

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 CO₂ release by Kola Pod Husk (KPH) and Pacesetter Grade B (PGB) (sorted city waste plus cow dung) in southwest Nigeria. Each of Kola Pod Husk and PGB applied at 0.25 g to 50 g soil, and a control were incubated for 16 weeks. The treatments were replicated four times on a completely randomized design. Evolution of CO₂ by all the treatments increased as the period of incubation increased from the first week to the sixth week of the experiment. After the 6th week, PGB decreased CO₂ at 7th and 8th week and increased it between 9th and 11th week and thereafter finally decreased it as incubation period progressed. KPH decreased CO₂ between 7th and 8th week and then increased it from 9th - 11th week before the CO₂ finally declined till the termination of the experiment. Compared with control, KPH and PGB significantly ($p > 0.05$) increased CO₂ 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 CO₂ evolution at 9th week of incubation while KPH reached its peak at 13th week of incubation

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

Introduction

Most Nigerian soils are low in native nutrient contents 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 CEC and are not able to retain adequate amount of nutrient elements, they therefore require split application of fertilizers to be able to support good crop 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

34 could afford the procurement of the fertilizer could not get adequate quantity from the
35 market. Most of the raw materials needed for local production are imported at exorbitant cost
36 (Fagbenro and Agboola, 1983). In addition, there has been recent clamour for organic foods
37 and agricultural products in the world market (Pawar *et al.*, 2003). The need to increase the
38 soil organic matter contents for sustainable Nigerian agricultural soils (Lombin, 1981;
39 Ogunwale *et al.*, 2002) coupled with the problems above has called for a shift from the use of
40 inorganic fertilizer to the use of organic fertilizers.

41 Organic materials are capable of promoting crop growth and increasing yield by way
42 of improving soil physical, chemical and biological properties (Titiloye *et al.*, 1985;
43 Wallace, 1994). Organic fertilizers improve the physical properties of soils; maintain the
44 soils in better tilth and increases water holding capacity (Agboola and Omuetti, 1982; Lal,
45 1986; Ogunwale *et al.*, 2002). It also supplies both major and minor plant nutrients (Ayeni,
46 2011, Ayeni *et al.*, 2008). The supplied nutrients can substitute for appreciable amounts of
47 inorganic fertilizer (Tollesa, 1999).

48 Over the years, various organic materials have extensively been used as fertilizers
49 and their beneficial effects documented. They have subsequently been recommended as
50 sources of nutrient supply to farm crops. It is observed that since the introduction of
51 inorganic fertilizers into the Nigerian agriculture, in-depth research into the use of organic
52 fertilizer as sources of plant nutrients. For example, the rate of decomposition of organic
53 materials has not been adequately determined. Although some information on the
54 mineralization of compost is available as reported by Van De Kerkove (1990) and cited by
55 Jedidi *et al* (1993), more data are needed on their mineralization rates in order to ascertain
56 the best time they could be applied to the crops for optimum performance. This study was
57 therefore set up to investigate the rate of decomposition of industrially manufactured organic
58 fertilizer called Pacesetter Grade B and Kola Pod Husk, using CO₂ evolution as an index.

59 **Materials and Methods**

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

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67 The CO₂ evolution as index method was used to compare the mineralization potential
 68 of the various amendments. The carbon dioxide evolution study was carried out according to
 69 the procedure described by Moorhead *et al.* (1988) and adopted by Ipinmoroti *et al* (1997).
 70 Fifty grams of 2 mm sieved soil were weighed into each of the 12 incubation flasks, with four
 71 flasks representing each of the two organic materials and the control without organic material
 72 addition. Each of the milled organic materials was weighed and mixed with soil in the flasks
 73 at the rate equivalent to 10 tonnes ha⁻¹ (i.e. 0. 25 g per 50 g soil). Each treatment was
 74 replicated four times. The treated soil in each flask was moistened to 70 % field capacity of
 75 the soil and incubated in the laboratory at room temperature (28°C). Absorbent was used to
 76 cover the mouth of each flask in order to reduce evaporation or gaseous escape. The moisture
 77 content was adjusted fortnightly with de-ionized water. The carbon dioxide evolved from the
 78 flasks was collected in a bottle containing 25 ml of 0.1 M Ca (OH)₂. The amount of carbon
 79 dioxide evolved was determined by titration with 0.05 M HCl, using phenolphthalein as
 80 indicator.

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

$$\begin{aligned}
 82 \text{ meq of CO}_2 &= 0.2727(25 - (\text{titre} \times f) 0.027 \\
 83 f &= \frac{\text{volume of Ca(OH)}_2}{\text{Blank titre}} \\
 84 & \\
 85 \text{ meq of C} &= \text{equivalent weight of C Molarity of Ca (OH)}_2 \\
 86 \text{ Where } 0.2727 &= \text{ratio of carbon in carbon dioxide} \\
 87 25\text{ml} &= \text{Volume of Ca (OH)}_2 \text{ in the flask/bottle}
 \end{aligned}$$


89 The soil pH was determined in 1:2 soil/water ratio and read with pH meter. Total N was
 90 determined by the normal Microckjedahl method soil OC was determined by wet dichromate
 91 oxidation method. Available P was determined by Bray -1- method. Exchangeable K, Ca, Na
 92 and Mg were extracted with 1N ammonium acetate at pH 7. Exchangeable K was determined
 93 by flame photometer while Ca and Mg were determined by Atomic Absorption
 94 Spectrophotometer Exchangeable acidity was extracted by 0.1M KCl before titrated with
 95 0.1M HCl. The micronutrients (Mn , Fe, Cu and Zn) were extracted with HCl and
 96 determined by AAS. The ECEC was determined by the summation of the cations.

97 Data analysis


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

100

101 **Result and Discussion**

102 The initial properties of the soil used for the incubation study (Table 1) indicated that
 103 the soil was slightly acidic, low in total N, C/N ratio, K, Ca and Mg. The soil was adequate
 104 in available P, Fe and Mn. This indicates that the soil is poor in plant nutrients, thus; **it is a**
 105 **medium that the potential of PGB and KPH in releasing plant nutrients could be adequately**
 106 **determined.** 

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

Parameters	Soil
pH (H ₂ O)	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)	
Sand	10.1
Silt	
Clay	912 
Texture Class	54 34 Sandy Loam

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Table 2: Chemical properties of Pacesetter Grade B and Kola Pod Husk




Nutrients	Pacesetter Grade B (PGB)	Kola Pod Husk (KPH)
pH (H ₂ O)	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


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116 In figure 1, evolution of CO₂ by the control experiment, KPH and PGB increased as
 117 the period of incubation increased from the first week up to the sixth week of the experiment.
 118 The control experiment decreased the volume of CO₂ produced as from the sixth week to the
 119 16th week when the experiment was terminated.

120 There was reduction in the volume of CO₂ produced by the Pacesetter Grade B
 121 Fertilizer at 7th and 8th week of incubation when compared with the rate at which CO₂ was
 122 released between 1st and 6th week of incubation. There were increases in the evolution of CO₂
 123 at 9, 10 and 11th week of incubation in the soil samples treated with PGB but at gradual rate
 124 when compared to the rate CO₂ evolution at the 8th week of incubation. Also, PGB gradually
 125 decreased the volume of CO₂ evolved as from 9th week till the termination of the experiment.
 126 Kola Pod Husk exhibited slight different characteristics in releasing CO₂ to the soil compared
 127 with control experiment and PGB. Kola Pod Husk increased the volume of CO₂ released as
 128 from the 1st week of incubation to the 6th week, decreased CO₂ evolution between 7th and 8th
 129 week and then increased CO₂ evolution from the 9th week of incubation to the 11th week
 130 before the CO₂ evolved finally declined till the termination of the experiment.

131 Compared with control, PGB significantly increased (P<0.05) CO₂ evolution from the
 132 1st week of the experiment to the 11th week (except 8th week) of incubation. Also, compared
 133 with control, KPH significantly (P<0.05) increased CO₂ evolution throughout the period of
 134 the conduct of the experiment (Fig. 1)

135 This work shows that the rate at which PGB and KPH released CO₂ was different
136 (Table 3) from each other. The percentage change in the volume of CO₂ evolved during the
137 incubation process by PGB and KPH showed that PGB had higher increase in CO₂ at the
138 earlier stage of the experiment (1-6 weeks) while KPH had higher increase in CO₂ at the later
139 end of the experiment. This shows that KPH tended to be slower in carbon mineralization
140 than PGB at early stage of incubation. 

141 Through out the period of the incubation, the values of CO₂ in the control experiment
142 were lower than the soil samples amended with PGB and KPH. This shows that the
143 treatments that were applied to the soil samples actually influenced the evolution of CO₂ in
144 the experiment. The high volume of CO₂ released by the control between 1-6 weeks of the
145 experiment might be  the addition of moisture and the presence of microorganism which
146 attacked the native organic carbon.

147 The results of this experiment showed that the incorporation of the amendments into
148 the soil significantly increased the biological activities which could be categorized into three
149 stages. A stage of intense activity at the beginning of incubation (1-6 weeks) caused by
150 rewetting of the soil plus amendment mixtures, corresponding to the use of the easily
151 metabolized C present in the PGB, KPH and the native soil. Secondly, a stage of reduced
152 activity (7-8 weeks) characterized by a drop in CO₂ as a result of the decreased amount of
153 easily biodegradable organic matter and lastly, a stage of moderate stable activity between 9-
154 16 weeks showing that the decomposition has reached advance stage.

155 The higher CO₂ released by KPH and PGB over the control indicated higher microbial
156 activities in these materials as reported by Kilpatrick *et al* (2001) and Leslie (2002).

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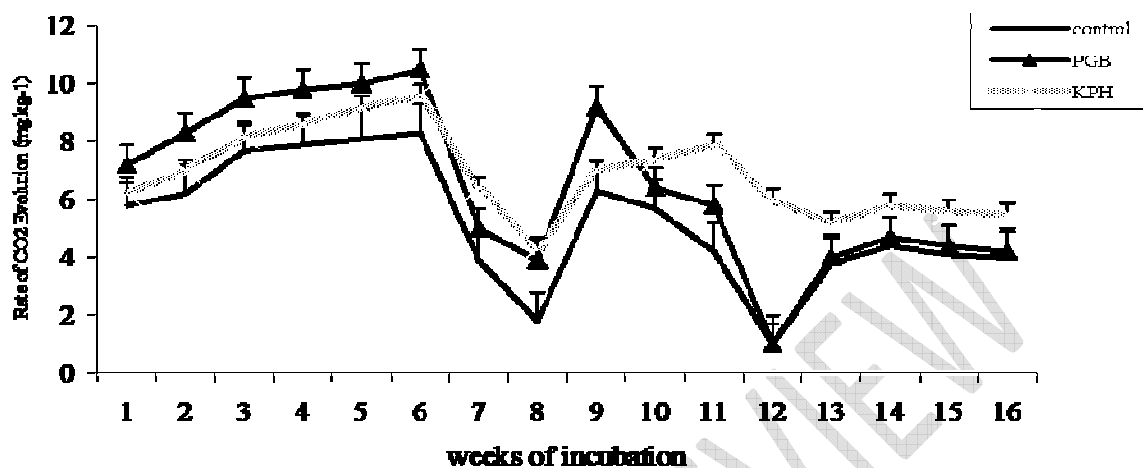


Figure: Time course of CO₂ evolution (mg kg⁻¹) by kola pod husk (KPH) and pacesetter organomineral fertilizer (PGB)

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Table 3: Percentage increase in CO₂ evolution as affected by Pacesetter Grade B Fertilizer (PGB) and Kola Pod Husk (KPH) 


weeks	PGB	KPH
1	41.38	6.45
2	33.87	11.43
3	23.38	6.09
4	24.1	8.14
5	23.46	11.96
6	26.51	13.51
7	2.04	23.44
8	2.08	9.43
9	50	32.43
10	36.11	36.49
11	38.1	46.83
12	25	42.36
13	5.26	47.22
14	6.82	24.14
15	7.32	26.49
16	5	27.27

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166 The reduction in CO₂ values after the initial upsurge might be caused by exhaustion of
167 the readily oxidized labile contents of the various media which include sugar, starch and
168 cellulose as reported by Obatolu (1991). However, the decomposition of the high molecule
169 carbohydrates and lignin thereafter must have resulted in the second phase of increase in CO₂
170 values thereafter. This supports the report by Olayinka and Adebayo (1987) that CO₂ release
171 increases over a period of time with organic materials. The relative decrease and the
172 subsequent stable values across the various media at the latter weeks (week 12 - 16)
173 confirmed the report of Kilpatrick *et al.* (2002) that decomposition of the organic materials
174 had reached advanced stage and their nutrient contents could be made available for plant use.

175 From the results of this study, it could be deduced that mineralization of organic
176 materials in the soil depends upon the type of organic material. Also, the rate of
177 mineralization is faster in the mixture involving city waste materials (PGB) with lower C/N
178 ratio and than in KPH, while the reverse was the case at the latter stage of the incubation. The
179 comparison of the two amendments using CO₂ evolution as an index method showed that
180 PGB was more stable than KPH at the initial stage. Arable crops such as leaf vegetables that
181 could complete their life cycles within eight weeks would benefit more from PGB than KPH
182 due to their nutrient releases patterns, while crops with longer life cycles would benefit more
183 from the use of KPH as fertilizer.

184 **Conclusion**

185 Experiment conducted to show the rate of CO₂ release by kola pod husk and organic fertilizer
186 called Pacesetter Grade B showed that both treatments increased CO₂ at different rates. The
187 two organic materials can be used to increase soil fertility. 

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