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Full Length Research Paper

Risk mitigation strategies and policy implications for carbon dioxide (CO_2) emission in organically- amended soils in Nigeria

Oladipo Oluwatosin Gbemisola[1]*, Olayinka Akin[2], Aladesanmi Omolara Titilayo[1], Sanni Maruf[1], Famurewa Akindele Joshua[1] and Siyanbola, William Owolabi[1]

[1]National Centre for Technology Management (NACETEM), Federal Ministry of Science and Technology, Obafemi Awolowo University, Ile–Ife Osun State, Nigeria.
[2]Department of Soil Science, Faculty of Agriculture, Obafemi Awolowo University, Ile – Ife Osun State, Nigeria.

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Global food security has been a challenge, especially in Africa. This has attracted the adoption of strategies to improve soil productivity and crop yield. One of such strategies is the use of solid wastes as soil organic matter amendments. An investigation of the effects of soil amendment using poultry manure, sawdust and their mixtures on carbon dioxide (CO_2) emission, maize (*Zea mays* L.) growth and dry matter yield were assessed under laboratory and greenhouse conditions. Top soil obtained from unfertilized plots at the Obafemi Awolowo University Teaching and Research farm, Ile-Ife, Nigeria was used for the experiments. The organic amendments were added at the rate of 10 g/kg, treatments were in triplicates and treatment means were separated using Duncan's Multiple Range Test at 95% level of significance. Results obtained revealed that CO_2 emission decreased while maize heights and dry matter yields significantly ($P > 0.05$) increased with increasing ratios of poultry manure in the poultry manure-sawdust mixtures. The CO_2 emission from poultry manure amended soil was about 61% that from sawdust amended soil while the mean height and dry matter yield in sawdust-amended soils were 84% and 52% respectively those obtained in poultry manure amended soil. This paper concludes that it is essential to design and implement policies that will guide and encourage the use of organic amendments at ratios that can enhance crop yield and mitigate CO_2 emission to the environment.

Key words: Food security, solid waste, carbon dioxide emission, organic amendments, environment and policy.

INTRODUCTION

The management of by-products that arise from man's agricultural, domestic and industrial activities have been an environmental challenge (Olayinka, 2009). A considerable percentage of urban wastes in developing countries are deposited either on or along the road sides, unapproved, open dump sites or in water ways (Olanike, 2003). This impairs environmental aesthetics and results in the pollution and contamination of the atmosphere, underground and surface water bodies (Kalu et al., 2009).

The use of organic wastes to improve soil fertility in developing countries has become an essential alternative to the costly inorganic fertilizers which are beyond the reach of farmers (Moyin-Jesu, 2008). Organic wastes are sources of plant nutrients like N, P, S, K, Ca and Mg needed for improved soil fertility, plant growth and yield (Oladipo et al., 2005; Olayinka, 2009). Land application of organic wastes is a good option as their indiscriminate dumping can cause environmental pollution (Olanike, 2003; Kalu et al., 2009).Nitrogen and phosphorus are the major nutrients released for plant uptake as a result of the decomposition of organic amendments by heterotrophic micro organisms added to the soil (Paul, 2007).

Carbon dioxide (CO_2) released into the atmosphere as a consequence, is an important greenhouse gas involved in global warming (Turley et al., 2005). Its most significant

*Corresponding author: E-mail: thosyney2k1@yahoo.co.uk, tosin.oladipo@nacetem.org. Tel: +234 802 930 1622.

Table 1. Results of soil analysis before planting.

Property	Value
Sand (%)	75
Silt (%)	5
Clay (%)	20
Textural class	Loamy sand
pH (1:2 soil - 0.01 M $CaCl_2$)	6.55
Organic carbon (%)	1.58
Total N (%)	0.20
Available P (mg $kg^{-}1$)	43.2
Exchangeable cations (c mol $kg^{-}1$)	
Ca	7.06
Mg	3.00
Na	1.04×10^{-2}
K	0.39

anthropogenic sources are found in the energy sector (mainly fossil fuel combustion) and industrial processes like cement production (Ramanathan et al.,1987; UNDP, 2005). Some of the greatest effects of global warming are the spread of diseases, warmer waters and more hurricanes, increased probability and intensity of droughts and heat waves, economic consequences and melting of polar ice caps. The mitigation of CO_2 emissions has been found to decrease the rate and extent of ocean acidification (Royal Society, 2005). The oceans are recognized buffers for limiting atmospheric CO_2 concentrations however, acidification reduces their capacity to absorb CO_2 thereby increasing the potential to affect a wide range of marine biogeochemical and ecological processes (Turley et al., 2005).

Poultry manure and sawdust are solid organic wastes. While sawdust has high lignin, cellulose and pectin content with characteristic high C:N ratio and generates large volumes of CO_2 on decomposition, poultry manure has a low C:N ratio which has the potential of reducing the volumes of CO_2 produced. Sawdust being carbonaceous immobilizes plant nutrients. On the other hand, poultry manure which is rich in N and P, encourages their mineralization and supports crop production and yield (Motavalli et al., 2001; Moyin–Jesu, 2002; Oladipo et al., 2005; Olayinka, 2009).

In order to control the problems of waste management and pollution, governments have instituted appropriate legislations. To this end, the Federal Government of Nigeria established the Federal Environmental Protection Agency (FEPA) in 1988 (Onibokun and Kumuyi, 2003). The FEPA was transformed to the Federal Ministry of Environment (Adegoke, 2005) and later the National Environmental Standards and Regulations Enforcement Agency (NESREA) in 2007. The limited success of environmental policies in Nigeria has been attributed to the sheer lack of a management framework exhibited through poor implementation (Nwaka, 2005).

Sawdust and poultry manure are organic wastes that have contrasting characteristics and if independently utilized as manure to increase food production or indiscriminately disposed off could cause environmental imbalance. There is therefore a need for their proper management in order to mitigate soil, water and air pollution. Policy makers need to be enlightened on such uncommon sources that can increase atmospheric CO_2 concentration.

The objectives of this study was therefore to determine which applications of poultry manure, sawdust and their mixtures will enhance crop growth and yield with minimal CO_2 emission and also to enlighten policy makers on optimum organic waste re-use strategy that can mitigate soil, water and air pollution.

MATERIALS AND METHODS

Soil sample and organic amendments

A bulk of soil sample of Apomu series (Oxic Tropudalf) was collected from unfertilized plots that had carried cassava for the past decade from unfertilized plots at the Obafemi Awolowo University Teaching and Research Farm, Ile –Ife, Nigeria (Latitude 7°25' N and Longitude 4°39' E) at 0 - 15 cm depth. The sample was air-dried and sieved through 2 mm mesh. Particle size analysis was carried out using the hydrometer method (Bouyoucos, 1962). Soil reaction pH was measured potentiometrically in a soil-solution ratio of 1:2 in 0.01 M CaCl2 solution using a pH meter. Organic Carbon was determined using the Walkley and Black (1934) method. Total N was determined using kjeldahl procedure followed by steam distillation (Bremner, 1965; Bremner and Keeney, 1966). Available P was extracted using Bray-1 method (Bray and Kurtz, 1945) and was determined colourimetrically at 660 nm after development of molybdenum blue colour. Exchangeable cations (Ca, Mg, K and Na) were extracted with 0.01 M NH_4OAc solution at pH 7.0. Magnesium (Mg^{2+}) and calcium (Ca^{2+}) ions in the extract were then determined using Perkin Elmer model 703 Atomic Absorption Spectrophotometer (AAS) while potassium (K^+) and sodium (Na^+) were determined using Gallenkamp model FH 500 Flame Photometer.

Poultry manure was obtained from a commercial poultry farm and sawdust of *Albizia zygia* (Engl.) was obtained from a local sawmill in Ile-Ife. Both were air-dried and passed through 2 mm mesh. The chemical compositions of the poultry manure and the sawdust are presented in Table 1. The treatments used for the experiments are as follows:

1. Control (No amendment)
2. Poultry manure (PM)
3. Sawdust (SD)
4. PM + SD (4:1)
5. PM + SD (2:1)
6. PM + SD (1:1)

Laboratory incubation experiment

Each treatment was incubated in the laboratory by dissolving it in distilled water into 500 ml glass jar in triplicates and wetted to 60% of the field moisture capacity (FMC) and arranged in Completely Randomized Design (CRD). Vials containing 10 ml of 1 M NaOH was lowered by means of threads into the glass jar, which was then tightly capped. The treatments including the control were incubated for a period of 16 weeks at 30°C. Every fortnight, the CO_2 evolved

Table 2. Chemical compositions (% dwb) of the poultry manure and sawdust used for the laboratory and greenhouse experiments.

Chemical components (%)	Poultry manure	Sawdust
C	14.42	26.02
N	1.84	0.37
P	2.76	0.86
K	2.50	7.81
Ca	3.00	1.15
Mg	1.01	0.34
Na	0.25	1.75
C:N*	8.00	70.00

* Values not in percentage.

was determined using the double acid titration method of Jackson (1958).

Greenhouse experiment

Air-dried poultry manure (PM) and sawdust (SD) were mixed in the ratios 4:1, 2:1 and 1:1 and were added at the rate of 10 g/kg which is equivalent to 24 t/ha to 5 kg of soil on dry weight basis (dwb) and thoroughly mixed. The treatments in triplicates, were thoroughly mixed with the soil and transferred into 5 L plastic pots, which were perforated at the bottom for free exchange of air and drainage. The treatments were allowed to incubate for three weeks in order to stabilize the organic matter and mobilize nutrients (Olayinka and Adebayo, 1989). The treated pots were then arranged in a Randomized Complete Block Design (RCBD). Three maize *(Zea mays* L.*)* seeds were planted per pot. The seedlings were thinned to one per pot two for weeks after planting. The pots were wetted to 75% of water holding capacity every other day. The seedlings were allowed to grow for 8 weeks in the first instance. After height measurements, the seedlings (shoots and roots) were harvested destructively. In the second instance, maize seeds were planted again and the seedlings were allowed to grow for 8 weeks in order to assess the residual effects of the treatments.

Statistical analyses

Statistical analyses of all data collected were carried out using one –way ANOVA. Separation of means was done using carried Duncan's multiple range test at 5% level of probability.

RESULTS AND DISCUSSION

Soil physical and chemical analyses

The soil is loamy sand and slightly acidic (pH 6.6). The organic C, total N and available P contents of 1.58 and 0.20%, and 4.32 mg/kg, respectively are low. The soil also contained low amounts of exchangeable Ca, Mg, K and Na with values of 7.06, 3.00, 0.39 and 1.04 × 10^{-2} c mol (+) /kg, respectively. The detail of the soil physical and chemical analysis is shown on Table 1.

Organic amendments

The chemical composition of sawdust and poultry manure shows that sawdust has a high carbon content of 26.02% while poultry manure is 14.42%. Also, poultry manure has a higher N content with a value of 1.84% while sawdust is 0.37%. This trend also applies to the available P present in poultry manure (2.76%) and sawdust (0.86%). The chemical compositions of the amendments are presented in Table 2.

Carbon dioxide evolution

The pattern of CO_2 evolved and its cumulative amounts from soils treated with organic amendments over a period of 16 weeks are presented in Figures 1 and 2 respectively. Flushes of CO_2 evolution were observed in all the treatments during the first 4 weeks with lower amounts in poultry manure treatments. The flushes were progressively lower as the quantity of poultry manure increased in treatments containing poultry manure. The cumulative CO_2 evolved in soils amended with sawdust alone (89.5 mg/100g of soil) was significantly ($P > 0.05$) higher than in all other treatments (Figure 2). The emission from poultry manure-amended soil was about 61% that from sawdust – amended soil. This trend confirms the fact that sawdust is carbonaceous and therefore released CO_2 in larger quantities (Motavalli et al., 2001; Moyin–Jesu, 2002; Oladipo et al., 2005; Olayinka, 2009). In treatments PM + SD 4:1, PM + SD 2:1 and PM + SD 1:1, CO_2 emission decreased with increasing amount of poultry manure. This could be attributed to the fact that poultry manure has low C:N ratio (Oladipo et al, 2005; Olayinka, 2009). This confirms the ability of poultry manure to act as a buffer in reducing the quantity of CO_2 emissions (Oladipo et al., 2005; Olayinka, 2009).

Growth and dry matter yields of maize

Table 3 shows the heights and dry matter yields of maize at the end of two successive cropping periods. Maize heights for PM, PM + SD (4:1) and PM + SD (2:1)

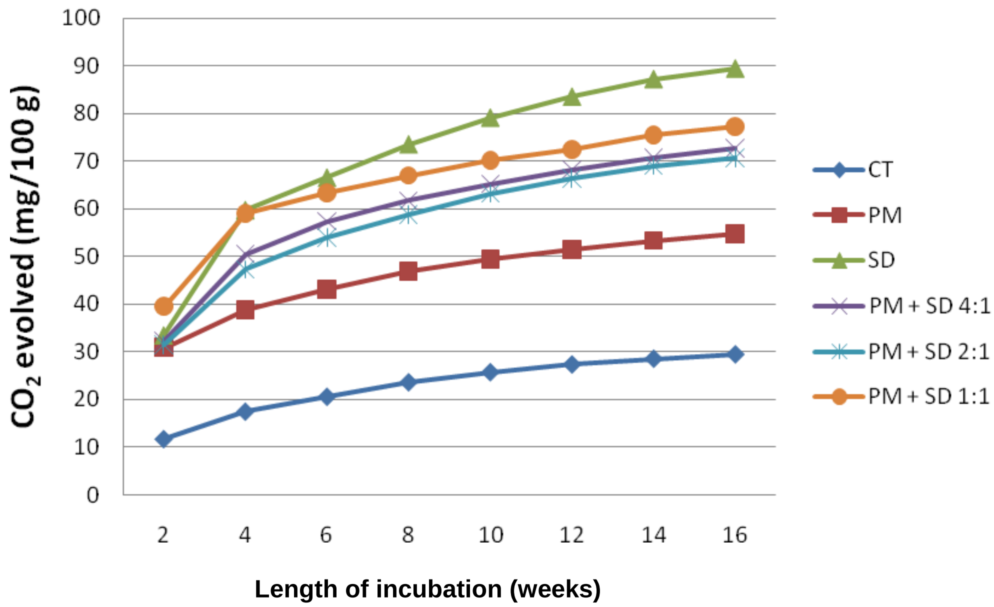

Figure 1. Pattern of CO_2 evolved from soil with and without organic amendments over a 16-week period of incubation at 30°C.

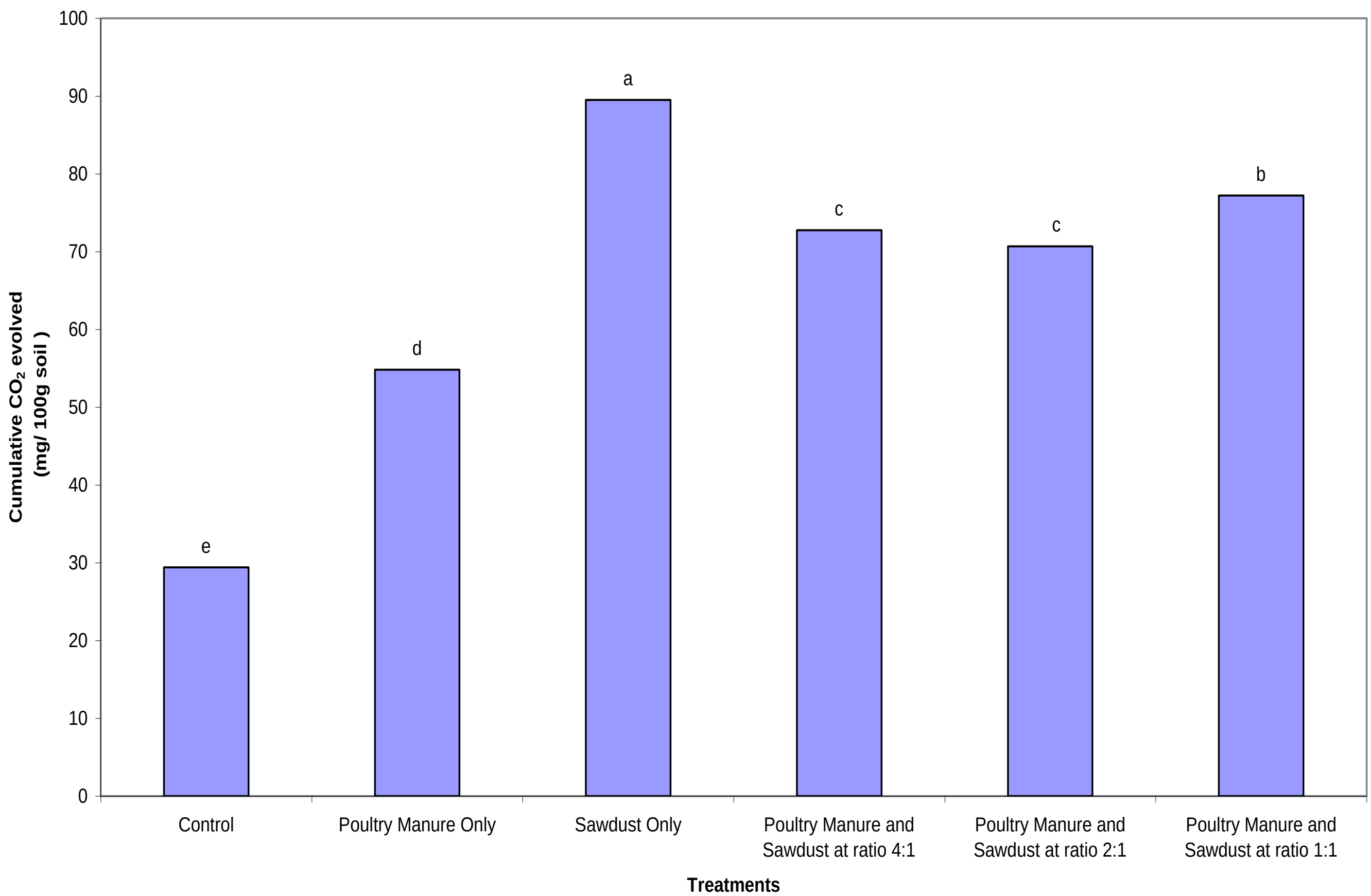

Figure 2. The cumulative amounts of CO_2 evolved (mg/100 g) from treatments at the end of 16 weeks of incubation at 30°C (Bars with same letters are not significantly different {$P < 0.05$} according to Duncan's multiple range test).

Table 3. Effects of organic amendments on heights (cm) and dry matter yields (t/ha) of maize (*Zea mays* L.) at the end of the first (1) and second (2) growth periods in the greenhouse.

Treatments	Plant heights (cm)		Dry matter yields (t/ha)	
	1	2	1	2
Control (CT)	115.0d*	76.8b	0.18d	0.14e
Poultry Manure (PM)	129.5a	83.1a	0.30a	0.30a
Sawdust (SD)	104.3e	75.0c	0.15e	0.16d
PM + SD (4:1)	123.0c	83.2a	0.24b	0.26b
PM + SD (2:1)	124.0b	81.8ab	0.23b	0.24b
PM + SD (1:1)	123.5b	79.5abc	0.20c	0.19c

* Means followed by the same letters each column are not significantly different {P < 0.05} according to Duncan's new multiple range test.

applications were significantly (P > 0.05) higher than those obtained with CT, SD and PM + SD (1:1). Also, there was no significant (P < 0.05) difference between PM and PM + SD (4:1). The mean maize height in sawdust-amended soil was 84% that in poultry manure-amended soil. Although, sawdust has been found to cause N and P immobilization (Olayinka and Adebayo, 1985, 1989), its content in PM + SD (4:1) was apparently not large enough to cause appreciable nutrient immobilization. This further show that sawdust and poultry manure additions can achieve the expected plant growth without disrupting the environmental balance which poultry manure alone can achieve with higher risk of soil and water pollution due to excessive release of N and P (Motavalli et al., 2001; Oladipo et al*.,* 2005; Olayinka, 2009). The height obtained with SD treatment was significantly (P < 0.05) lower than those of other treatments except PM + SD (1:1) that showed no significant difference. This may be due to the low content of poultry manure in this treatment PM + SD (1:1). The significantly lower plant heights obtained with SD can be attributed to immobilization of nutrients due to its carbonaceous nature (Brady and Weil, 1999; Moyin-Jesu, 2002). Similar findings had been reported by Oduekun (2003), Oladipo et al. (2005) and Olayinka (2009).

However, using the same amended soil for the second time, there was a general decrease in plant height at the end of the second planting period. This can be attributed to the fact that the plants depended on residual nutrients after the first set of plants had exhausted the available nutrients.

For the dry matter yields, similar trends as that of the plant heights were obtained for the treatments at the ends of both plantings. The dry matter yields obtained from the control at the end of both plantings were significantly (P < 0.05) lower than all the other treatments. The dry matter yields obtained with PM at the end of both plantings were significantly (P < 0.05) higher than those of other treatments but closely followed by PM + SD (4:1) and PM + SD (2:1). However, due to the fact that poultry manure has the tendency to release excess N and P above plant requirements (Motavalli et al., 2001; Oduekun, 2003; Oladipo et al*.,* 2005; Olayinka, 2009), it may not therefore be the best option. It was also found that at the end of both plantings, the dry matter yields increased in the poultry manure - sawdust treatments as the ratio of poultry manure increased. The mean dry matter yield obtained in sawdust-amended soil was about 52% that from poultry manure – amended soil.

CONCLUSION AND POLICY RECOMMENDATION

The laboratory and greenhouse studies showed that a mixture of poultry manure and sawdust treatments is environmentally safer than treatments of sawdust and poultry manure alone. The poultry manure and sawdust amended soils had significantly (P > 0.05) higher maize heights and dry matter yields and at the same time released significantly (P < 0.05) lower amounts of CO_2 emissions. Poultry manure and sawdust additions especially PM + SD 4:1 and PM + SD 2:1 combined the good qualities of poultry manure and sawdust, while their poultry manure content enhanced the release of N and P which supported crop growth and yield and reduced the excessive release of carbon dioxide, a recognized greenhouse gas. In conclusion, combining poultry manure with sawdust is environmentally friendly. Policy makers are urged to provide guidelines on re-use strategies of wastes as soil organic matter amendments to achieve improved plant yield as well as mitigate soil, water and air pollution.

REFERENCES

Adegoke A (2005). The Challenges of environmental enforcement in Africa: The Nigerian Experience. In: Third International Conference on Environmental Enforcement, pp. 43 – 54.

Bouyoucos GF (1962). Hydrometer method improved for making particle size analysis of soils. Agron. J., 54:464 – 465.

Brady NC, Weil RR (1999). The Nature and Property of Soils. Prentice-Hall, Upper Saddle River. New Jersey, pp. 1-880.

Bray RH, Kurtz LT (1945). Determination of total organic and available forms of Phosphorus in Soils. Soil Sci., 59: 39-45.

Bremner JM (1965). Total Nitrogen. In; C.A. Black (ed.), Methods of Soil Analysis, Part 2 American Society of Agronomy, Madison, WI, pp. 1149 -1178.

Bremner JM, Keeney DR (1966). Determination of nitrogen in soils: 3. Exchangeable ammonium, nitrate and nitrite by extraction-distillation methods. Soil Sci. Soc. Am. Proc., 30: 577-582.

Jackson ML (1958). Soil Chemical Analysis, Prentice-Hall Inc., Englewood Cliffs, New Jersey.

Kalu C, Modugu WW, Ubochi I (2009). Evaluation of solid waste management Policy in Benin Metropolis, Edo State, Nigeria. Afr. Sci., 10: 1-7. Klobex Academic Publishers, Nigeria.

Motavalli P, Marler T, Cruz F, Mc Connell J (2001). Fertilizer Facts-Forms of Fertilizers and other Soil Amendments. Soil Science Programs, College of Agriculture and Life Sciences, University of Guam, U.S.A.

Moyin-Jesu EI (2002). Raising of oil palm seedlings in urban cities using sole and amended forms of wood ash saw dust. J. Trop. Agric. Sci. Pertanika, 25(2):31-37.

Moyin-Jesu EI (2008). Evaluation of different organic fertilizers on the soil, leaf chemical composition and growth performances of coffee seedlings (*Coffee Arabica* L.). Afr. J. Sci. Eng., 9(2):105 – 112.

Nwaka IG (2005). The urban informal sector in Nigeria: Towards economic Development, environmental health and social harming. Global Urban Dev. Mag., 1(1): 1-24.

Oduekun OG, (2003). Effects of some organic amendments on soil chemical properties and microbial activity. A M.Sc. Thesis of the Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile – Ife, Nigeria.

Oladipo OG, Olayinka A, Aduayi EA (2005). Effects of organic amendments on microbial activity, N and P mineralization in an Alfisol. Environ. Manage. J., 2: 30-40.

Olanike KA (2003). Consequences of pollution and Degradation of Nigerian Aquatic Environment on Fisheries Resources. Environmental, 23(4): 297-306.

Olayinka A (2009). Soil Micro organisms, Wastes and National Food Security. Inaugural Lecture Series 222 of Obafemi Awolowo University, Ile-Ife, Nigeria.

Olayinka A, Adebayo A (1985). The effect of methods of application of sawdust on plant growth, plant nutrient uptake and soil chemical properties. Plant Soil Chem. Prop., 86: 47 – 56.

Olayinka A, Adebayo A (1989). Effect of pre-incubated sawdust-based cow dung on growth and nutrient uptake of *Zea mays* (L.) and on soil chemical properties. Biol. Fertil. Soils, 7: 176 – 179.

Onibokun AG, Kumuyi AJ (2003). International Development Research Centre: Science for Humanity. Ch 3. Ibadan, Nigeria.

Paul EA (2007). Soil Microbiology, ecology and biochemistry. 3^{rd} Edition. Academic Press, Oxford, United Kingdom.

Ramanathan V, Callis L, Cess R, Hansen J, Isaksen I, Kuhn W, Lacis A, Luther F, Mahlman J, Reck R (1987). Climate-Chemical Interactions and Effects of Changing Atmospheric Trace Gases. Rev. Geophys., 25:1441 –1482.

Royal Society (2005). Ocean acidification due to increasing atmospheric carbon dioxide. Document 12/05 Royal Society: London.

Turley C, Blackford JC, Widdicombe S, Lowe D, Nightingale PD, Rees AP (2005). Reviewing the impact of increased atmospheric CO_2 on oceanic pH and the marine ecosystem. Defra, 21(26): 65–70.

United Nations Development Programme (UNDP) (2005). Technological needs assessment report under project: climate change enabling activity (Phase II). Republic of Croatia.

Walkley A, Black IA (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci., 37: 29-38.