil fertility, farmers and stakeholders have attempted various practices. Nigeria has over the years used the bush fallow system to solve the soil fertility problems (Ojeniyi, 2002). However, the traditional bush fallow system does not sustain much crop production because of low nutrient availability, shortened fallow periods, and shortage of land due to increase population. Researchers (Aoyama *et al.,* 1999; Olayinka, 2009) have recommended the application of organic amendment to tropical soils as sources of nutrients because of the inherently low in organic matter content, and low activity clays predominant in the clay mineralogy (Okusami*et al.,* 1997). Application of farmyard manure to soil improves crop performance, soil fertility, soil organic matter, microbiological activities and soil structure for sustainable agriculture (Blair *et al.,* 2005; Kundu*et al.,* 2006). The application of organic materials influence the degree of aggregation and aggregate stability and can reduce bulk density, increase porosities, water holding capacity, moisture retention and transmission, and drought resistance in plant (Cheng *et al.,* 1988). In view of these, it is pertinent to investigate the effect of composted oil palm bunch waste on selected soil physical properties and growth of oil palm seedlings raised on a degradedultisol of southeastern Nigeria.

MATERIALS AND METHODS

Location of study area: This study was conducted in the research and experimental farm of the University of Nigeria.Nsukka, is located in Enugu State of Southeastern Nigeria and lies at latitude 06°52'N and longitude 07°24'E; with a mean elevation 419 meters above sea level. The vegetation of the area can be described as derived savanna. The study site is within the humid tropical climate and has an annual rainfall of 2000mm. The rainfall pattern is bimodal and falls between April and October, while the dry season is between November and March. The area is characterized with mean annual minimum (night) and maximum (day)temperatures of 21^{o}C and 31^{o}C respectively, while the average relative humidity is rarely below 60 % (Asadu, 2000). The soil used for this study is deep, porous and has been classified as TypicKandiustult, derived from a false bedded sand stone (Akamigbo and Igwe, 1990).

Soil sampling and analysis: Top-soil from 0-15cm was collected at the research and experimental farm of the University of Nigeria, Nsukka. The samples were sieved using 2mm mesh. Some portions were analyzed for initial physico-chemical properties.

Preparation of composted empty oil palm bunch waste (EFB): Oil palm bunch refuse was shredded into smaller particle. The shredded bits were packed in windrows (aerated compartment) and mixed with poultry droppings in bunch waste to poultry dropping of 4:1 and palm oil effluent to increase microbial activity and reduce the carbon: nitrogen ratio. The heap was turned weekly and moistened with the effluent for proper decomposition. The composting process was lasted for 10 weeks after which the compost was analyzed and used as soil amendment. The overall procedure was the method adopted by Hang (1993) and Catton (1983).

Chemical analysis of the uncomposted and composted materials used for the study: Samples of the empty oil palm fruit bunch, palm oil mill effluent, poultry manure and the final compost were crushed and selected chemical properties such as pH, total N, avail P, exchangeable bases, and organic carbon were determined.

Establishment of oil palm seedlings: Pre-nursery polybag measuring 12.5x 25cm were filled with sieved topsoil and pre-sprouted oil palm seeds sourced from the Nigerian Institute for Oil Palm Research (NIFOR), Benin City were planted. At three leaf stages, i.e. after 10 weeks of growth at the pre-nursery, all healthy seedlings of uniform growth were selected and transplanted singly into each prepared main nursery poly bag measuring 40cm X 45cm. Before the transplanting operation, the soilsin the main nursery polybags were mixed thoroughly with composted oil palm waste according to the treatment levels and incubated for two weeks. Four rates of the composted material were applied at 0 g, 100 g, 200 gand 300 g per seedlings per polybag andarranged in a completely randomized design with five replications. Core and disturbed soil samples were collected from the polybags at 6 and 12 MAP for the determination of soil bulk density, dispersion ratio, total porosity and aggregate stabilityfollowing standard laboratory methods. Oil palm growth parameters were measured at 5, 8 and 12 MAP. Plant height which was measured as the distance from the soil surface to the tallest leaf and the number of leaves per seedlings was determined by counting the fully unfurled leaves on each plant. Stem girth was measured with a screw gauge placed at the maximum girth of the seedlings. The leaf area was estimated as the leaf length multiplied by its maximum width multiplied by 0.05 following, Harden *et al.* (1968)

Laboratory methods

Particle size distribution was determined bythe hydrometer method. Soil pH was determined in 1:2.5 soil to water ratio using pH meter (Maclean, 1965).Bulk density was measured by the core method, as described by Blake and Hartge (1986). Total porosity (t) was calculated from bulk density (Bd) value assuming a particle density (Pd) of 2.65gcm^{-3}. The dispersion ratio (DR) of Middleton as described by Mbagwu (1990) was used as an index to determine micro-aggregate stability.The distribution of water stable aggregate (aggregate stability) was estimated by the wet sieving technique described in detail by Kemper and Rosenau (1986).Total nitrogen was determined by kjeldahl method (Bremner, 1996) using selenium tablet as catalyst. Organic carbon was determined by chromic acid wet oxidation method of Nelson and Sommers (1982), while organic matter was determined by multiplying percentage organic carbon by 1.724. Available phosphorus was determined using Bray No 1 method (Bray and Kurtz, 1945). Exchangeable bases were determined by 1N neutral NH_4OAC saturation method of Grant (1982).

Data Analysis: The statistical analysis was performed using Genstat Statistical Package for the analysis of variance (ANOVA).Treatment means were compared using the Fisher's Least Significant Difference (F-LSD) at 5% probability

RESULTS

Table 1 shows the initial properties of the soil before treatment application. The soil was sandy loam with a high percentage of sand, low percentages of clay and silt. The textural class may negatively affect plant growth by exhibiting low water and nutrient retention capacities. The soil was low in pH, total N, available P, exchangeable K, Ca, Mg, Na and organic matter respectively.Table 2 showed the chemical properties of the materials used during the nursery media composting and composted oil palm bunch waste. Chemical analysis of the composted oil palm bunch waste showed higher nutrient composition in terms of total nitrogen available phosphorus, exchangeable bases and pH relative to the raw materials. The composted oil palm bunch waste had a lower C/N ratio compared to the raw oil palm bunch waste used for the composting (Table 2).

Table 1: Initial physico–chemical properties of the soil used for the study

Characteristics	Values
Fine Sand (%)	26
Coarse Sand (%)	50
Silt (%)	11
Clay (%)	13
Textural class	Sandy Loam
pH (H_20)	4.4
Total Nitrogen (%)	0.03
Organic Matter (%)	1.15
Organic Carbon (%)	0.67
Available Phosphorus (mg/kg)	9.14
Exchangeable potassium (cmol/kg)	0.06
Exchangeable Calcium (cmol/kg)	2.02
Aggregate stability (%)	42.84
Mean weight diameter (mm)	0.43
Hydraulic conductivity (cm/hr)	10.61
Bulk Density (g/cm^3)	1.56
Total Porosity (%)	41.29

Table 2: Chemical properties of the materials used for composting EFB and compostedEFB

Properties	Poultry Manure	POME	SOBW	Composted OBW
pH (H_20)	5.8	3.3	7.3	8.2
EC(ds/m)	18.80	7.44	10.44	5.4
Total nitrogen (%)	1.62	0.44	0.36	2.24
Potassium(cmol/kg)	1.05	0.49	1.30	9.81
Magnesium(cmol/kg)	0.32	0.07	0.24	3.12
Calcium (cmol/kg)	1.89	0.42	0.49	4.82
Phosphorus(mg/kg)	0.05	0.02	0.04	0.65
C/N ratio	0.39	7.00	35.47	17.85
Organic Carbon (%)	0.64	3.08	12.77	40.00

POME=Palm oil mill effluent, SOBW=Shredded oil palm bunch waste

Effect of treatment on soil physical properties

Bulk Density: Figure 1 shows main effect of composted EFB on bulk density at 6 and 12 MAP. At 6MAP, lowest (P<0.05) value was obtained at 300g composted EFB compared to other compost application rates. Similar trend was observed at 12MAP.

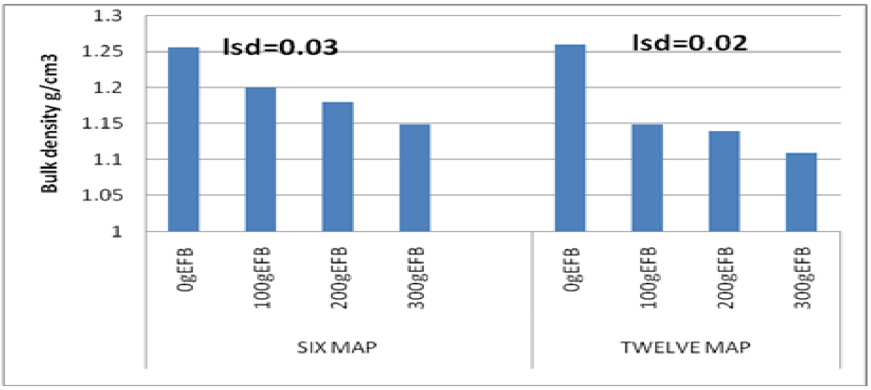

Fig 1: Main effect of composted EFB on bulk density at 6 and 12MAP

Dispersion ratio: Figure 2 showed main effect of composted EFB on dispersion ratio at 6 and 12 MAP. At 6MAP, lowest (P<0.05) value was observed at 300 g composted EFB compared to other compost application rates. Similar trend was observed at 12MAP

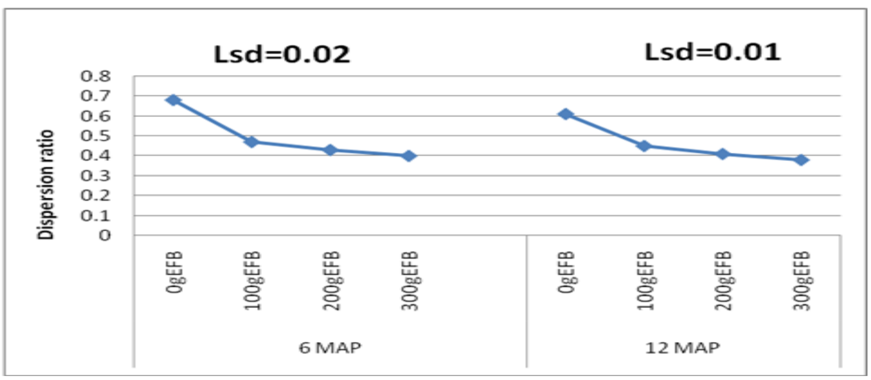

Fig 2: Main effect of composted EFB on dispersion ratio at 6 and 12MAP

Total porosity: Figure 3 showed main effect of composted EFB on total porosity at 6 and 12 MAP. At 6MAP, highest (P<0.05) value was obtained at 300 g composted EFB compared to other compost application rates. Similar trend was observed at 12MAP.

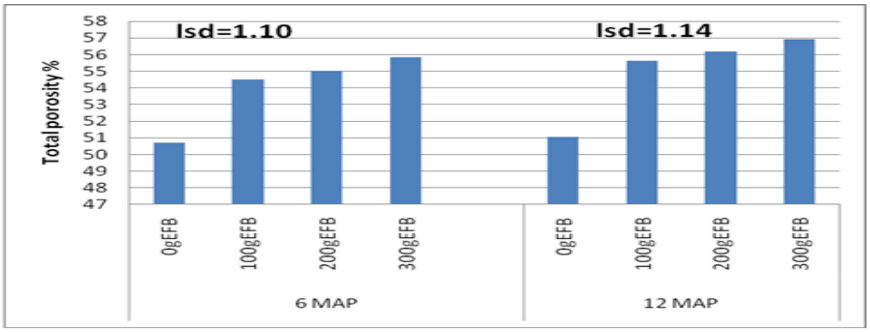

Fig 3: Main effect of composted EFB on total porosity at 6 and 12MAP

Aggregate stability: Figure 4 showed main effect of composted EFB on aggregate stability at 6 and 12 MAP. At 6MAP, highest (P<0.05) value was obtained at 300 g composted EFB compared to other compost application rates. Similar trend was observed at 12MAP.

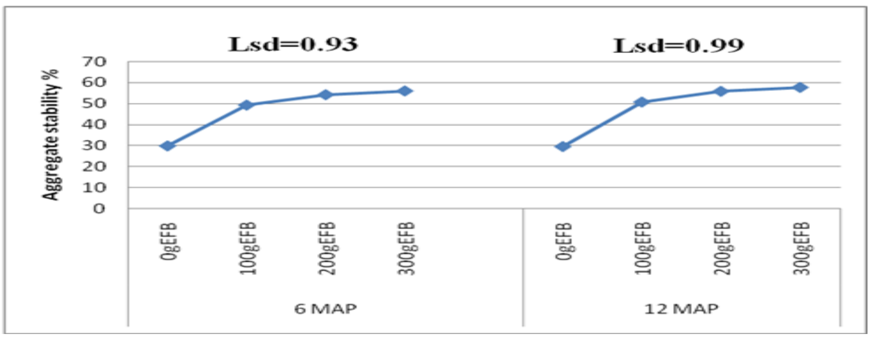

Fig 4: Main effect of composted EFB on aggregate stability at 6 and 12 MAP

Effects of treatment on growth of oil palm seedlings

Stem girth: At 5 MAP, highest (P <0.05)value was obtained at 300 g EFB. Similar trend were observed at 8 and 12 MAP (Fig 5)

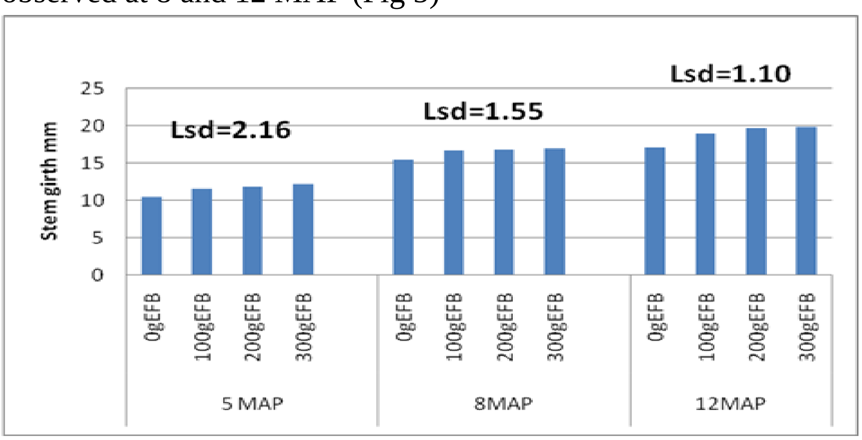

Fig 5: Main effect of composted EFB on stem girth at 5, 8 and 12 MAP

Height: At 5 MAP, highest (P < 0.05)value was obtained at 300 g EFB. Similar trend were observed at 8 and 12 MAP (Fig 6)

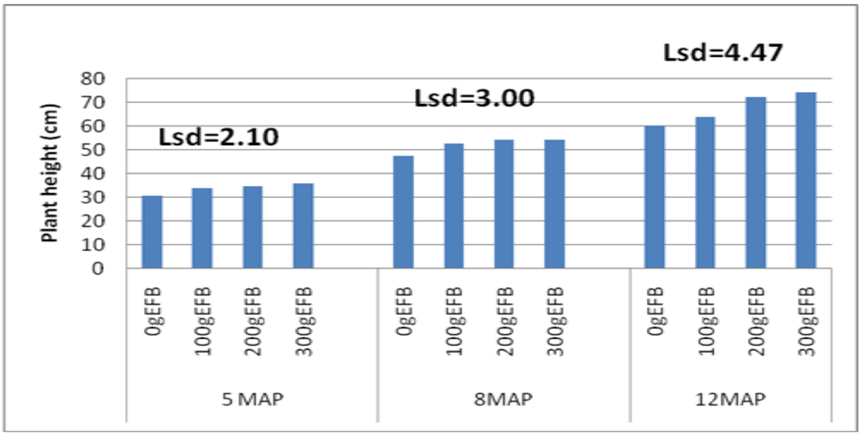

Fig 6: Main effect of composted EFB on stem girth at 5, 8 and 12 MAP

Leaf area: At 5 MAP, highest (P < 0.05)value was obtained at 300 g EFB. Similar trend were observed at 8 and 12 MAP (Fig 7)

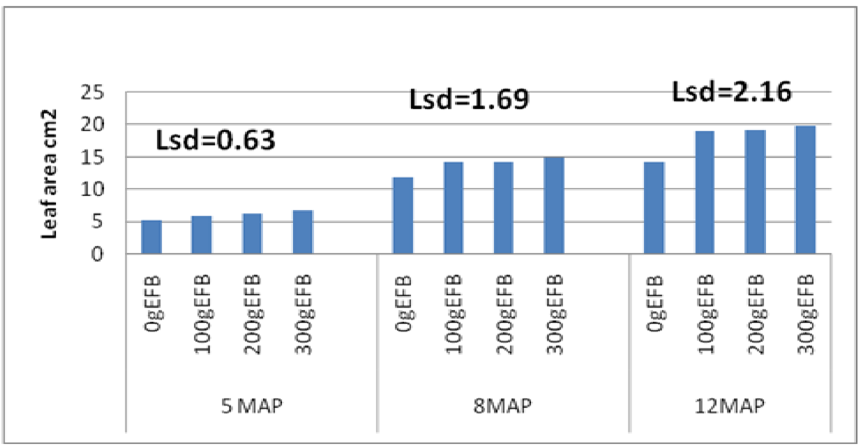

Fig 7: Main effect of composted EFB on stem girth at 5, 8 and 12 MAP

Leaf number: At 5 MAP, highest (P < 0.05)value was obtained at 300 g EFB. Similar trend were observed at 8 and 12 MAP (Fig 8)

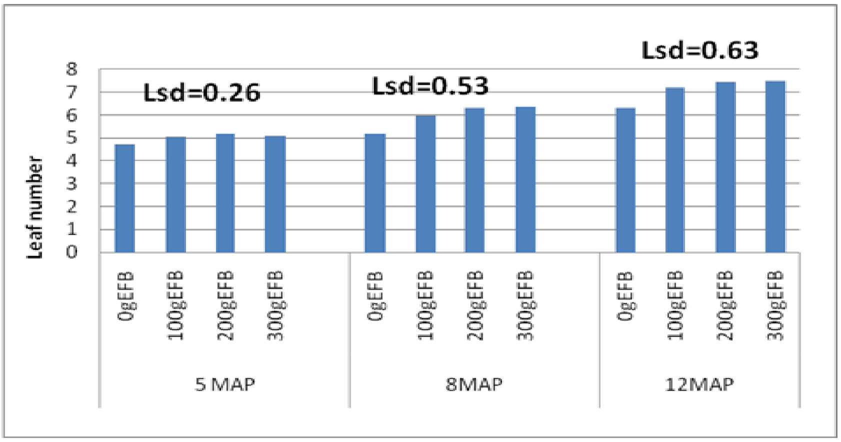

Fig 8: Main effect of composted EFB on stem girth at 5, 8 and 12 MAP

DISCUSSION

The relative high sand content of soil used for the study is a reflection of a sandy parent material. The parent materials of the soils of eastern Nigeria have been noted to influence the texture of the native soils (Akamigbo, 1983).A bulk density of 1.54g/cm^3 as observed in the initial soil physical properties showed a compacted soil and can create hindrances to root proliferation for nutrients (Ashrad*et al.*, 1996). Also, Brady and Weil (1999) noted that growth of roots into moist soil is generally limited by bulk densities ranging from 1.45Mg/cm^3 in clays to 1.85Mg/cm^3 in loamy sand. The relatively low pH, total N, available P, exchangeable K, Ca, Mg and soil organic matter content of the experimental soil confirmed the soil to be low in fertility (Ibeawuchi*et al.*, 2006). The observed low fertility status may be attributed to the high temperature prevailing in the area and is probably responsible for the low organic matter as it accelerates organic matter mineralization (Onweremadu*et al.*, 2008).

The observed improvements in nutrient composition of the composted material relative to the raw materials may be adduced to increase organic matter mineralization and humification brought about by the action of micro-organism. The composting makes the compost organic matter similar to soil organic matter (Senesi*et al.*, 1996).Similarly, Brady and Weil (2002) reported that finished compost is generally more concentrated in nutrients than the initial combination of raw material used.

The remarkable improvements in soil physical properties as observed with increasing rates of composted EFB may be attributed to improve soil structurewhich may have been brought about by an improved soil organic matter content. The decreased bulk density mayalso be as a result of increased microbial activities which may have led to the pulverization of the soil. This was associated with an increase in total porosity as was observed in this study. Previous studies (Kutu and Omueti, 2003; Aribe, 2003; Obe 2009) had established improvements of soil physical properties by the application of organic materials. Similarly, Lombin*et al.* (1971), Mbah*et al.* (2004) reported that organic materials improves soil fertility indices such as bulk density, porosity, aggregation, penetration resistance and cohesion force.

The enhancement in growth of oil palm seedlingsas observed with increasing rates of composted EFB may also be attributable to increased microbial activities and mineralization of nutrients induced by composted EFB addition. Giwa and Ojeniyi (2004) reported that organic material improved tomato growth with increased in soil organic matter, total N, available P and exchangeable K, Ca and Mg availability respectively. The low C/N ratio of 17.85 as observed with the composted EFB may have enhanced nutrients mineralization. This is line with the findings of Olayinka (2001) who observed that organic material having C/N ratio less than 30:1 encourages faster organic matter decomposition and ease of nutrient release. This further corroborates the findings of Ahmad *et al.* (2008) who reported that composed poultry manure improved morphological growth of plant due to the readily available nitrogen it supplied. Similarly, Juo and Kang (1989) reported that farmyard manure improved nutrient and water use efficiencies as well as yields of common crops in the tropics.The stunted growth as observed with the control may have resulted from decreased nitrogen availability and other essential plant nutrient as recorded in the initial soil chemical properties.

CONCLUSION

The study has demonstrated the effectiveness of using composted oil palm bunch wastes to improve on the physical properties and growth of oil palm seedlings raised the a degraded ultisol. Results revealed that soil bulk density,dispersion ratio, total porosity and aggregate stability significantly differed with composted oil palm waste addition. The application of 300 g per seedlings of the composted material had lowest ($p<0.05$) effect on soil bulk density, dispersion ratio and highest significant ($p<0.05$) effect on total porosity and aggregate stability throughout the sampling period. The application of composted oil palm waste significantly affected the growth of oil palm seedlings throughout the growth period. The application of 300 g per seedlings of the composted material showed highest ($p<0.05$) effect on all growth parameters of oil palm seedlings relative to other rates of amendment and the control.In this study,the application of 300g composted EFB was most effective in improving the selected physical properties and growth of oil palm seedlings raised on the degraded ultisol.

REFERECES

Babalola, O. and Obi, M. E. 1981.Physical properties of acid sands in relation to land use.In: Udo, E. J. and Sobulo, R. A. (ed) Acid sands of Southern Nigeria. Soil Science Society of Nigeria Special Publication Monography. 1: 27-55

Igwe, C. A., Akamigbo, F. O. R. and Mbagwu, J. S. C. 1995. Physical properties of soils of southeastern nigeria and the role of some aggregating agents on their stability. Soil Science Society of Nigeria. 160:431- 441

Mbagwu, J. S. C., Unamba-Oparah, I. and Nevoh, G. O. 1995.Physico-chemical properties and productivity of two tropical soils amended with dehydrated swine waste. Bioresources Technology.49:163-171

Ahmed, A. Y. 2000. Waste generation and management techniques. In: Jimoh, H. I. and Bababe, B. and Kwari, J. D. Appraisal of farmers' initiatives in the use of soil organic amendments in the sudan-sahel regions of Northeastern Nigeria. In: farmers and scientists in a changing Environment-assessing Research

Kang, B. T. and Spane, J. M. 1986.Management of Low Activity Clay (LAC) Soil with special reference to Alfisol, ultisols and Oxisols in the tropics. In: Proceedings of the symposium on low activity clay soils. Technical monograph No 14, Soil management support services, Washington D.C., U.S.A. Pp107-131.

Adediran, J. A., Akande, M. O. and Adeoye, G. O. 1999 Comparative effectiveness of organic manure and complimentary use of inorganic fertilizer on the growth of maize Africa Soils.SSSN.29: 41-57.

Ojeniyi, S. O. (2002). Soil management, Natural Resources and Environment.Adeniran Commercial press. Ibadan, Nigeria.Pg 12-20

Aoyama, M, Angers, D.A.,and Dayegamiye, A. N. 1999.Particulate and mineral associated organic matter in water-stable aggregates as affected by mineral fertilizer and manure applications.CanadianJournalof Soil Science. 79:295 – 302

Okusami, R.A., Rust, R.Hand Alao, A.O.1997. Red soils of different origins from southwest Nigeria: characteristics, classification and management considerations. Canadian Journal of Soil Science. 77: 295-307.

Blair, N.R., D. Fulkner, Till, A.R. and Poulton, P.R. 2005. Long-term management impacts on soil carbon, nitrogen and physical fertility. Soil and Tillage Research. 91:30-38.

Kundu, S.R., Bhattacharyya, V., Parkash, B.N., Ghosh and Gupta, H.S. 2006. Carbon sequestration and relationship between carbon addition and storage under rainfed soybean-wheat rotation in a sandy loam soil of the Indian Himalayas. Soil and Tillage Research. 92:87-95.

Cheng, F.J., Yang, D.Q. and Wu, Q.S. 1998. Physiological effects of humic acid on drought resistance of wheat.Chinese Journal of Applied Ecology.6:363 – 367.

Asadu, C.L.A. 2002.Fluctuations in the characteristics of an important short tropical season "August Break" In eastern Nigeria.Discovery and Innovation. 14:92-101.

Akamigbo, F.O.R., and Igwe C.A. 1990.Morphology, genesis and taxonomy of three soil series in eastern Nigeria.Samaru Journal of Agricultural Research. 7:33-48

Hang, R.T. 1980. The practical handbook of compost engineering, Lewis Publishers, ISBN 0-87371-373-7, Boca Raton (Florida).Catton, C. (1983).The Oil Palm.Longmans London 3rd edition.Pg 45-49

Harden, J.J., Williams, C and Watson I 1968. Leaf area and yield of the oil palm in Malaysia Expl Agric. 5: 25-32.

Maclean, E.O. 1965. Soil pH and lime requirement. In: A.L. Page et al (Ed.). Methods of Soil Analysis Part 2.2nd (Ed.) Agron. Mono. ASA and SSSA Madisson,W. I Mono. 9.

Blake, G.R. and Hertge, K.H. 1996. Bulk density: In methods of soil analysis. I (Ed.A Klute).America and Crop Science. 186:222-237

Mbagwu, J.S.C. 1990. Mulch and tillage effects on water transmission characteristics of an ultisol and maize grain yield in Southeastern Nigeria. Pedologie, XL-2.6, 155-168.

Kemper, D.W. and Rosenau, B. 1986.Aggregate stability and size distribution. In methods of soil analysis part I. (Ed. A. Klute) (American Society of Agronomy Madison WI). 9:425-442.

Brenner, J.M. 1996. Nitrogen-Total. In: D.L. Sparks (Editor) Methods of Soil Analysis Part 3-Chemical Methods, Soil Science Society of America. Book Series 5, Madison, Wisconsin, USA. Pp. 1085 – 1122.

Nelson, D.W. and Sommers, L.E. 1982. Total carbon, organic carbon and organic matter. In: D.L. Sparks (Editor). Methods of Soil Analysis Part 3 – Chemical Methods, American Society of Soil Science, Book Series 5, Madison, Wisconsin, USA. Pp. 961 – 1010.

Bray, R.N. and Kurtz, L.T. 1945.Determination of the organic and available forms of phosphorus in Soils. Soil Sci. 59:39-45.

Grant, W.T. 1982. Exchange cations. In: A Page et al (Eds). Methods of Soil Analysis.Part 2, 2nd (Ed).Agron.Mone ASA and SSSA, Madison W.I.

Akamigbo, F.O.R. 1983. The accuracy of field textures in a humid tropical environment. Soil Survey and Land Evaluation. 4(3):63-70.

Ashad, M., Lowery A. and Grossman, B. 1996.Physical test for monitoring soil quality. In: J.W. Doran and A.J. Jones (eds.) methods for assessing soil quality. Soil Science Society American Spec. Publishers. 49. Madison, WI: 123-142.

Brady, N.C. and Weil,R.R. 1999.The nature and properties of soils.Twelfth Edition. Prentice-Hall, Inc. New Jersey. Pp.144

Ibeawuchi, I.I., Onweremadu, E.U. and Oti, N.N. 2006. Effects of poultry manure on green (*Amaranthuscruentus)* and degraded ultisol of Owerri, Southeastern Nigeria. Journal of Animal and Veterinary Advances. 5(1): 53-56

Onweremadu, E.U., Ibeawuchi, I.I. and Duruigbo, C.I. 2008.Land Evaluation and productivity of organically fertilized crop mixtures in a degraded tropical soil.Nature and Science, 6(1): 34-42.

Senesi, N., Miano, T.M. and Brunetti, G. 1996. Humiculture substances in organic amendments and effects on native soil humic substances, in: A Piccolo (ed.), Humic substances in Terrestrial Ecosystems (Chapter 14).

Brady, N.C. and Weil,R.R. 2000.The nature and properties of soils.Thirteenth Edition.Pearson Education. Page 976

Kutu, F.R. and Omueti, J.A.I. 2003. Dynamics of soil organic matter fractions and maize grain yield under different residue management practices. Proceedings of the 28th Annual Conference of Soil Science Society of Nigeria. Pp. 136–143.

Aribe, S.N. 2003.Effects to tillage practices and crop residues management on soil fertility and maize yield.America Journal of Soil Science. 15 (3):21-26.

Obe, W.T. 2009.Fertilizer use under different residue management techniques.Fertilizer Research. 30: 281-286.

Lombin, I.G.,Adepetu, I.A. and Ayotade, A. 1991.Complementary use of organic manures and inorganic fertilizer in arable production. Proceedings of the 23rdNational Organic Fertilizer Seminar Held at Durbar Hotel, Kaduna, Nigeria. Pp. 146

Mbah, C.N., Mbagwu, J.S.C., Onyia, V.N. and Anikwe, M.A.N. 2004.Effect of application of biofertilizers on soil densification, total porosity, aggregate stability and maize grain yield in a dystricleptosol at Abakaliki. Nigeria Journal of Science and Technology 10:74-85

Giwa, D.D. and Ojeniyi, S.O. 2004. Effect of integrated application of pig manure and NPK on soil nutrient content and yield of tomato.Proceedings 29th Annual Conference of Soil Science Society of Nigeria, University of Agriculture, Abeokuta (UNAAB). Pp. 164-169.

Olayinka, A. 2001. Environmentally-friendly means of managing poultry litter. Invited paper presented at the Workshop "Improving Poultry Feed Supply and Litter Managerment" organized by Worlds Poultry Science Association, Nigeria Branch in Partnership with the Department of Animal Science, ObafemiAwolowo University, Ile-Ife, Nigeria, February 15.

Ahmad, R.M.,Arshad, Z.A., Zahir, M., and Asghar, H.N. 2008.Integrating n-enriched compost with biologically active substances for improving growth and yield of cereals.Pakistan Journal of Botany. 1:283-293.

Juo, A.S.R. and Kang, B.T. 1989. Nutrient effect of modification of shifting cultivation in West Africa In: Mineral Nutrients in Tropical Forest and Savanna Ecosystems. Pp. 289-299.