

## **Original Research Article**

**COMBINED USED OF DRY COCOA BEAN TESTA ASH (*Theobroma cacao* L.) AND POULTRY DROPPING FOR THE IMPROVEMENT OF SOIL FERTILITY AND MAIZE (*Zea mays* L.) GROWTH AND YIELD ON A HUMID ALFISOL SOUTHWESTERN, NIGERIA.**

### **ABSTRACT**

The combine use of dry cocoa bean testa ash and poultry droppings for the improvement of soil fertility, maize growth and yield was studied on an Alfisol south western Nigeria, located at Joseph Ayo Babalola University Ikeji-Arakeji, Ilesha Osun State, Research farm from April to July 2018 and from August to November 2018. Four treatments of poultry droppings (PD) at 5  $\text{tones ha}^{-1}$ ,  $\text{tones/ha}$ ,  $\text{hectare}$ , cocoa bean testa ash (CBTA) ash at 5  $\text{tones ha}^{-1}$ ,  $\text{tones/ha}$ , mixture of poultry droppings and cocoa bean testa ash (PD + CBTA) at 2.5  $\text{tones ha}^{-1}$  each and control (C) were used in a Randomized Complete Block Design (RCBD) with three replications. The study showed that organic manure is a valuable fertilizer and can serve as a suitable alternative to inorganic fertilizer in the south western Nigeria especially, CBTA that has higher concentration of potassium (K) and organic carbon (OC). Poultry droppings (PD 2.5  $\text{tones ha}^{-1}$ ,  $\text{tones/ha}$ ) treatments plus cocoa bean testa ash (CBTA 2.5  $\text{tones ha}^{-1}$ ,  $\text{tones/ha}$ ) produced higher values for plant height, leaf area, chlorophyll, leaf area index, plant diameter, cob length, cob diameter and grain yield against the control that recorded the lowest value. Also, CBTA improves ~~improves~~ soil pH as well as increases minerals such as N, P, Ca, Mg, and Na. Organic fertilizer applications increase maize growth towards the later stage and were significantly different from the control according to DMRT at  $p < 0.05$ . Cocoa bean testa ash (CBTA) and poultry dropping (PD) application registered over 53% increases of N levels in the soil, from 0.15% to 0.77% to 0.84%. Organic carbon (~~OC~~) increased as poultry droppings plus cocoa bean testa ash were added to

**Formatted:** Font: (Default) Times New Roman, 12 pt, Font color: Black, Superscript

**Comment [H1]:** To adequate levels?

24 the soil. Maize grain yield increased from control plot to 1.95 t/ha<sup>1</sup> in CBTA + PD plot. The study  
25 recommends an application rate of cocoa testa ash and poultry droppings for maize growth on this type  
26 of soil in this agro-ecology.

27 Key words [soil fertility, potassium, soil chemical properties, dry cocoa bean testa ash (CBTA), soil, poultry  
28 droppings (PD)]

## 29 Introduction

30 Combining compost and ashes may play a significant role for tropical soil security by mitigating nutrients  
31 leaching [1]. Besides, compost is also known to increase plant yield through the addition of nutrients [2; 3]. They  
32 suggest that an addition of organic matter, such as compost, to wood ashes could play this role [4]. Soil fertility  
33 is dynamic, changing based on processes such as accumulation or depletion, which are governed by the interplay  
34 between physical, chemical, biological and anthropogenic processes [5]. As a result, deteriorating soil fertility is  
35 considered a fundamental biophysical factor responsible for declining per-capita food production in SSA [6]. So  
36 far, application of mineral fertilizers is the main soil fertility management strategy used by many, but if not  
37 handled properly, can cause environmental problems such as soil acidity and eutrophication [7]. It is also un-  
38 affordable for most African farmers [6]. In addition to the supply of plant nutrients and organic carbon, the use of  
39 organic manure improves soil physical properties and enhances its water holding ability [8]. In Nigeria and other  
40 developing countries, the use of mineral fertilizer in crop production has not been sustainable due to its high cost  
41 and scarcity and nutrient imbalance [6]. Hence, there is renewal interest in locally available agro-waste such as  
42 poultry droppings and dry cocoa bean testa ash by poor resource farmers to fertilize their farms. The farm wastes  
43 and animal excreta are used directly as compost manure and farm yard manure. Due to high quantity needed,  
44 adequate quantity of organic wastes may not be obtained; hence the farmers often apply different wastes  
45 combined. Since the wastes are of different quantity and nutrient composition, their combined use is expected to

**Formatted:** Font: (Default) Times  
New Roman, 12 pt, Font color: Black,  
Superscript

**Comment [H2]:** Who?

46 have positive cumulative and complementary effects in nutrient supply and improvement in crop yield [9]. It is  
47 the goal of most farmers in Nigeria to produce sustainable high crop yield. However, decrease in soil fertility  
48 after few years of cropping is a major limitation. The need to improve soil fertility and crop production to  
49 support the rapidly growing population has led to a renewed interest in the use of organic sources of nutrients and  
50 mineral fertilizers for soil fertility maintenance. In addition, the continuous use of mineral fertilizers adversely  
51 affects soil chemical and physical properties, causing nutrient imbalance, increase soil bulk density and causing  
52 low water infiltration rate [9]. Thus, the needs to investigate alternative sources of nutrients that will be less  
53 damaging to the soil become imperative.

54 In southwestern Nigeria, huge quantity of poultry wastes (manure) is generated and also constitute environmental  
55 hazard [10]. Studies also showed that poultry manure increased soil organic matter and nutrient status [11].  
56 However, the huge amount of poultry manure required for field crop production and its handling problems limits  
57 its use to distant farmers. There is also a renewed interest in the use of burnt organic residues from plants as  
58 sources of phosphate and potash fertilizers [12]. The sole and integrated use of crop wastes such as cocoa pod  
59 husk has not received much research attention [13]. Animal manures especially that of poultry have received  
60 much research attention in crop nutrition and had been found to be effective source of nutrient for crops [14] not  
61 that of dry cocoa bean testa ash as an organic fertilizer.

**Comment [H3]:** In which search?

**Comment [H4]:** Just saying that the  
residue received attention in a research is  
relevant in the scientific environment?

62 The cocoa bean testa, which constitutes about 40% of the seed, is a by-product of the cocoa processing industry.  
63 It is considered a waste hence; vast quantity is being disposed off day in day out as a result of ignorance of its  
64 potential as an organic source of fertilizer. Though, cocoa bean testa ash is being locally used to manufacture  
65 black soap. Its potentials as an organic fertilizer have not been researched upon. It is a recommended cheap  
66 source of ~~potassium-nutrient~~K, which prevents leaching and therefore makes nutrient more available to plants,  
67 ~~because, i-~~It releases nutrient slowly relative to inorganic fertilizers [15]. Cocoa bean testa has found its  
68 usefulness in concentrating ~~potassium~~K. It has been found to have a high level of ~~potassium~~-K that is about

69 4.31% dry bases. Cocoa testa ash is organic fertilizer obtains from dried cocoa beans during industrial  
70 processing, it is abundant in Nigeria as well as in other parts of West Africa such as Ghana, Ivory Coast as well  
71 as South America e.g Brazil etc. The potential of cocoa testa ash as a source of organic fertilizer has not received  
72 adequate attention as well as publicity; therefore, this work is aimed to ~~expose-study~~ cocoa testa ash as an  
73 alternative source of organic fertilizer either alone or in combination with poultry droppings.

Comment [H5]: Repetitive.

## 74 2. MATERIAL AND METHODS

### 75 2.1: Site Description

76 The experiment was conducted on the teaching and research field plot of the College of Agricultural Science of  
77 Joseph Ayo Babalola University, Ikeji Arakeji which lies between latitude  $07^{\circ}16'$  and  $07^{\circ}18'$  and longitude  $05^{\circ}$   
78  $09'$  and  $05^{\circ}11'$  E between April to July and August to November, 2018. The area is characterized by a tropical  
79 climate ~~and~~. ~~The study area~~ is situated in the humid tropical forest zone of Nigeria. It has an annual average  
80 rainfall of between 1500-1800mm and relative humidity of between 80-85% annually. It has a gentle undulating  
81 elevation of about 1150m-1250m above sea level [16].

### 82 Experiment Design

83 The experiment was laid out as a randomized complete block design (RCBD) with four treatments and three  
84 replicates. A  $12\text{m} \times 15\text{m}$  plot was demarcated on the teaching and research farm of Joseph Ayo Babalola  
85 University Ikeji-Arakeji, Nigeria. The plot was partitioned into three blocks of  $4\text{m} \times 15\text{m}$  separated by 1.0m  
86 buffer. Each  $4\text{m} \times 15\text{m}$  block was further partitioned into four  $3\text{m} \times 3\text{m}$  plots separated by buffer of 1.0m wide.

87 The treatments were:

- 88 a. Poultry droppings (from layers) at 5 tones ~~ha<sup>-1</sup>/Ha.~~
- 89 b. Cocoa testa ash at 5 ~~tones ha<sup>-1</sup>tons/Ha.~~

Formatted: Superscript

c. Mixture of poultry droppings and cocoa testa ash at 2.5 ~~tones ha<sup>-1</sup>~~ ~~tons/Ha~~ each.

d. Control.

For the plots that received poultry droppings, cocoa testa ash and the mixture of poultry droppings and cocoa testa ash, the applications were incorporated in the soil a week before the seeds were planted.

The test crop was maize (*Zea mays* L.). Planting of Maize as done between April to July and August to November, 2018. Maize seeds (SUWAN-1) medium maturing maize cultivar was obtained from the Institute of Agricultural Research and Training (IAR&T), Ibadan, Nigeria. Two seeds were planted at 0.75m x 0.25m spacing. Maize seedlings were later thinned to one plant per stand to obtain plant population of 53,333 Plants per hectare. All treatments were allocated to the plots in each block at random. However, control plot did not receive any amendment. Weeding, diseases and pests control etc were done at appropriate time and the manure was applied two weeks after planting in a ring at 10 cm from the maize plant while the land preparation was ploughed and harrowed once [17].

#### Cocoa Bean Testa Ash Preparation

Dry cocoa bean testa was collected from cocoa products and processing factory located in the major communities producing in Nigeria, up till now, cocoa testa was a waste product after the beans for producing beverages were removed and many a time constitutes major environmental problem in such area. It was carefully dried in the sun and set fire on it, until it turns into ashes, the ashes were carefully packed in jute bags and kept in a safe place.

#### Data collection

Collection of data commenced three weeks after planting and was done at two weeks interval till tasseling stage.

Comment [H6]: Explain better.

111

112 **Plant sample collection**

113 This was done at four and four weeks after planting (WAP) and two weeks after treatments application, plant  
114 height and diameter of ten randomly selected plant stems were taken with meter rule and veneer caliper.

115 Also, four plants were uprooted per plots, per treatment and washed and bulked into composite samples. Fresh  
116 weights of the samples were taken. Sub-samples of each treatment per plot were oven dried at 100°C for 48hrs to  
117 constant weight to determine dry matter content. Sub-sample dry weight was used to compute the total dry  
118 weights, using the relationship [18]:

119  $\text{Sample dry wt. (g)} = \text{Sample fresh wt (g)} \times \text{sub-sample dry wt. (g)} / \text{sub-sample fresh wt. (g)}.$

120 At maturity (six weeks after transplanting WAT), ten plants were randomly selected from each plot, harvested  
121 and weighed and calculated as tone per ha based on this formula [11]:  $Pp = \{(B + b) (L + l) / lb\} \times N$  (11), where

122  $Pp$  = Plant population,  $L$  = Length of the farm,  $B$  = Breadth of the farm,  $l$  = Length of spacing of the farm,  $b$  =  
123 Breadth of spacing of the farm and  $N$  = Number of fruits per farm stand.

124 **Determination of the total leaf area per plant, leaf area index and chlorophyll content:**

125 The total leaf areas of fifteen randomly selected maize plants per plot were taken at 60 days after planting and  
126 the corresponding leaf area index computed. The leaf area was measured following the procedure of [19, 20] by  
127 multiplying the length of a leaf by its widest width by alpha, where alpha is 0.743 ( $L \times W \times 0.743$ ). The leaf area  
128 index was computed by dividing the area of a maize plant stand by the total land area occupied by single stand  
129 [21]. The chlorophyll was determined by extraction in 80% acetone and reading the absorbance of the solution at  
130 645, 663 and 652 nm [22].

Formatted: Justified

131

## 132 Soil sample collection and analysis

133 Soil samples were collected before planting, 60 days after planting (DAP). ~~A~~After the manure application, for  
134 the first maize crop planted in April, 2018 and to observe the residual effects of the applied manure, soil samples  
135 were taken at 60 days after planting for the second maize crop planted in August 2018 using a 3.5 cm diameter  
136 soil auger. There were four auger points in each plot and samples were collected at 0-20cm depth. Samples from  
137 each plot were bulked and composite were collected and taken to the laboratory for analysis.

Formatted: Justified

## 138 Soil Analysis

139 The soil samples collected were air dried and sieved through a 2 mm mesh and analyzed for soil chemical  
140 properties [23]. pH was determined using a glass electrode 1:1 (w/v) in a deionized water. Organic matter was  
141 determined using method described by [24]. K, Ca, Mg, Na, P, will be determined by plasma-atomic emission  
142 spectroscopy [25]. The total ~~nitrogen~~N was determined using micro-kjeldahl method and the available  
143 ~~phosphorus~~P extracted colorimetrically by the molybdenum blue method. Cation exchange capacity was  
144 determined by the summation of NH<sub>4</sub>OAC – extractable cations plus 1.0N KCl extractable acidity.

Formatted: Justified

## 145 Data analysis

146 The data collected were subjected to analysis of variance (ANOVA) and the means were compared by the use of  
147 Duncan multiple range test (DMRT) at 5% significance level. SPSS version 20 (statistical package for social  
148 sciences). T-test was used to determine the significant difference between cocoa bean and wood ash.

149

150

151

152   **RESULTS AND DISCUSSION**

153   **RESULTS**

154   **PROPERTIES SOIL OF THE EXPERIMENTAL SITE**

155   Table 1 shows some of the physical and chemical properties of the soil of the experimental site before the  
156   treatments were applied. The texture of the soil sandy loam with 69.52% sand and organic matter 3.2164%. The  
157    $P_{H-PH}$  (H<sub>2</sub>O) show that the soil was slightly acidic ( $pH-P_H=5.72$ ). The soil contains high organic matter, low total  
158   nitrogen but relatively adequate phosphorus content.0.15% and 12.24 ( $ppmmg\ dm^{-3}$ ) respectively. The organic  
159   carbon  $OC-(OC)$  was 1.87 while the cation exchange capacity was  $2.83\ cmolc\ 100g^{-1}$  of soil.

160   **Table 1: Physical and chemical properties of the experimental soil.**

161   Soil properties	Soil test value
162 $P_{H-PH}$ (H <sub>2</sub> O) 1:1	5.72
163   Sand (%)	69.52
164   Silt (%)	16.38
165   Clay (%)	14.38
166   Ca ( $cmol_c\ kg^{-1}$ )	1.73
167   Na ( $cmol_c\ kg^{-1}\ emol/kg$ )	0.35
168   K ( $cmol_c\ kg^{-1}\ emol/kg$ )	0.5
169   Mg ( $cmol_c\ kg^{-1}\ emol/kg$ )	0.82
170   H ( $cmol_c\ kg^{-1}\ emol/kg$ )	0.12

**Comment [H7]:** This item is not Result.  
This is part of the material and methods

**Comment [H8]:** The units of  
measurement used in the text are wrong or  
old. They need to be reviewed.

**Comment [H9]:**  
**Formatted:** Superscript

**Comment [H10]:** Or  $cmolc\ kg^{-1}$ ? does  
 $cmolc\ 100g^{-1}$  exist?  
**Formatted:** Superscript

**Comment [H11]:** convert to  $g\ kg^{-1}$

**Comment [H12]:** convert to  $g\ kg^{-1}$

**Comment [H13]:** convert to  $g\ kg^{-1}$

**Formatted:** Portuguese (Brazil)  
**Formatted:** Portuguese (Brazil),  
Subscript  
**Formatted:** Portuguese (Brazil)  
**Formatted:** Portuguese (Brazil),  
Superscript  
**Formatted:** Portuguese (Brazil)



171	<del>Al</del> Al (cmol <sub>c</sub> kg <sup>-1</sup> emol/kg)	0.06
172	C.E.C (cmol <sub>c</sub> kg <sup>-1</sup> emol/kg)	3.52
173	O.C (%)	1.87
174	O.M (%)	3.22
175	T.N (%)	0.15
176	Av.P (mg dm <sup>-3</sup> ppm)	12.24
177	Cu (mg dm <sup>-3</sup> ppm)	3.15
178	Fe (mg dm <sup>-3</sup> ppm)	142.4
179	Mn (mg dm <sup>-3</sup> ppm)	6.16

Formatted: Portuguese (Brazil)

Comment [H14]: convert to g kg<sup>-1</sup>

Formatted: Portuguese (Brazil)

Comment [H15]: convert to g kg<sup>-1</sup>

Formatted: Portuguese (Brazil)

Comment [H16]: convert to g kg<sup>-1</sup>

Formatted: Portuguese (Brazil)

180 put a caption below the table.

Formatted: Font: (Default) Times New Roman

#### 181 Proximate Analysis of the Cocoa Testa Ash and Poultry Droppings

Comment [H17]: Was their objective also to evaluate the chemical and physical characteristics of the substrates? or only their effects on the plants?  
You have to contemplate this in your objective.

182 The result of the characterization of dry cocoa bean testa ash and poultry droppings used for the experiment is  
183 presented in Table 2. Organic carbon in cocoa bean testa ash was significantly higher than the poultry droppings.  
184 while Poultry-poultry dropping had the higher value of nitrogen-N content of 28.82 g kg<sup>-1</sup> while dry cocoa bean  
185 testa ash (CBTA) had 2.1 g kg<sup>-1</sup> g/kg. There was significant difference (p < 0.05) in the nitrogen-N content of the  
186 two organic manures. Phosphorous values in poultry droppings (PD) and cocoa bean testa ash (CBTA) showed  
187 no significance difference. Potassium values in Cocoa bean testa ash (CBTA) was 25.87 g kg<sup>-1</sup> g/kg as against  
188 13.87 g kg<sup>-1</sup> g/kg in poultry dropping and were significantly different. Calcium values were not significantly  
189 different while magnesium values and sodium values were all significantly different. The moisture content value  
190 in CBTA was 11.40 g kg<sup>-1</sup> g/kg as against 9.71 and were significantly different.

Formatted: Superscript

191

192

193

194

**Table 2: Paired T Test Value of the Proximate Analysis of Poultry Dropping and Cocoa Testa ash**

Properties	Poultry Dropping (PD) g/kg <sup>-1</sup>	Cocoa Bean Testa Ash (CBTA) g/kg <sup>-1</sup>	Mean Difference	T-Value
Crude fiber	22.71	17.26	5.45	0.0005*
Ether Extract	2.07	3.2	1.13	0.0003*
Crude protein	19.67	12.77	6.91	<0.0001*
pH	7.8	6.6	1.3	0.0062*
Organic carbonOC	28.82	31.92	-3.1	0.008*
NitrogenN	3.17	2.1	1.07	0.0002*
PhosphorusP	0.38	0.34	0.04	0.075ns
PotassiumK	13.87	25.87	12.00	0.0023*
MagnesiumMg	0.32	0.28	0.03	0.150*
CalciumCa	0.23	0.22	0.003	0.225ns
NaSodium	0.13	0.17	-0.04	0.0013*
Moisture Content	9.71	11.4	-1.7	<0.0001*
Ash	11.9	6.55	5.35	<0.0001*

195 \*Significant @ 0.05: ns = not significant

196 Note: 1 g/kg<sup>-1</sup> = 0.1%

197

Formatted: Superscript

Response of maize plant to different organic based fertilizer

4.1.2 Vegetative growth of maize plant (plant height cm)

Table 3 shows that there is no significant difference in the effect of the organic materials, their mixture and control on the plant height in the week 2 after planting. At 4WAP and 5WAP, the maize plants treated with combination of cocoa bean testa ash and poultry droppings and sole cocoa bean testa ash respectively, gave the better plant height than other treatments, but the organic treated plants were significantly difference from the control which received no treatment at  $p<0.05$  using DMRT.

Table 3: Effect of organic fertilizers on maize plants height (cm)

Treatments	WAP			
	2	3	4	5
Control	19.95a	30.72b	47.46b	73.53c
CBTA 5.5 t ha <sup>-1</sup>	18.76a	35.21a	63.34a	99.73b
CBTA 2.5 t ha <sup>-1</sup> +PD 2.5 t ha <sup>-1</sup>	20.78a	36.15a	64.76a	105.0a
PD 5 t ha <sup>-1</sup>	20.89a	36.74a	62.74a	97.80b

WAP- Weeks after planting

CBTA- Cocoa bean testa ash

PD-Poultry dropping

Means in the same column followed by the same letters are not significantly different by DMRT at  $p<0.05$

Formatted: Font: Not Bold

Formatted: Portuguese (Brazil)

Formatted: Portuguese (Brazil)

Formatted: Portuguese (Brazil)

Formatted: Superscript

Formatted: Portuguese (Brazil)

Formatted: Portuguese (Brazil)

Formatted: Portuguese (Brazil)

### Effect of organic fertilizer on maize plant stem diameter (mm)

The maize stem diameter increased across all the treatment from 3, 4, and 5 weeks after planting.

At ~~2~~two weeks after planting, there was no pronounced difference in diameter across all treatment because there was no difference in the maize stem.

Between 3WAP and 4WAP, there was a significant difference between treated plot the control using DMRT at  $p < 0.05$ .

**Table 4. Effect of organic fertilizers on maize plant diameter (mm)**

Treatments	WAP			
	2	3	4	5
CONTROL	3.10b	7.80ab	14.27b	20.33c
<del>CBTA 5t ha<sup>-1</sup></del> <del>CBTA 5t/ha</del>		3.35ab	10.60a	19.83a
26.90a				
<del>CBTA 2.5 t ha<sup>-1</sup>+PD 2.5 t ha<sup>-1</sup></del> <del>CBTA 2.5t/ha+PD 2.5t/ha</del>			3.40ab	10.07a
20.38a	26.87a			
<del>PD 5t ha<sup>-1</sup></del> <del>PD 5t/ha</del>		3.76a	9.27a	18.67a
23.73b				

WAP-weeks after planting

CBTA-cocoa bean testa ash

PD-poultry droppings.

Means in the same column followed by the letters are not significantly different by DMRT at  $p < 0.05$ .

**Effect of Cocoa Bean Testa Ash and Wood Ash on leaf area, leaf area index and chlorophyll of maize plant**

Cocoa bean testa ash (CBTA) + poultry dropping (PD) Table 5, recorded highest values for leaf area with  $97.8 \text{ cm}^2$  while the lowest value of  $38.18 \text{ cm}^2$  was recorded in the control plot. There were significant differences between CBTA + PD, CBTA, PD and control, in contrast, there was no significant difference between CBTA and PD. In the same vein, Cocoa bean testa ash (CBTA) + poultry dropping (PD) recorded highest value for leaf area index and chlorophyll with 2.68 and  $3.61 \text{ mg g}^{-1}$  respectively while the lowest value was recorded in the control plots with values of 1.62 and  $1.11 \text{ mg g}^{-1}$ . There were significant differences between CBTA + PD, CBTA, PD and control for both comb diameter and grain yield, in contrast, there was no significant difference between CBTA and PD for both leaf area index and chlorophyll respectively.

**Table 5: Effect of Cocoa Bean Testa Ash and Wood Ash on leaf area and chlorophyll of maize plant (7WAP)**

Treatments	Leaf Area ( $\text{cm}^2$ )	Leaf Area index	Chlorophyll ( $\text{mg g}^{-1}$ )
Control	38.18d	1.62d	1.11d
CBTA 5t/ha	86.58b	2.57b	2.89b
PD 5t/ha	76.17c	2.07c	2.31c
CBTA 2.5t/ha+ PD 2.5t/ha	97.8a	2.68a	3.61a

**Formatted:** Superscript

**Comment [H18]:** Leave all tables equal. Standardize the text.

**Formatted:** Superscript

CBTA-Cocoa bean testa ash

CTA+PD - Cocoa bean testa ash + Poultry droppings

PD- Poultry droppings

Means in the same column followed by the same letters are not significantly different by DMRT at  $p < 0.05$ .

**Soil chemical properties of the experimental site as influenced by the application of organic fertilizer.**

On the table 6 are presents The data shown in the table 6 below represent the result of the analysis carried out to determine the effect of the organic fertilizer in the soil. This is to access the ability of the organic fertilizer to improve the soil condition for future production. The soil pH of the experimental site was slightly acidic (5.72) before the treatment were applied, but was 5.8 after the application of treatment (poultry) as seen in the table 5. Some macro-nutrients such as N, Ca, Mg, nitrogen (N), calcium (Ca), magnesium (Mg) of the location improved across the whole treatment plots. It was only the combination of poultry droppings and cocoa bean testa ash that increased the soil organic carbon (OC) from 1.87% before treatment application to 3.12% after treatment application [26].

**Table 6: Some Soil chemical properties of the study site as affected by the application of organic fertilizers.**

Treatments	PH	OC	N	P	K	Na	Ca	Mg
		%	%	ppm		cmol/kg		
Control	5.72	1.87	0.15	2.24	0.10	0.15	1.73	0.82
PD 5t/ha	5.80	2.12	0.84	4.93	0.26	0.34	3.25	1.93
CBTA 5t/ha	6.04	2.14	0.77	6.00	0.52	0.42	3.24	1.91

**Comment [H19]:** Arrange the table and units of measure of nutrients.

CBTA 2.5t/ha+PD 2.5t/ha 6.12 3.12 0.81 7.17 0.54 0.56 3.48 1.97

CBTA-Cocoa bean testa ash

CBTA+PD - Cocoa bean testa ash + Poultry droppings

PD- Poultry droppings

**Effect of Cocoa Bean Testa Ash and Wood Ash on cob diameter, length and grain weight of maize plant.**

Cocoa bean testa ash (CBTA) + poultry dropping (PD), recorded highest values for cob diameter with 6.81 cm while the lowest value of 3.08 cm was recorded in the control plot. There were significant differences between CBTA + PD, CBTA, PD and control, in contrast, there was no significant difference between CBTA and PD.

In the same vein, Cocoa bean testa ash (CBTA) + poultry dropping (PD) recorded highest value for cob length and grain yield with 23.80 cm and 1.95 tones  $\text{ha}^{-1}$  respectively while the lowest value was recorded in the control plots. There were no significant differences between CBTA + PD and CBTA. However, there were significant differences between all treated plots and control plot, in contrast, there was no significant difference between CBTA and PD for both cob diameter and cob length yield respectively

**Table 7: Effect of Cocoa Bean Testa Ash and Wood Ash on cob diameter, length and grain weight of maize plant.**

Treatments	Cob Diameter (cm)	Cob Length (cm)	Maize grain weight (ton/ha)
Control	3.08c	16.58c	0.64c
CBTA 5t/ha	5.67b	22.98b	1.82a
PD 5t/ha	5.15b	22.40b	1.75b
CBTA 2.5t/ha+ PD 2.5t/ha	6.81a	23.80a	1.95a

Formatted: Superscript

Comment [H20]: Idem.

CBTA-Cocoa bean testa ash

CTA+PD - Cocoa bean testa ash + Poultry droppings

PD- Poultry droppings

## Discussion

### Pre-Planting Physico-Chemical Properties of Soil of the Experimental Site.

The texture of the area was sandy clay loam. This may be attributed to the lithology of the parent material Smyth and Montgomery 1962 [27]; Olojugba, 2010 [16]. They maintained that more sand contents at the topsoil may be due to the high rate of weathering and low soil organic matter. The pH 5.72 of the soil in the experimental site before the application of manure indicated the soil to have medium acidity level. Soil with a pH range of 5.2 - 5.76 had been reported to be of medium acidity Brady and Weil, 1999 [28]; Adekayode and Olojugba, 2010 [29]. N, P, K, Ca, Mg and Na Nitrogen, phosphorous, potassium, calcium, magnesium and sodium were low in the study area. This may be due to the over cropping, leaching of soluble cations, soil erosion and lack of proper land management practices in the area, Tisdale *et al.* 2003 [30] had explained with Mitscherlich's principle of plant's positive response to applied nutrients that were previously limiting in the soil. The acidic nature of the soil may be due to the leaching of soluble cations observed in the area as well as the distribution of exchangeable acidity. Leaching of Na, K, Ca and Mg were largely responsible for the development of acidity in the soil. The low value of organic matter in the area may be due to continuous cropping without the addition of organic manure Adekayode and Olojugba, 2010 [16].

Comment [H21]: And after?

Comment [H22]: Because the texture...

Comment [H23]: The texture of the soil...

### Nutrient Concentration in Cocoa bean testa ash (CBTA) and Poultry dropping (PD) Used for the Experiment

The value of organic carbonOC in both CBTA and PD showed that they are good sources organic matter for soil fertility and crop growth and yield, however, the significantly higher value of organic carbon in CBTA over that of PD showed that the former might be better source of organic carbon than the latter. Cocoa bean testa ash (CBTA) has pH of 6.6 while poultry dropping has pH of 7.8, it shows that more nutrients would be more available and soluble if CBTA is used to fertilize soil than poultry dropping



(PD). This is in agreement with the findings of Pagani and Mallarino, 2015 [31]. They were of the opinion that more nutrients such as N, P, K, S, Ca, Mg are more available between pH 6.5 to 7.5. Also, high proportion of potassium (K) as well as moisture content in CBTA shows that it might be a better source of potassium as well as moisture content. This finding is in agreement with that of Adeoye *et al.* 2001 [15].

#### **Changes in Growth Parameters as a results of addition of Cocoa Bean Testa Ash (CBTA) and Poultry Dropping (PD)**

The significantly higher values of maize length and diameter in the cocoa bean testa ash (CBTA) and poultry dropping (PD) treated plots over that of the control plot may be due to the concentration of essential minerals, ~~organic carbon~~OC and ~~nitrogen~~N in the manure used which might responsible for the high yield of maize length and diameter. This finding is in agreement with the that of Marcel *et al.*, 2016 [32], they were of the opinion that there was a significant interaction among doses of wood ash and soil moisture for length of flower spikes and of flower stems at harvest. The higher values of maize length and diameter obtained ~~fro~~ CBTA and CBTA+PD plots might be due to the concentration of ~~potassium (K)~~K in CBTA. Cocoa bean testa ash has been known to have high value of potassium Adeoye *et al.* 2001 [15], According to Mirza *et al.*, 2018 [33], they found out that among the plant nutrients, ~~potassium (K)~~K is one of the vital elements required for plant growth and physiology. Potassium is not only a constituent of the plant structure but it also has a regulatory function in several biochemical processes related to protein synthesis, carbohydrate metabolism, and enzyme activation. Several physiological processes depend on K, such as stomata regulation and photosynthesis. Potassium regulates the biosynthesis, conversion, and allocation of metabolites that ultimately increases the yield. Many research works strongly supported the notion that K is directly or indirectly responsible for higher yield of crops Islam and Muttaleb, 2016 [34], Cheema *et al.*, 2012 [35], Uddin *et al.*, 2013 [36].

Comment [H24]: ???

#### **Changes in Leaf Area, Leaf Area Index and Chlorophyll as a results of addition of Cocoa Bean Testa Ash (CBTA) and Poultry Dropping (PD)**

The order of size of total leaf area the leaf area index and chlorophyll values which were significantly higher in Cocoa bean testa ash plus poultry dropping (CBTA+PD) and Cocoa bean testa ash (CBTA) plots might be due to higher values of potassium (K) and organic carbon OC in CBTA as opposed to control and PD plots and which also reflected in the yield of maize grain. The corroborated the assertion that K helps to increase the utilization of carbohydrates and it increases the leaf area index, which helps to increase the dry matter accumulation and ultimately increase the yields of many field crops Cheema *et al*, 2012 [35]. In the same vein, Subedi and Ma, 2005[37], maintained that leaf area was essential for simulation of light interception and photosynthate production. Potassium K controls photosynthesis through sunlight interception. The leaf surface area and sunlight interception were both reduced dramatically when the K was below the level required by the plant Mirza *et al*, 2018 [33], Le *et al*, 2016 [38].

The leaf number and the leaf size are reduced while the plant is deficient in K. The leaf number and size reduction later hasten the diminished photosynthetic rate per unit leaf area and thus account for an overall reduction in the amount of photosynthetic assimilates available for growth Mirza *et al*, 2018 [33], Le *et al*, 2016 [38].

#### Changes in some soil chemical properties as a results of addition of Cocoa Bean Testa Ash (CBTA) and Poultry Dropping (PD)

The higher pH values of 6.04 and 6.12 in cocoa bean testa ash (CBTA) and cocoa bean testa ash plus poultry dropping (CBTA+PD) mixture plots might due to the liming effects of CBTA due to high concentration of potassium (K) nutrient Adeoye *et al*. 2001 [15]. Marcel *et al*, 2016 [32] submitted that the pH increases can be attributed mainly to the release of potassium K carbonate by reaction of ash in the soil. Also, Demeyer *et al*. 2001[39] and Lickaaz 2002 [40] had described wood ash to be similar to burned or hydrated lime as it contained oxides and hydroxides of potassium K, Nasodium, Ca calcium and Mgmagnesium. The significant higher in nitrogen, potassium, calcium and phosphorous could be attributed to their higher in cocoa bean testa ash (CBTA).

**Comment [H25]:** But do they have the same functions? Because if they do not, they are not equal.

#### Changes in Maize yield as a results of addition of Cocoa Bean Testa Ash (CBTA) and Poultry Dropping (PD)

The highest grain yield values of 1.82  $t/ha$  and 1.95  $t/ha$  obtained in cocoa bean testa ash (CBTA) and cocoa bean testa ash plus poultry dropping (CBTA+PD) compared with other treatments showed a high

**Formatted:** Superscript

**Formatted:** Superscript

yield obtainable when cocoa bean testa ash (CBTA) alone or in combination with other organic manure was used to improve soil fertility for increased crop production. The high maize grain yield in plot fertilized with CBTA alone or with PD might be due to high concentration of ~~potassium (K)~~ <sup>K</sup> and ~~OC~~ <sup>organic carbon</sup> in CBTA. ~~a~~ According to Cheema *et al* 2012 [35] K helps to increase the utilization of carbohydrates and it increases the leaf area index, which helps to increase the dry matter accumulation and ultimately increase the yields of field crops. The total leaf area, leaf area index and chlorophyll content which had positive correlation with the maize grain yield ( $r = 0.96, 0.97$  and  $0.95$  respectively) confirmed the assertion of Mohamed *et al.* 2008 [41]. Uddin *et al.* 2013 [36] found that 1000 grain weight, grain yield increased by K. Also, when other nutrients are in optimum condition, K played an important role to increase the yield of NERICA 1 rice.

## Conclusion

The improvement of soil fertility and subsequent higher maize grain yield obtained in  $5\text{t/ha}^{-1}$  CBTA and  $2.5\text{t/ha}^{-1}$  CBTA +  $2.5\text{t/ha}^{-1}$  PD confirmed that a combination of both organic sources gave higher maize grain yield than when each was applied separately. Also, Cocoa bean testa ash (CBTA) contained higher quantity of ~~potassium (K)~~ <sup>K</sup> which made it to perform better than poultry dropping (PD) in improving soil fertility in term of pH increment as well as other nutrients such as N, P, Ca, Mg and Na. CBTA also increased maize grain better than PD. Application of CBTA and PD appeared to have performed better in both soil fertility improvement and maize grain yield due to higher concentrations of ~~potassium (K)~~ <sup>K</sup> in CBTA and ~~organic carbon~~ <sup>OC</sup> in PD. ~~As potassium (k)~~ <sup>As potassium (K)</sup> has been proved to be vital for plant survival under both physiological and stress conditions. It is not only a part of the chemical structure but also plays vital regulatory functions in biochemical and physiological processes that contribute to plant growth and development. Proper use of K with other nutrients helps to attain sustainable productivity and quality of crops and ensure nutritional food security for animals and human beings.

Formatted: Superscript

Comment [H26]: This is literature review, not a result of your research.

## References

1. Agegnehu, G., Nelson, P. N., & Bird, M. I. (2016). Crop yield, plant nutrient uptake and soil physicochemical properties under organic soil amendments and nitrogen fertilization on Nitisols. Soil and Tillage Research, 160, 1–13. <https://doi.org/10.1016/j.still.2016.02.003>.

2. Mbau, S. K., Karanja, N., & Ayuke, F. (2014). Short-term influence of compost application on maize yield, soil macrofauna diversity and abundance in nutrient deficient soils of Kakamega County, Kenya. *Plant and Soil*, 387, 379–394. <https://doi.org/10.1007/s11104-014-2305-4>
3. Zhang, Y., Li, C., Wang, Y., Hu, Y., Christie, P., Zhang, J., & Li, X. (2016). Maize yield and soil fertility with combined use of compost and inorganic fertilizers on a calcareous soil on the North China Plain. *Soil and Tillage Research*, 155, 85–94. <https://doi.org/10.1016/j.still.2015.08.006>.
4. Bougnom, B. P., Knapp, B. A., Elhottová, D., Koubová, A., Etoa, F. X., & Insam, H. (2010). Designer compost with biomass ashes for ameliorating acid tropical soils: Effects on the soil microbiota. *Applied Soil Ecology*, 45, 319–324. <https://doi.org/10.1016/j.apsoil.2010.05.009>.
5. Smaling, E.M.A., Nandwa, S.M., Janssen, B.H., 1997. Soil fertility in Africa is at stake. In: Buresh, R.J., Sanchez, P.A., Calhoun, F. (Eds.), *Replenishing Soil Fertility in Africa*. American Society of Agronomy and Soil Science Society of America, Madison, USA, SSSA Special Publication no. 51, pp. 47–61
6. Sanchez, P.A. (2002) Soil fertility and hunger in Africa. *Science*. Vol 295, pp. 2019 – 2020.
7. Bhardwaj, D , Mohammad W, A , Ranjan ,K. S and Narendra T: Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity, . *Microbial Cell Factories* 2014,
8. Amanullah, Zakirullah M., Khalil S. K. (2010). Timing and rate of phosphorus application influence maize phenology, yield and profitability in Northwest Pakistan. *Int. J. Plant Prod.* 4 281–292. soil properties and nutrient uptake: an overview. *Bioresource Technology*. Vol: 77, pp. 287 – 295.
9. Nottidge, D.O., Ojeniyi, S.O., Asawalam, D.O., 2005. Comparative effect of plant residue and NPK fertilizer on nutrient status and yield of maize (*Zea mays* L.) in a humid Ultisol Niger. *J. Soil Sci.* 15, 1e8.
10. Adediran, J.A., I.B. Taiwo and R.A. Sobulo, 2003. Comparative nutrients level of some solid organic wastes and their effect on tomato (*Lycopersicum esculentus*) yield. *African Soils*, 33: 100-113.
11. Adeniyi, O.N. and S.O. Ojeniyi, 2005. Effect of poultry manure, NPK 15-15-15 and combination of their reduced levels on maize growth and soil chemical properties. *Nig. J. Soil Sci.*, 15: 34-41
12. Ayeni LS. Oso OP. Ojeniyi SO. 2008. Effect of sawdust and wood ash application in improving soil chemical properties and growth of cocoa (*Theobroma cacao*) seedlings in the Nurseries. *Medwell. Agric. J.* 3(5): 323 - 326.
13. Ayeni, L.S., 2010. Effect of combined cocoa pod ash and NPK fertilizer on soil properties, nutrient uptake and yield of maize (*Zea mays*). *J. Am. Sci.*, 6: 79-84.

14. Ayeni, L.S. and M.T. Adetunji, 2010. Integrated application of poultry manure and mineral fertilizer on soil chemical properties, nutrient uptake, yield and growth components of maize. *Nat. Sci.*, 8: 60-67.
15. Adeoye, G.O, Sridhar, M.K.C and Ipinmoroti, R.R: Potassium recovery from farm wastes for crop growth. *Journal of communication in soil science and plant nutrition*: vol. 32, 2001; 15-16;
16. Olojugba, M. R (2010) characterization, classification and fertility evaluation of the forest soil of basement complex in the south western Nigeria. Evidence from forestry plantations of the Federal University of Technology, Akure, Nigeria. *International Journal of Agriculture and Food Science*: 1, 208-222
17. Michael Rotimi Olojugba and Ibiyeye John Olufemi. Inter & Active Effect of Tillage and Fertilizer on Maize (*Zea mays L.*) Performance on Humid Alfisol, Southwestern Nigeria. *Asian Journal of Soil Science and Plant Nutrition*: 4(3): 1-11, 2019
18. Adeboye OC, Ajadi SO and Fagbohun AB. An accurate mathematical formula for estimating Plant population in four dimensional fields of sole crop. *Journal of agronomy*; 2006: 289-292
19. Stewart, D.W and Dwyer, I.M (1999). Mathematical characterization of leaf shape and area of maize hybrids. *Crop science* 29: 422-427.
20. Elings A. 2000. Estimation of leaf area in tropical maize. *Agron. J.* 92: 436 - 444.
21. Mauro A, Homem A, Elizabeth A, Walter-Shea AM. 2001. Test of an extended mathematical approach to calculate maize leaf area index and leaf angle distribution. *Agricultural and Forest Meteorology* 108(1): 45 - 53.
22. Ibitoye, A.A (2005). Laboratory manual on basic methods in analytical chemistry. *Concepts IT and Educational Consult*, Nigeria. 47pp
23. Carter MR (1993). Soil Sampling and Methods of Soil Analysis. Canadian Society of Soil Science. Lewis Publishers, London p. 823.
24. Allison, F.E (1973). Soil organic matter and its roles in crop production. *Elsevier scientific publication Co. Amsterdam*. 637pp.
25. Hendershot, W.H., Lalonde, H. and Duquette, M (1993). *Soil reaction and exchangeable acidity*. In; Soil Sampling and Methods of Analysis M.R. Carter (eds). 141-145. Lewis publishers, USA.

Formatted: Portuguese (Brazil)

26. Audu M, M. Haliru<sup>1</sup> and A. M. Isah<sup>1</sup> Influence of Poultry Droppings on Soil Chemical Properties and Performance of Rice (*Oriza sativa* L.) in Sokoto, Sudan Savanna Zone of Nigeria *International Journal of Plant & Soil S* 7(2): 128-135, 2015; Article no.IJPSS.2015.138 ISSN: 2320-7035
27. Smyth, A. J .and Montgomery, R.F. 1962. Soils and land use in central western Nigeria.The Government of Western Nigeria, Ibadan.
28. Brady NC, Weil RR (1999). The Nature and Properties of Soils. (12 th Editon). Prentice Hall, New Jersey pp. 881.
29. Adekayode F.O and Olojugba, M.R (2010). The utilization of wood ash as manure to reduce the use of mineral fertilizer for improved performance of maize (*Zea mays* L.) as measured in the chlorophyll content and grain yield, *Journal of Soil Science and Environmental Management*: 1(3). 40-45.
30. Tisdale SL, Nelson WL, Beaton JD, Havlin JL. (2003). Soil Fertility and Fertilizers, 5th Edition, Pearson Education, Inc. New Jersey. p. 634.
31. Pagani A, Mallarino AP (2015) On-farm evaluation of corn and soybean grain yield and soil pH responses to liming. *Agron J* 107(1):71–82
32. Marcel Thomas Job Pereira, Tonny José Araújo da Silva, Edna Maria Bonfim-Silva, Renata Bachin Mazzini-Guedes; Applying wood ash and soil moisture on gladiolus (*Gladiolus grandiflorus*) cultivation: *AJCS* 10(3):393-401 (2016) ; DOI: 10.21475/ajcs.2016.10.03.p7236.
33. Mirza Hasanuzzaman , M. H. M. Borhannuddin Bhuyan , ID , Kamrun Nahar, Md. Shahada Hossain, Jubayer Al Mahmud, Md. Shahadat Hossen, Abdul Awal Chowdhury Masud, ID Moumita and Masayuki Fujita; *Agronomy* 2018, 8, 31; doi:10.3390/agronomy8030031
34. Islam, A.; Muttaleb, A. Effect of potassium fertilization on yield and potassium nutrition of Boro rice in a wetland ecosystem of Bangladesh. *Arch. Agron. Soil Sci.* 2016, 62, 1530–1540.
35. Cheema, M.A.; Wahid, M.A.; Sattar, A.; Rasul, F.; Saleem, M.F. Influence of different levels of potassium on growth, yield and quality of canola (*Brassica napus* L.) cultivars. *Pak. J. Agric. Sci.* 2012, 49, 163–168
36. Uddin, S.; Sarkar, M.A.R.; Rahman, M.M. Effect of nitrogen and potassium on yield of dry direct seeded rice cv. Nerica 1 in Aus season. *Int. J. Agron. Plant Prod.* 2013, 4, 69–75.
37. Subedi KD, Ma BL. 2005. Ear Position, Leaf Area and contribution of individual leaves to grain yield in conventional and leafy maize hybrids. *Crop Science* 45: 2246 - 2257.

38. Lu, Z.; Lu, J.; Pan, Y.; Lu, P.; Li, X.; Cong, R.; Ren, T. Anatomical variation of mesophyll conductance under potassium deficiency has a vital role in determining leaf photosynthesis. *Plant Cell Environ.* 2016, 39, 2428–2439..
39. Demeyer A, Voundi NJC, Verloo MG (2001). Characteristics of wood ash and influence on soil properties and nutrient uptake: An Overview. *Bioresource Technology* 77(3): 287 - 295
40. Lickaez J (2002). Wood Ash: An Alternative Liming Material for Agricultural Soils. *Agdex* 534-2. <http://www/.agric.gov.ab.ca/dept.docs.nsf/all/agdex/534-2.pdf>
41. Mohamed SA, Ewees SA, Sawsan A, Seaf EY, Dalia MS. 2008. Improving maize grain yield and its quality grown on a newly reclaimed sandy soil by applying micronutrients, organic manure and biological inoculation. *Res. J. Agric. Biol. Sci.* 4:537 - 544.