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DETERMINATION OF MINERALIZATION RATE OF ORGANIC MATERIALS USING CARBON DIOXIDE EVOLUTION AS AN INDEX

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ABSTRACT

A study was conducted on a sandy loam soil to determine the rate of CO_2 release by Kola Pod Husk (KPH) and Pacesetter Grade B (PGB) (sorted city waste plus cow dung) in southwest Nigeria. Each of KPH and PGB was applied at 0.25 g to 50 g soil; and control without treatment application was incubated for 16 weeks. The treatments were replicated four times on a completely randomized design. Evolution of CO_2 by all the treatments increased as the period of incubation increased from the first week to the 5th week of the experiment. After the 6th week, PGB decreased CO_2 at 7th and 8th week and increased it between 9th and 11th week and thereafter finally decreased it as incubation period progressed. KPH decreased CO_2 between 7th and 8th week and then increased it from 9th - 11th week before the CO_2 finally declined till the termination of the experiment. Compared with control, KPH and PGB significantly ($P<$ 0.05) increased CO_2 evolution. The rate of mineralization in the first 1-7 weeks of incubation was in the order of PGB > KPH> control, while the last 12-16 weeks of incubation was in the order of KPH>PGB> control. Pacesetter Grade B reached its peak of CO_2 evolution at 9th week of incubation while KPH reached its peak at 13th week of incubation. Grade B pacesetter had the highest CO_2 emission.

Keywords: Kola pod husk, Pacesetter Grade B Fertilizer, organic carbon, soil nutrients

1. INTRODUCTION

Most Nigerian soils are low in native nutrient content and soil organic matter. They are however high in clay content of Kaolinic (1:1) type (Ogunwale *et al*., *2002).* The soils are hence low in cation exchange capacity and are not able to retain adequate amount of nutrients, they therefore require split application of fertilizers to be able to support good crop

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growth (Agboola *et al.,* 1981). The procurement costs of the fertilizers are higher than what an average Nigerian farmer can afford (Agbede and Kalu, 1995). The few rich farmers that could afford the procurement of the fertilizer could not get adequate quantity from the market. Most of the raw materials needed for local production are imported at exorbitant cost (Fagbenro and Agboola, 1983). In addition, there has been recent clamour for organic foods and agricultural products in the world market (Pawar *et al.,* 2003). The need to increase the soil organic matter content for sustainable Nigerian agricultural soils (Lombin, 1981; Ogunwale *et al.,* 2002) coupled with the problems above has called for a shift from the use of inorganic fertilizer to the use of organic fertilizers where organic fertilizers are in abundant.

Organic materials are capable of promoting crop growth and increasing yield by way of improving soil physical, chemical and biological properties (Titiloye *et al*., 1985; Wallace, 1994, Lal, 2006,). Organic fertilizers improve the physical properties of soils; maintain the soils in better tilth with; increases water holding capacity (Agboola and Omueti, 1982; Lal, 1986; Ogunwale *et al*., 2002) and supplies both major and minor plant nutrients (Ayeni, 2011, Ayeni *et al*., 2008, Pettit, 2006). The supplied nutrients can substitute for appreciable amounts of inorganic fertilizer (Tollesa, 1999, Bell 2005, Fisher 2005, Kirkby *et al.* 2006).

Over the years, various organic materials have extensively been used as fertilizers and their beneficial effects documented. They have subsequently been recommended as sources of nutrient supply to farm crops. It is observed that since the introduction of inorganic fertilizers into the Nigerian agriculture, in-depth research into the use of organic fertilizer as sources of plant nutrients for i.e., the rate of decomposition of organic materials has not been adequately determined. Although some information on the mineralization of compost is available as reported by Van De Kerkove (1990) and cited by Jedidi *et al* (1993), but there is scanty information on the rate of Kola pod husk and Pace setter organic fertilizer in south western Nigeria. This study was therefore set up to compare the rate of decomposition of industrially manufactured organic fertilizer called Pacesetter Grade B and Kola Pad Husk, using CO_2 evolution as an index.

2. MATERIAL AND METHODS

Kola Pod Husks (KPH) and Pacesetter Grade B fertilizer (non fortified sorted city wastes plus cow dung, PGB) were used for the conduct of the experiment. The KPH was obtained from the Kola processing unit of Cocoa Research Institute of Nigeria (CRIN) and PGB fertilizer was obtained from the Pacesetter Fertilizer Plant at Bodija, Ibadan Nigeria.

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Kola Pod Husk (KPH) was sun dried to constant weight and milled to pass through 2 mm sieve before analysis.

The CO_2 evolution as index method was used to compare the mineralization potential of the various amendments. The carbon dioxide evolution study was carried out according to the procedure described by Moorhead *et al.* (1999) and adopted by Ipinmoroti *et al* (1997). Fifty grams of 2 mm sieved soil were weighed into each of the 12 incubation flasks, with four flasks representing each of the two organic materials and the control without organic material addition. Each of the milled organic materials was weighed and mixed with soil in the flasks at the rate equivalent to 10 tonnes ha^{-1} (i.e. 0. 25 g per 50 g soil). Each treatment was replicated four times. The treated soil in each flask was moistened to 70 % field capacity of the soil and incubated in the laboratory at temperature of 28℃. Absorbent was used to cover the mouth of each flask in order to reduce evaporation or gaseous escape. The moisture content was adjusted fortnightly with de-ionized water. The carbon dioxide evolved from the flasks was collected in a bottle containing 25 ml of 0.1 M $Ca(OH)_2$. The amount of carbon dioxide evolved was determined by titration with 0.05 M HCl, using phenolphthalein as indicator.

The amount of carbonate evolved was calculated using the following equation:

meq of CO_2 = 0.2727(25 – (titre x f) 0.027

$$f = \frac{\text{volume of } Ca(OH)_2}{\text{Blank titre}}$$

meq of C = equivalent weight of C Molarity of $Ca(OH)_2$

Where 0.2727 = ratio of carbon in carbon dioxide

25ml = Volume of $Ca(OH)_2$ in the flask/bottle

The soil pH was determined in 1:2.5 soil/water ratio and read with pH meter. Total N was determined by the normal Microckjedahl method soil OC was determined by wet dichromate oxidation method (Jackson, 1958). Available P was determined by Bray -1- method. Exchangeable K, Ca, Na and Mg were extracted with 1N ammonium acetate at pH 7. Exchangeable K was determined by flame photometer while Ca and Mg were determined by Atomic Absorption Spectrophotometer (AOAC, 1990) Exchangeable acidity was extracted by 0.1M KCl before titrated with 0.1M HCl. The micronutrients (Mn , Fe, Cu and Zn) were extracted with HCl and determined by AAS. The ECEC was determined by the summation of the cations. Ground KPH was ashed in muffle furnace before digested with mixture of nitric-sulphuric- perchloric acid for the extraction of P, K, Ca and Mg (A O A C, 1990). Nitrogen was determined by the normal microckjedahl method

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Data obtained were analysed using ANOVA. Least Significant Difference (LSD) was employed to separate the differences among the treatments at $P < 0.05$.

3. RESULTS AND DISCUSSION

Kola Pod Husks (KPH) and Pacesetter Grade B fertilizer (non fortified sorted city wastes plus cow dung, PGB) were used for the conduct of the experiment. The KPH was obtained from the Kola processing unit of Cocoa Research Institute of Nigeria (CRIN) and PGB fertilizer was obtained from the Pacesetter Fertilizer Plant at Bodija, Ibadan Nigeria. Kola Pod Husk was sun dried to constant weight and milled to pass through 2 mm sieve before analysis.

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The amount of carbonate evolved was calculated using the following equation:

meq of $C0_2$ = 0.2727(25 – (titre x f) 0.027

$$f = \frac{\text{volume of } Ca(OH)_2}{\text{Blank titre}}$$

meq of C = equivalent weight of C Molarity of Ca $(OH)_2$

Where 0.2727 = ratio of carbon in carbon dioxide

25ml = Volume of Ca $(OH)_2$ in the flask/bottle

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Data obtained were analysed using ANOVA. Least Significant Difference (LSD) was employed to separate the differences among the treatments at $P < 0.05$.

RESULT AND DISCUSSION

The initial properties of the soil used for the incubation study (Table 1) indicated that the soil was slightly acidic, low in total N, C/N ratio, K, Ca and Mg (Agboola *et al*., 1980). The soil was adequate in available P, Fe and Mn. This indicates that the soil is poor in plant nutrients, thus; the soil needs fertilization

Table 1: Some physical and chemical characteristics of soil used in the study

Parameters	Soil
pH (H_2O)	5.3
Total N (g kg^{-1})	1.3
Organic Carbon (g kg^{-1})	10.5
C/N ratio	7.7
Available P (mg kg^{-1})	8.3
Exchangeable bases (c mol kg^{-1})	
K	0.2
Ca	0.2
Mg	0.2
ECEC	0.7
H + Al	0.1
% Base Saturation	84.5
Micronutrients (mg kg^{-1})	
Mn	
Fe	21.0
Cu	11.0
Zn	1.5
Particle size analysis (g kg^{-1})	10.1
Sand	
Silt	
Clay	912
Texture Class	54
	34
	Sandy Loam

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Table 2: Chemical properties of PGB and KPH

Nutrients	Pacesetter Grade B (PGB)	Kola Pod Husk (KPH)
pH (H_2O)	6.5	6.8
C:N	13.19	24.8
%		
N	1.46	1.06
C	19.55	26.05
P	0.92	1.11
K	5.83	7.65
Ca	0.33	0.38
Na	0.15	0.2
Mg	0.28	0.28
$mgkg^{-1}$		
Zn	10.4	11.0
Cu	1.9	2.0
Mn	30.0	31.0
Fe	11.0	11.1

In figure 1, evolution of CO_2 by the control experiment, KPH and PGB increased as the period of incubation increased from the first week up to the fifth week of the experiment. The control experiment decreased the volume of CO_2 produced as from the sixth week to the 16^{th} week when the experiment was terminated.

There was reduction in the volume of CO_2 produced by the PGB Fertilizer at 7th and 8^{th} week of incubation when compared with the rate at which CO_2 was released between 1^{st} and 6^{th} week of incubation. There were increases in the evolution of CO_2 at 9, 10 and 11th week of incubation in the soil samples treated with PGB but at gradual rate when compared to the rate CO_2 evolution at the 8^{th} week of incubation. Also, PGB gradually decreased the volume of CO_2 evolved as from 9^{th} week till the termination of the experiment. Kola Pod Husk exhibited slight different characteristics in releasing CO_2 to the soil compared with control experiment and PGB. Kola Pod Husk increased the volume of CO_2 released as from the 1^{st} week of incubation to the 6^{th} week, decreased CO_2 evolution between 7^{th} and 8^{th} week and then increased CO_2 evolution from the 9^{th} week of incubation to the 11th week before the CO_2 evolved finally declined till the termination of the experiment.

Compared with control, PGB significantly increased ($P<0.05$) CO_2 evolution from the 1^{st} week of the experiment to the 11^{th} week (except 8^{th} week) of incubation. Also, compared with control, KPH significantly ($P<0.05$) increased CO_2 evolution from 10^{th} week till the termination of the experiment (Fig. 1)

This work shows that the rate at which PGB and KPH released CO_2 was different from each other. The percentage change in the volume of CO_2 evolved during the incubation process by PGB and KPH showed that PGB had higher increase in CO_2 at the earlier stage of the experiment (1-6 weeks) while KPH had higher increase in CO_2 at the later end of the

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experiment. This shows that PGB tended to increase the rate of carbon mineralization than KPH at early stage of incubation.

Through out the period of the incubation, the values of CO_2 in the control experiment were lower than the soil samples amended with PGB and KPH. This shows that the treatments that were applied to the soil samples actually influenced the evolution of CO_2 in the experiment.

The results of this experiment showed that the incorporation of the amendments into the soil might have significantly increased the biological activities which could be categorized into three stages (Ayeni, 2011). A stage of intense activity at the beginning of incubation (1-6 weeks) caused by rewetting of the soil plus amendment mixtures, corresponding to the use of the easily metabolized C present in the PGB, KPH and the native soil. Secondly, a stage of reduced activity (7-8 weeks) characterized by a drop in CO_2 as a result of the decreased amount of easily biodegradable organic matter and lastly, a stage of moderate stable activity between 9-16 weeks showing that the decomposition has reached advance stage.

The higher CO_2 released by KPH and PGB over the control indicated higher microbial activities in these materials as reported by Ayeni (2011) and Leslie (2002).

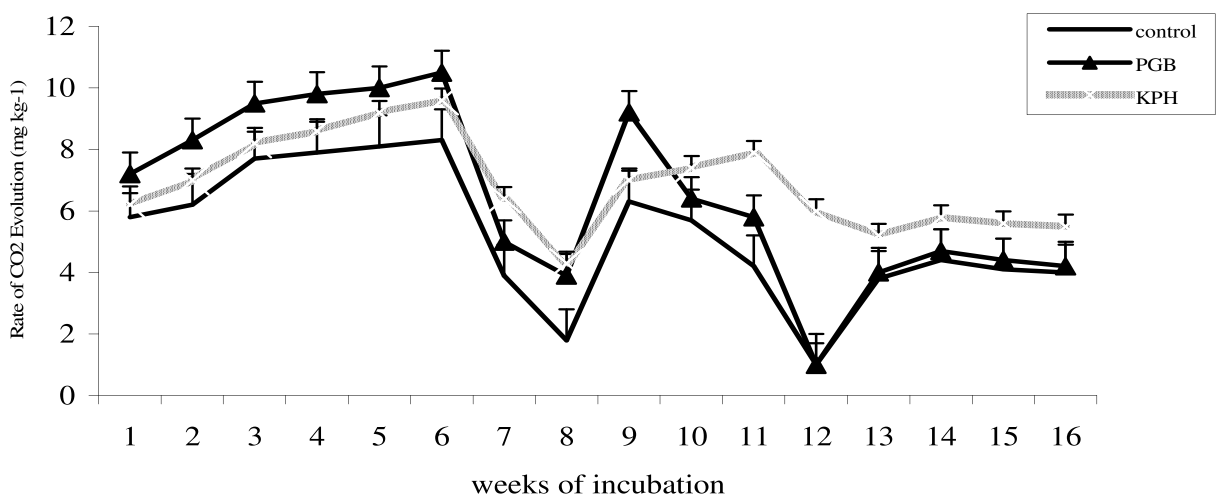

Figure:Time course of CO2 evolution (mgkg-1) by kola pod husk (KPH) and pacesetter organomineral fertilizer (PGB)

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The reduction in $C0_2$ values after the initial upsurge might be caused by exhaustion of the readily oxidized labile contents of the various media which include sugar, starch and cellulose as reported by Obatolu (1991). However, the decomposition of the high molecule carbohydrates and lignin thereafter must have resulted in the second phase of increase in $C0_2$ values thereafter. This supports the report by Olayinka and Adebayo (1987) that $C0_2$ release increases over a period of time with organic materials. The relative decrease and the subsequent stable values across the various media at the latter weeks (week 12 - 16) confirmed the report of Ayeni (2011) that decomposition of the organic materials had reached advanced stage and their nutrient contents could be made available for plant use.

From the results of this study, it could be deduced that mineralization of organic materials in the soil depends upon the type of organic material. Also, the rate of mineralization is faster in the mixture involving city waste materials (PGB) with lower C/N ratio and than in KPH, while the reverse was the case at the latter stage of the incubation. The comparison of the two amendments using $C0_2$ evolution as an index method showed that PGB was more stable than KPH at the initial stage. Arable crops such as leaf vegetables that could complete their life cycles within eight weeks would benefit more from PGB than KPH due to their nutrient releases patterns, while crops with longer life cycles would benefit more from the use CO_2 of KPH as fertilizer.

4. CONCLUSION

Experiment conducted to show the rate of CO_2 release by kola pod husk and organic fertilizer called Pacesetter Grade B showed that both treatments increased CO_2 at different rates. The percentage change in the volume of CO_2 evolved during the incubation process by PGB and KPH showed that PGB had higher increase in CO_2 at the earlier stage of the experiment while KPH had higher increase in CO_2 at the later end of the experiment. The cumulative increase in CO_2 evolution showed that Pacesetter Grade B fertilizer had higher rate of carbon mineralization than Kola Pod Husk.

COMPETING INTERESTS

Authors have declared that no competing interests exist

AUTHORS' CONTRIBUTIONS

Dr (Mrs) E.A Makinde designed the study and carried out the incubation study while Dr L.S. Ayeni analyzed the data and prepared the manuscript

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