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Decomposition and Nutrient Release Patterns of Some Farm Wastes under Controlled Room Temperature

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Abstract Decomposition rate of five commonly used organic fertilizer materials for tea production in Nigeria – cocoa husk (CH), tea fluff (TF), cow-dung (CD), poultry droppings (PD) and siam weed (SW), was determined under controlled laboratory room temperature range of 28 – 32℃ using carbon-dioxide evolution as an index, while the pH, amount of N, P and K released over four months incubation were assessed. The amount of CO_2 evolved significantly ($p \leq 0.05$) increased for the first 2 months and decreased in the subsequent months for SW, TF, CH and CD, with one peak of upsurge, while it increased for PD in the 1st month, decreased in the 2nd month, increased in the 3rd month and drastically decreased at the 4th month. Carbon-dioxide evolved was highest for TF followed by CH, PD, SW, CD and least for control. Total N (151-265mg/mL), P (7.24-9.1mg/kg) and K (3.1-5.4g/kg) released and the soil pH (6.36-6.61) differed between the manures and were significantly ($P \leq 0.05$) higher compared to control with 59.0mg/mL N, 5.98mg/kg P, 2.30g/kg K and pH of 5.28. The significantly higher value of the soils amended with organic wastes for CO_2, N, P and K from the onset of incubation indicated immediate commencement of nutrient release by the organic wastes, which suggests their capacity for gradual release of nutrients to meet the need of tea plants.

Keywords Fertilizer, Crop Nutrient Supply, Incubation, Optimal Yield, Soil Organic Matter

1. Introduction

Soils under tea cultivation on the Mambilla Plateau, Nigeria are highly leached with very low N, P and basic elements[1]. The quantity of tealeaf currently produced from the area is just about 20% of the present demand by tea processing industries in the locality[2]. This supply is grossly inadequate, which was attributed to low tealeaf production as a result of nutritional problems[2]. Fertilizer rates of 150 kg N, 30 kg P and 30 kg K ha^{-1} $year^{-1}$ have been established for consistent optimal tealeaf harvest on the Mambilla Plateau[1], which were based on the use of inorganic fertilizers. Unfortunately, fertilizer supply has been inadequate, erratic and costly to be procured by the peasant poor resource farmers for the past few decades[3]. Their usage over time makes the soil moribund and unsuitable to grow tea and or other crops[4]. Unfortunately, tea cannot grow economically without fertilizer application[5].

Fertilizer application amounts to over 50% of the total annual farm inputs in tea production[6]. Nigerian farmers have been advised on the use of readily available farm wastes as alternative sources of nutrient supply on tea farms in order to remain in production at optimal profit, and to maintain good physical, chemical and biological conditions of soils under tea cultivation[7]. There are arrays of farm wastes that are used to advantage on cultivated lands in Nigeria for arable and tree crops[8, 9, 10] but the most readily available and commonly used on tea farms includes cocoa husk, cow-dung, poultry droppings and tea fluff[2, 7]. The rates of mineralization and nutrient release patterns of the farm wastes have not been adequately studied. This investigation was conducted to determine the decomposition rate and nutrient release patterns of these farm wastes using CO_2 evolution and amount of nutrients released as indices

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2. Materials and Methods

The decomposition rate of five organic materials which are common sources of nutrient supply to tea farms were assessed using the CO_2 evolved and the amount of nutrient released over the months of incubation in the laboratory as indices with the following procedures:

2.1. Carbon Dioxide Evolution Study

Carbon dioxide evolution study was carried out according to procedure previously described[11]. Fifty grams of 2 mm sieved topsoil were weighed into each of 24 incubation flasks, with four flasks representing each of the five organic material types and the control with no amendment. Each of the milled organic materials was weighed and mixed with the soil in the flasks at the rate of 10 tones ha^{-1} (0.25g 50 g^{-1} soil). The flasks' contents were moistened to 70 % water holding capacity of the soil and incubated in the laboratory at room temperature (28 – 32℃). The moisture content of the flasks was adjusted fortnightly with de-ionized water and the carbon dioxide evolved from the flasks was led through a delivery tube into 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 N HCl, using phenolphtha lein as indicator.

The amount of carbonate formed was calculated using the following equation[11]:

Meq of CO_2 = 0.2727[25-(titre x f)] 0.027
Where 0.2727 = ratio of carbon in carbon dioxide
0.027 = 0.2727 x molarity of $Ca(OH)_2$
25 ml = Volume of $Ca(OH)_2$ originally taken for trapping CO_2
f = $\frac{\text{volume of } Ca(OH)_2}{\text{Blank titre}}$

2.2. Nutrient Release Patterns during Incubation in the Laboratory

Sieved (2 mm) topsoil (40 g) + river sand (10 g) were weighed into each of 96 Petri dishes and arranged in 6 rows of 16 Petri dishes per row. Each row was labeled against a manure material and the control. The manures were added to their representative row of dishes at 0.25 g/dish and the Petri dishes were randomly arranged on the laboratory bench. The contents of each Petri dish were mixed thoroughly and moistened periodically to keep contents at 70% water holding capacity and allowed to remain at room temperature. Four Petri dishes were retrieved per treatment monthly and the contents transferred into 100 ml beakers at soil/water ratio of 1:2.5, and the pH determined using pH meter. The beaker contents were then leached into separate 100 ml volumetric flask, using funnel fitted with What-man 42 filter paper and filtrates analyzed for total N, NO_3^{-} N, NH_4^{+} N, P using Vanado-Molybdate method calorimetrically and K contents by flame photometer. Statistical analysis of variance was used to determine significant mean differences, which were separated using Duncan Multiple Range Test {DMRT} at $p < 0.05$.

2.3. Soil and Organic Materials Analysis

Determination of the initial nutrient contents of the soil and organic materials used for the study were carried out as follow: The soil pH was measured electronically with glass electrode pH meter in soil/water ratio of 1:2.5. organic carbon was determined by wet oxidation method[12], total N by microjeldahl digestion, while available P was determined colorimetrically by molybdenum blue method[13]. The exchangeable cations were extracted by leaching 5 g soil with 50 mL of 1N NH4OAC at pH 7 and the K in the leachate was determined with flame photometer, while Ca and Mg were measured by atomic absorption spectrophotometer (AAS). Total N of the organic material samples was determined by Kjeldahl method; the P, K, Ca and Mg were determined after wet digestion using acid mixtures. The P was determined using Vanado-molybdate yellow method and read using UV-VIS recording spectrophotometer (UV – 2400PC) at 420 nm, the K by flame photometer, while the Ca and Mg were by AAS.

3. Results and Discussion

3.1. Nutrient Contents of Soil and Organic Materials

The soil organic carbon and total soil N contents were 24.2g/kg and 9.0g/kg soil respectively with C:N ratio of 2.69 (Table 1). The soil organic carbon and total soil N contents were below the 30.0 and 10.0 gm kg^{-1} soil ideal for suitable soil for tree crop production[14]. The P value of 5.81 mg/kg was moderate, while the K, Ca and Mg contents of 0.52, 2.09 and 0.37 cmol/kg respectively were all below their soil critical values of 1.2, 8.0 and 0.80 cmol/kg soil respectively[14]. This suggests the need to increase the soil organic matter (SOM) content in order to allow for optimal and sustainable cropping on the soil. The low nutrient content of the soil is a general characteristic of most Nigerian soils[15] which indicates that the soil could not be cropped profitably without fertilizer application for optimal plant growth and productivity, however, the soil pH value of 6.2 was optimum for tea cultivation.

Table 1. Initial physical and chemical properties of soil used

Soil property	Values
N (g/kg)	9.0
C (g/kg)	24.2
C/N	2.69
pH	6.2
Available P (mg/kg)	5.81
Exchangeable K (cmol/kg)	052
Ca ,,	2.09
Mg ,,	0.37

The N contents in tea fluff (TF), poultry droppings (PD) and siam weed (SW) were high but relatively low in cocoa husk (CH) and cow dung (CD) (Table 2). The PD was between 0.33 and 2.6 times higher in P content compared to the other four organic materials. The higher P content of the PD may probably be due to the bone, blood and shell meal contents of poultry feeds, which are needed for better bone and eggshell development in poultry, the excess of which must have passed out with the dung. The organic materials of animal origin were lower in K values compared to those of plant origin. The high K content of the CH and SW is characteristic and similar high K values have been reported which made CH and SW good sources of K supply for high K demanding crops[16, 17]. The Ca contents of the organic materials followed similar trend with the P contents. The Ca values of the animal manures were higher compared to those of plant origin. The Mg in the organic materials ranged between 0.23 and 0.76 %, with the lowest content in TF while it was highest in SW. The low Mg content of TF probably resulted from the low Mg contents of the inorganic fertilizers commonly used on tea fields in Nigeria, as well as the notably reported Mg deficiency syndrome of the tea estates on the Mambilla plateau[1]

Table 2. Nutrient contents of the fertilizer materials used for the experiments

Properties	TF	CH	PD	CD	SW
N (%)	3.54	1.46	2.92	1.29	2.47
C (%)	44.3	39.9	25.4	16.5	43.0
C:N	12.5	25.6	8.7	12.8	17.4
P (%)	0.30	0.15	1.55	0.60	0.21
K (%)	2.16	3.96	1.83	0.83	3.08
Ca (%)	0.64	0.77	3.55	1.57	1.21
Mg (%)	0.23	0.33	0.54	0.43	0.76

TF = Tea fluff, CH = Cocoa husk, PD = Poultry droppings, CD = Cow dung, SW = Siam weed

3.2. Carbon Dioxide Evolution Study

The amount of CO_2 evolved increased for the first 2 months and decreased in the subsequent months for SW, TF, CH and CD, with one peak of upsurge. For PD, the CO_2 evolved had two peaks of upsurge (Table 3). It increased for the first month, decreased in the second month, increased again at the 3rd month and drastically decreased at the 4th month. The TF gave the highest amount of CO_2 evolved and was followed by CH, PD, SW, CD and control in descending order. The organic materials produced significantly ($p < 0.05$) higher amount of CO_2 than the control. The higher values of CO_2 released by the manures over the control might probably be due to upsurge in the microbial population and the resultant increase in their activities that might have taken place in the amended soils. The reduction in CO_2 evolved after the initial upsurge indicated that the more rapidly oxidize-able labile contents like sugars, starch and cellulose had been exhausted. The upsurge in CO_2 values after initial decline indicated that the high molecular weight carbohydrates and lignin were being decomposed[18, 19]. Higher values of CO_2 evolved in the organic material-treated soils over the control from the onset indicated that decomposition commenced immediately the organic materials were added to the soil. Continual decrease in CO_2 values from the 3rd month and thereafter showed that decomposition of the organic materials had attained a peak after which their nutrient contents could be made available for crop plants usage.

Table 3. Average CO_2 evolved (milli-equivalent) by organic materials over 4 months of incubation

Treatments	Months of incubation 1	2	3	4
Cocoa husk	320b	669a	553a	280a
Cow-dung	200bc	314b	227bc	164b
Poultry dropping	308b	252bc	375b	234a
Siam weed	260b	377b	312b	163b
Tea fluff	685a	687a	603a	232a
Control	188c	164c	144c	125b

Means followed by the same letters within a column are not significantly different at ($p<0.05$)

3.3. Nutrient Release Patterns of Manures and PH Change over Four Month's Incubation

The NO_3^- –N released by the soils amended with manures were significantly ($p<0.05$) higher than the control (Table 4). The difference was between 29-200 % over the control after one month incubation. Total N released by the manures treated soils was significantly ($p<0.05$) higher than for the control. The NO_3^- –N constituted about 98.01 - 99.96 % of the total N released. At the second month, NO_3^- - N generated by soils treated with manures were higher than for control by a range of 6.41 – 287.91 %. The NH_4^+ - N content produced by TF was highest compared to other treatments. The NO_3^- – N constituted 98.41 - 99.91% of the total N. At the third month, the results showed that CH, PD and control resulted to decrease in the amount of NO_3^- – N released compared to the preceding month, whereas CD, SW and TF gave increased values. The NO_3^- – N generated by manure treated soils were between 21.9 - 880.82% higher than for control, while NH_4^+ - N values were higher than values obtained for previous months. Total N generated showed that 91.45-100% was made up of NO_3^- – N. At the end of fourth month the NO_3^- N generated decreased across the manure treated soils and control. Tea flush (2 leaves + bud) harvest is carried out forthrightly with great demand for NO_3^- N. The higher quantity of total N and more importantly NO_3^- N in the organic material treated soils indicated that the organic wastes could readily supply the N need of tea plants. However, rational use of the organic wastes is needed to checkmate excess release of NO_3^- N that could be detrimental to the environment through underground water pollution[20].

Table 4. Effect of organic fertilizer materials on NO_3^- - N, NH_4^+ - N and total N (mg/ml) released over four months of incubation

Treatment	Month 1 NO_3-N	Month 1 NH_4+N	Month 1 Total N	Month 2 NO_3-N	Month 2 NH_4+N	Month 2 Total N	Month 3 NO_3-N	Month 3 NH_4+N	Month 3 Total N	Month 4 NO_3-N	Month 4 NH_4+N	Month 4 Total N
CH	118c	1.0b	119c	138d	2.0b	140d	105d	4.0b	109d	252a	12a	264a
CD	121c	0.0c	121c	169c	1.0d	170c	319b	2.0c	321b	204a	13a	217a
PD	158b	0.0c	158b	247b	0.0e	247b	179c	0.0d	179c	164b	4.0c	168b
SW	91d	1.0b	92d	162c	1.0c	163c	178c	0.0d	178c	143b	9.0b	152b
TF	213a	2.0a	215a	373a	5.0a	378a	839a	62a	901a	255a	10b	265a
Cont.	72e	1.0b	73e	129e	3.0b	132d	86e	8.0b	94d	49c	10b	59c

CH = Cocoa husk; CD = Cow-dung; PD = Poultry droppings; SW = Siam weed; TF = Tea fluff, Cont. = Control
Means followed by the same letters along a column are not significantly different at $p<0.05$

The quantity of P released by PD, CD and SW in the first month, were significantly ($p<0.05$) higher compared to the control but not significantly higher by CH and TF (Table 5). The very high P release in the PD amended soil may be due to the high bone meal, fish meal and oyster shell contents in the feeds of poultry birds. Poultry meals are high in P, a portion of which might have been passed out in the droppings. In the second month, the P released in PD was significantly higher than in the SW, CH and the control but not over the CD and TF, while in the fourth month, the manures of plant and animal origins behaved differently compared with the previous months of incubation. While the plant materials had increased in the quantity of P released than it was for the third month, the animal wastes resulted to decrease in the amounts of P released. However, the increase or decrease in the amounts of P released at the fourth month compared to the third month was marginal, which showed that the P mineralization had attained stability. The mean amounts of P released by the PD, SW and TF were significantly higher than in CD.

Table 5. Effect of organic fertilizer materials on P release (mg/kg) over four months of incubation

Treatments	Months of incubation			
	1	2	3	4
Cocoa husk	9.90$_{cd}$	7.15$_{c}$	5.44$_{c}$	8.39$_{ab}$
Cow-dung	16.59$_{b}$	12.93$_{b}$	6.77$_{b}$	5.98$_{b}$
Poultry droppings	35.83$_{a}$	29.33$_{a}$	9.66$_{a}$	9.05$_{a}$
Siam weed	15.09$_{b}$	7.66$_{c}$	3.98$_{d}$	9.14$_{a}$
Tea fluff	12.51$_{cd}$	7.46$_{c}$	6.06$_{b}$	8.61$_{a}$
Control	6.95$_{d}$	4.82$_{c}$	5.27$_{c}$	7.24$_{ab}$

Means followed by the same letters along a column are not significantly different from one another at $p<0.05$

Potassium released was highest for CH and followed by values for TF, SW, PD, CD and least in control (Table 6). There was an upsurge in K released at the 4th month over the 2nd and 3rd months with organic materials having significantly ($p<0.05$) higher amounts of K compared with the control. The sharp increase in K values in the fourth month may probably be due to the fact that greater levels of decomposition have taken place in the various media.

Table 6. Potassium (g/kg) released by organic materials over four months of incubation

Treatments	Months of incubation			
	1	2	3	4
Cocoa husk	3.70a	3.09a	5.00a	5.40a
Cow-dung	1.20c	1.40c	2.40d	3.10c
Siam weed	2.60b	3.10a	3.80b	3.90b
Poultry droppings	2.00b	1.90c	3.10c	3.20c
Tea fluff	3.40a	2.40b	3.20c	4.20b
Control	1.00c	0.90d	2.00d	2.30d

Means followed by the same letters along a column are not significantly different from one another at $p<0.05$

The pH values were low in the 1st month of incubation but the values increased thereafter with increase in length of incubation (Table 7). This trend was a direct opposite with the values obtained for the CO_2 evolved (Table 2). This showed that the more the CO_2 released, the more acidic the soil condition became. At each period of pH determination, the values for the organic material treated soils were significantly higher than for the control ($p<0.05$). The higher pH observed for the organic materials over the control was probably influenced by the mineralization and subsequent release of nutrients from the organic wastes[21, 22, 19].

Table 7. Change in pH during incubation of organic materials

Treatments	Months of incubation			
	1	2	3	4
Cocoa husk	4.88ab	5.20bc	5.50c	6.36c
Cow-dung	4.80b	5.30b	5.50c	6.39c
Siam weed	5.00a	5.35ab	5.75a	6.47b
Poultry droppings	4.80b	5.48a	5.58b	6.57a
Tea fluff	4.60c	5.13c	5.40d	6.61a
Control	4.53d	4.93d	5.18e	5.28d

Means followed by the same letters along a column are not significantly different from one another at $p<0.05$

Organic materials as nutrient sources undergo composting into manures and curing before being used on the field for tea. Tea is a high N demanding crop, with application rate of 150 kg N/ha in Nigeria[1]. Under normal growing condition, tea plants take all the nutrients it needs from the soil. Tea utilizes N in form of NO^-_3, hence the high contents of the incubated materials in NO^-_3 – N indicated that N will be readily available for tea uptake. This will be more effective in that mineralization of manures is gradual over long period of time. The amount of the cured manures to be applied is normally based on rational need by tea plants, which is indicated by soil test level and applied in two split applications. This helps to guide against loading the soil with excess $NO\text{-}_3$ N that could curse food and environmental contaminations as well as the pollution of water bodies[20]. The use of the farm wastes would be very advantageous in building up the soil organic matter content that is naturally low.

4. Conclusions

Based on the trend of CO_2 evolved and pattern of N, P and K released over the incubation period, it suggests that mineralization and nutrient released by the evaluated farm wastes would be without inhibition on the field for eventual crop benefits. The quantum of NO-3 N would be enough to meet the high demand of tea for N. Its gradual release is advantageous especially for tea plants with long gestation period.

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