Original Research Article

Combined used of Dry Cocoa Bean Testa Ash and Wood Ash for Soil Fertility Improvement and Maize Yield on Degraded Tropical Humid Alfisol, Southwestern Nigeria

Abstract

Combine use of dry cocoa bean testa ash (DCBTA) and wood ash (WA) for the improvement of soil fertility and yield of maize (*Zea mays*, L.) was studied on an Alfisol South Western Nigeria, located at Joseph Ayo Babalola University Ikeji-Arakeji, Ilesa Osun State, Nigeria Teaching and Research Farm from April to July 2017 and from August to November 2017. Four treatments of dry cocoa bean testa ash (DCBTA) at 5 tons/ha, wood ash (WA) at 5 tones/ hectare, dry cocoa bean testa ash (DCBTA) at 2.5 tons/ha, mixed with wood ash (WA) at 2.5 tons/ha and control (C) were used in a Randomized Complete Block Design (RCBD) with three replications. The data collected were subjected to analysis of variance (ANOVA) and the means were compared by the use of Duncan multiple range test (DMRT) at 5% significance level. The study showed that dry cocoa bean testa ash (DCBTA) either used alone or in combination with wood ash (WA) is a valuable fertilizer and can serve as a suitable alternative to inorganic fertilizer in the south western Nigeria especially, DCBTA has higher concentration of potassium (K) and organic carbon than wood ash. Wood ash (WA) 2.5 tones/ha) treatment plus dry cocoa bean testa ash (DCBTA 2.5 tones/ha) produced higher values for plant height, leaf area, chlorophyll, plant diameter, cob length, cob diameter and grain yield against the control that recorded the lowest value. Also, DCBTA improves improves soil pH as well as increases minerals such as Ca, Mg, Na and in particular, made available phosphorous due to its increment on soil pH. pH increased fro 5.4 to 7.4 (DCBTA), 6.9 (WA) and 7.42 (DCBTA + WA). N levels in the soil increased from 0.05% to 2.61% (DCBTA) and 1.95% (DCBTA + WA). Organic carbon (OC) increased from 0.08% to 2.31% (DCBTA) and 3.11% (DCBTA + WA). P level decreased from 3.5 mg/kg to 2.49 mg/kg (DCBTA) and 2.50 mg/kg (DCBTA + WA) which was an indication of P availability to crop during growing season. Maize grain yield increased from 0.74 ton/ha in the control plot to 1.82 tons/ha in DCBTA and 1.89tons/ha in (DCBTA + WA). The study recommends an application rate of 5 tons/ha of dry cocoa testa ash (DCBTA) alone or 2.5 tons/ha combination each of (DCBTA) and and WA for maize yield and soil fertility improvement on this type of soil in this agro-ecology.

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Key words [soil fertility, potassium, soil chemical properties, dry cocoa bean testa ash (DCBTA), soil, wood ash (WA)]

Introduction

Alfisol are predominant soil class in the southwestern Nigeria, characterized by the low natural fertility, low activity clay minerals, high aluminum saturation, acid pH and low levels of calcium and magnesium needing of fertilizer complementation. Therefore, to make these soils more productive, it is essential to use agricultural practices such as liming and supplementary fertilization (Fasina *et al*, 2015).

The amount of plant available phosphorus can be increased if pH is raised (Kisinyo *et al.*, 2014a). In acidic soils plant growth can be inhibited due to toxic concentrations of Al3+.

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Agriculture is one of the major sources of Nigeria's economy. It provides employment to over 70% of the population either as subsistence or commercial farmers.Majority of farmers earn their living from agriculture and declining yields have greatly increased poverty in their various communities. Farmers are increasing sensitive to declining fertility of their soils but are too poor to procure inorganic fertilizers. Additionally,the quantity and quality organic (biomass) are low and poor respectively. This had led to declining in nutrient and negative balances especially for N (Ayeni, 2010).

Different organic wastes have also been combine with positive results. For example, Ayeni *et al*. (2008), Ayeni (2010) and Adeleye and Ayeni (2010) combined cocoa pod husk ash and poultry manure and got positive response on maize yield and increase in soil fertility when low level of cocoa pod ash was combine with poultry manure. Also worked on integrated application of organo-mineral fertilizer and kola pod husk on growth, quality and yield of *Amaranthus cruentus* L. and got more positive result than when they were singly applied in South – western Nigeria.

Wood ash is the residue left from the combustion of wood. In many farming households in the study area wood and harvest residues are the main sources of fuel used for cooking, thus producing ash. It often has a high pH (above 7) and a relatively high content of base cations and phosphorus, even though properties are very variable. Due to the chemical composition, it has been shown that ash can be used to raise pH in soils. Its content of many of the plant nutrients often limiting plant growth suggests that wood ash could also be useful as fertilizer. However, since the content of nitrogen is low, fertilization with only wood ash would not be sufficient for most crops.

On the other hand, Cocoa bean testa has found its usefulness in concentrating potassium. It has been found to have a high level of potassium that is about 4.31% dry bases Adeoye *et al*. 2001. Cocoa testa ash is organic fertilizer obtains from dried cocoa beans during industrial processing, it is abundant in Nigeria as well as in other parts of West Africa such as Ghana, Ivory Coast as well as South America e.g Brazil etc. The potential of cocoa testa ash as a source of organic fertilizer has not received adequate attention as well as publicity; therefore, this work is aimed to expose cocoa testa ash as an alternative source of organic fertilizer either alone or in combination with wood ash. With the urgent need for new fertilization alternatives either singly or in combinations of organic plus organic or organic plus inorganic, there is the need to test the potential of dry cocoa testa ash (DCBTA) and widely tested wood ash (WA) which serves as the main objective of this paper. Hence the present investigation was undertaken to explore the feasibility of using Dry Cocoa Testa Ash (DCBTA) as component of Integrated Plant Nutrient System with Wood Ash (WA) for sustaining soil productivity and crop yield.

MATERIAL AND METHODS

Site Description

The experiment was conducted on the teaching and research field plot of the College of Agricultural Science of Joseph Ayo Babalola University, Ikeji Arakeji which lies between latitude 07º16^{l} and 07º 18^{l} and longitude 05º 09^{l} and 05º 11^{l} E first cropping season was between April to July, 2017, while the second season cultivation was between August to November in 2017. The area is characterized by a tropical climate. The study area is situated in the humid tropical forest zone of Nigeria. It has an annual average rainfall of between 1500-1800mm and relative humidity of between 80-85% annually . It has a gentle undulating elevation of about 1150m-1250m above sea level [Olojugba, 2010].

2.2: Experiment Design

The experiment was laid out as a randomized complete block design (RCBD) with four treatments and three replicates. A 12m × 15m plot was demarcated on the teaching and research farm of Joseph Ayo Babalola University Ikeji-Arakeji, Nigeria. The plot was partitioned into three blocks of 4m × 15m separated by 1.0m buffer. Each 4m × 15m block was further partitioned into four 3m x 3m plots separated by buffer of 1.0 m wide. The treatments were:

a. Control (no treatment application);

b. b. Dry cocoa bean testa ash (DCBTA) at 5 tons/ha;

c. Wood ash (WA) at 5 tons/ha;

d. Dry cocoa bean testa ash (DCBTA) plus wood ash (WA) at 2.5 tons/ha each.

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 (Adekayode and Olojugba 2010).

Cocoa Bean Testa Ash Preparation

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Dry cocoa bean testa (DCBTA) was collected from cocoa products and processing factory located in the major communities producing in Nigeria, up till now, cocoa bean testa was a waste product after the beans for producing beverages were removed and many a times 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 ash was carefully packed in jute bags and kept in a safe place.

Plate 1: Dry Cocoa Bean

Nutrient Concentration in the Dry Cocoa Bean Testa Ash (DCBTA) and Wood Ash (WA).

This was carried out to determine the nutrient concentration in the Dry cocoa bean testa (DCBTA) collected from cocoa products and processing factory located in the major communities producing in Nigeria, while Wood Ash (WA) was collected from dried and burnt wood. Samples were taken and analyzed for pH, some nutrients (Nitrogen, Phosphorus, Potassium, Calcium and Magnesium) content and total carbon content.

a) pH. This was determined by pH meter in the following ratio 1:5 ash : water ratio.

b) **Total nutrients analysis:** Materials were air dried for five days, ground to pass through 1mm sieve. Nutrients (N, P, K Ca and Mg) were analyzed through complete oxidation of 0.3g of material by Kjedahl digestion using sulphuric acid, hydrogen peroxide and selenium digestion mixture (Anderson and Ingram, 1993). Nitrogen and Potassium were determined from 5ml of aliquot of digestion mixtures using an auto

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analyser. Phosphorus was determined by adding ammonium molybdate/antimony potassium tartrate solution and ascorbic acid and the absorbance read at 880nm. Calcium and Magnesium were determined by adding 10ml of 0.5% lanthanum chloride and analysis in atomic absorption spectrophotometer.

b). Total carbon analysis: Total carbon was determined by oxidation with concentrated sulphuric acid and 1m aqueous potassium dichromate mixture with external heating, followed by titration against 0.2m ferrous ammonium sulphate solution using 1, 10 phenanthroline ferrous sulphate indicator (Anderson and Ingram, 1993).

Data collection

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

The total leaf areas of fifteen randomly selected maize plants per plot were taken at 60 days after planting and the corresponding leaf area index computed. The leaf area was measured following the procedure of Stewart and Dwyer (1999) Elings (2000) by multiplying the length of a leaf by its widest width by alpha, where alpha is 0.743 (L x W x 0.743). The leaf area index was computed by dividing the area of a maize plant stand by the total land area occupied by single stand (Mauro *et al*, 2001). The chlorophyll was determined by extraction in 80% acetone and reading the absorbance of the solution at 645, 663 and 652 nm (Ibitoye, 2005).

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Soil sample collection and analysis

Soil samples were collected before planting, 60 days after planting (DAP) After the manure application, for the first maize crop planted in April 2017, and to observe the residual effects of the applied manure, soil samples were taken at 60 days after planting for the second maize crop planted in August 2017 using a 3.5 cm diameter soil auger. There were four auger points in each plot and samples were collected at 0-20cm depth. Samples from each plot were bulked and composite were collected and taken to the laboratory for analysis.

Soil Analysis

Particle size distribution was determined by hydrometer method (Gee and Or,2002).

The soil samples collected were air dried and sieved through a 2 mm mesh and analyzed for soil chemical properties (Carter, 1993). pH was determined using a glass electrode 1:1 (w/v) in a deionized water. Organic matter was determined using method described by Wander *et al.* (1998). K, Ca, Mg, Na, P, will be determined by plasma-atomic emission spectroscopy (Hendershort, 1993). Fe, Mn, Cu and Zn (DTPA extraction); Free oxides of iron and aluminium were extracted by sodium-dithionitecitrate-bicarbonate buffer solution (Coffin, 1963). The total nitrogen was determined using micro-kjeldahl method and the

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available phosphorus extracted colorimetrically by the molybdenum blue method. Cation exchange capacity was determined by the summation of NH4OAC – extractable cations plus 1.0N KCl extractable acidity.

Data analysis

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

Properties Soil of the Experimental Site.

Table 1 shows some of the physical and chemical properties of the soil of the experimental site before the treatments were applied. The texture of the soil sandy loam with 69.52% sand and organic matter 3.2164%. The P_H (H_20) show that the soil was slightly acidic.P_H=5.3. The soil contains low organic matter, low total nitrogen of 0.05 % as well as low phosphorus content 3.6 mg/kg. The organic carbon (OC) was 0.08% while the values of K, Ca, Mg are equally low in the entire area. The micro nutrients (Zn, Cu, Mn and Fe) are low in the area. The textural class of the study area was Sandy Loam.

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Table 1: Pre-planting soil properties of the study area

Soil Chemical Properties/macro nutrients		Exchangeable Micro nutrient (g/100g)		Particle size analysis (g/kg)	
Properties	Values	Properties	Values	Properties	Values
pH (H_2O) 1:1	5.3	Zn	0.8	Sand	84.4
Total Nitrogen (%)	0.05	Cu	1.6	Silt	5.8
Organic Carbon (%	0.08	Mn	91	Clay	9.8
Available P (mg/kg)	3.6	Fe	26.3	Textural class	Sandy Loam
K cmol/kg of soil	0.2				
Mg cmol/kg of soil	1.9				
Ca cmol/kg of soil	1.8				
Na cmol/kg of soil	0.6				
Exchangeable acidity	0.5				

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Nutrient Concentration in the Dry Cocoa Bean Testa Ash (DCBTA) and Wood Ash (WA)

The result of the characterization of dry cocoa bean testa ash (DCBTA) and wood ash (WA) used for the experiment is presented in Table 2. Dry cocoa bean testa ash has significantly higher values of organic carbon and nitrogen with 43.07g/kg and 23.60 g/kg respectively. Also, phosphorus, potassium, magnesium, iron and copper in cocoa bean testa ash were significantly higher than the wood ash, while wood ash has the higher value of calcium content of 2.47 g/kg while dry cocoa bean testa ash (CBTA) has 0.74 g/kg. pH value of wood ash is more basic than that of dry cocoa bean testa ash with values of 10.5 and 10.3 respectively.

Table 2: Paired T Test of Nutrient Concentration in the Dry Cocoa Bean Testa Ash (DCBTA) and Wood Ash (WA)

Properties	Dry Cocoa Bean Testa Ash (DCBTA) g/kg	Wood Ash (WA) g/kg	Mean difference	T Value
Organic carbon	43.07	23.6	19.47	<0.0001*
Nitrogen	0.82	0.17	0.66	0.0004*
Phosphorus	19.93	0.54	19.39	<0.0001*
Potassium	25.87	2.6	23.27	<0.0001*
Calcium	0.74	2.47	-1.72	0.0002*
Magnesium	15.5	1.17	14.33	<0.0001*
Iron	2.7	0.85	1.85	<0.0001*
Copper	8.9	0.73	8.17	<0.0001*
pH	10.3	10.5	-0.2	<0.0001*

Soil chemical properties of the experimental site as Affected by the application of Dry Cocoa Bean Testa Ash and Wood Ash (7WAP)

The data shown in the Table 3 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 (5.4) before the treatment were applied, but was 7.40, 6.9 and 7.42 after the application of DCBTA, WA and DCBTA + WA respectively Table 3. Some macro-nutrients such as nitrogen (N) calcium (Ca) magnesium (Mg) of the location improved across the whole treatment plots. The reduction in the values of soil phosphorous from 3.5 mg/kg in the control plot to 2.49 mg/kg, 2.07 mg/kg and 2.5 mg/kg in the DCBTA, WA and DCBTA + WA plots respectively showed that more of it were available to the plants in a soluble form especially in the treated plots. It was only the combination of Dry Cocoa Bean Testa Ash and Wood Ash that increased most of the soil nutrients, however, there was no significant difference between DCBTA and DCBTA + WA in most of the parameters measured.

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Table 3: Soil Chemical Properties of Study Site as Affected by the Application of Dry Cocoa Bean Testa Ash and Wood Ash (7WAP)

Treatments	pH(H_2O	OC (%)	N (%)	P	K	Ca	Mg

	)			(mg/kg)	(Cmol/Kg)	(Cmol/Kg)	(Cmol/Kg)
Control	5.40b	0.07c	0.06c	3.5c	0.30c	1.9d	1.8b
DCBTA	7.40a	2.31b	2.61a	2.49a	2.81a	6.50c	3.55a
WA	6.90ab	1.58c	1.75b	2.07b	0.88b	9.26b	2.98b
DCBTA + WA	7.42a	3.11a	1.95a	2.50a	2.86a	12.76a	3.77a

DCBTA= Dry Cocoa Bean Testa Ash

WA= Wood Ash

Effect of Dry Cocoa Bean Testa Ash (DCBTA) and Wood Ash (WA) on leaf area and chlorophyll of maize plant

Dry Cocoa bean testa ash (DCBTA) + Wood Ash (WA) Table 4, recorded highest values for leaf area with 83.4 cm^2 while the lowest value of 48.08 cm^2 was recorded in the control plot. There were significant differences between DCBTA + WA, DCBTA, WA. In the same vein, dry Cocoa bean testa ash (DCBTA) + wood ash (WA) for chlorophyll with 2.60 mg/g while the lowest value was recorded in the control plot with value 1.21 mg/g. There were significant differences between DCBTA + WA, WA and control for chlorophyll, in contrast, there was no significant difference between DCBTA + WA and DCBTA chlorophyll.

Table 4: Effect of Dry Cocoa Bean Testa Ash (DCBTA) and Wood Ash (WA) on leaf area and chlorophyll of maize plant (7WAP)

Treatments	Leaf Area (cm^2)	Chlorophyll (mg/g)
Control	48.08d	1.21c
DCBTA	79.57b	2.79a
WA	75.18c	2.41b
DCBTA + WA	83.40a	2.60a

DCBTA= Dry Cocoa Bean Testa Ash

WA= Wood Ash

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

Dry cocoa bean testa ash (DCBTA) + wood ash (WA) Table 5, recorded highest values for cob diameter with 6.12 cm while the lowest value of 2.8 cm was recorded in the control plot. There were significant differences between DCBTA + WA, WA and control, in contrast, there was no significant difference between DCBTA + WA and DCBTA.

In the same vein,dry Cocoa bean testa ash (DCBTA) + wood ash (WA) recorded highest value for cob length and grain yield with 24.74 cm and 1.89 tons/ha respectively while the lowest value was recorded in the control plots. There were no significant differences between DCBTA + WA and DCBTA. However, there were significant differences between all treated plots and control plot, in contrast, there was no significant differences between DCBTA and WA for both cob diameter and cob length and maize grain weight.

Table 5: Effect of Dry Cocoa Bean Testa Ash and Wood Ash on Cob Diameter, length and Grain weight of maize plant.

Treatments	Cob Diameter (cm)	Cob Lenght (cm)	Maize grain weight (tons/ha)
Control	2.8c	16.58c	0.74c
DCBTA	6.17a	25.02a	1.82a
WA	5.75b	18.01b	1.15b
DCBTA + WA	6.12a	24.74a	1.89a

DCBTA= Dry Cocoa Bean Testa Ash

WA= Wood Ash

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; Olojugba, 2010). 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 5.3 of the soil in the experimental site before the application of dry cocoa bean testa ash and wood ash 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; Adekayode and Olojugba, 2010). 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 soil fertility management practices in the area, Tisdale *et al*. (2003) 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.

Nutrient Concentration in Dry Cocoa Bean Testa Ash (DCBTA) and Wood Ash (WA) Used for the Experiment

The significantly higher value of organic carbon in DCBTA showed that it was a better source organic matter for soil fertility and crop growth and yield. Dry cocoa bean testa ash (DCBTA) has pH of 7.4 while wood ash (WA) has pH of 6.9, it shows that more nutrients would be more available and soluble if both DCBTA and WA were used to fertilize soil. This is in agreement with the findings of (Mallarino & Pagani, 2015). 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 DCBTA 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).

Changes in Leaf Area and Chlorophyll as a results of addition of Cocoa Bean Testa Ash (CBTA) and Wood Ash (WA)

The order of size of total leaf area and chlorophyll values which were significantly higher in dry Cocoa bean testa ash plus wood ash (DCBTA+WA) and dry Cocoa bean testa ash (DCBTA) plots might be due to higher values of potassium (K) and organic carbon in DCBTA as opposed to control and WA 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). In the same vein, Subedi & Ma, (2005), maintained that leaf area was essential for simulation of light interception and photosynthate production. 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, Le *et al*, 2016). Potassium plays an imperative role in the photosynthesis process and the subsequent carbohydrate translocation and metabolism, which eventually increase the crop yield and improve the grain quality (Zorb, *et al*, 2014). 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 (Bednarz, *et al*, 1998). Both the leaf number and the leaf size are reduced while the plant is deficient in K. Bonfim-Silva, *et al* (2013) presented results from studies with wood ash rates in the culture of the radish (Raphanus sativus), reported the influence in the chlorophyll index, effect provided by the availability of nutrients, which participate in the synthesis of chlorophyll and photosynthetic processes. (Bonfim-Silva, *et al*, 2015) while evaluating rates of wood ash

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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, Le *et al*, 2016).

Changes in some soil chemical properties as a results of addition of Dry Cocoa Bean Testa Ash (DCBTA) and Wood Ash (WA)

The higher pH values of 7.4, 6.9 and 7.42 in dry cocoa bean testa ash (DCBTA), wood ash (WA) and dry cocoa bean testa ash plus poultry dropping (DCBTA+WA) mixture plots might due to the liming effects of DCBTA and WA 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 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, sodium, calcium and magnesium. Ash amendment is known for its alkalinity properties which rise the soil pH (Demeyer et al., 2001. The significant higher in nitrogen and potassium in DCBTA as well as DCBTA + WA may be due to higher quantities of N, P and K found in DCBTA Table 2, however, WA has higher quantities of calcium, this findings is in agreement with Adekayode and Olojugba, (2010), they maintained that wood ash contained higher value of calcium. Then, the modification of soil pH following ash amendment changes soil nutrient availability, in particular phosphorus. In tropical acid soils P availability is mostly controlled by the strong adsorption capacity of iron and aluminum minerals, which tend to occlude phosphorus (Frossard, *et al*, 1995). An increase in pH favors the release of those occluded phosphorus forms into the soil solution and increase phosphorus availability (DeBano & Klopatek, 1988). Rani and Kalpana, (2010) also reported that application of fly ash to soil increased the nutrient availability such as nitrogen, phosphorus, and other micro nutrients .

Changes in Maize yield as a results of addition of Dry Cocoa Bean Testa Ash (DCBTA) and Wood Ash (WA)

The highest grain yield values of 1.82 t/ha and 1.89t/ha obtained in dry cocoa bean testa ash D(CBTA) and dry cocoa bean testa ash plus wood ash (CBTA+WA) compared with other treatments showed a high yield obtainable when dry cocoa bean testa ash (DCBTA) alone or in combination with other organic manure was used to improve soil fertility for increased crop production. The high maize grain yield in plots fertilized with DCBTA alone or with WA might be due to high concentration of potassium (K) and organic carbon in DCBTA, 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

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Comment [U21]: D(CBTA) must be changed as a (DCBTA) 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. Coskun, *et al*, 2017 [67] reported that potassium activates nitrate reductase (NR), a starch synthetase, and these two enzymes create a balance by producing protein and carbohydrates, respectively. Therefore, K shortages lead to a breakdown in these processes and the plants suffer, even though other nutrients are available. As previously stated by *Mirza et al* (2018), K has a role in the xylem and phloem transport system. Consequently, Ca2+, Mg2+, NO3 −, and PO4 3− as well as plant hormones and enzymes cannot be translocated, if K is deficient.

Conclusion

The improvement of soil fertility and subsequent higher maize grain yield obtained in 5t/ha DCBTA and 2.5t/ha DCBTA + 2.5t/ha WA confirmed that a combination of both organic sources gave higher maize grain yield than when each was applied separately. Also, Dry Cocoa bean testa ash (DCBTA) contained higher quantity of potassium (K) an organic carbon which made it to perform better than Wood ash (WA) in improving soil fertility in term of pH increment as well as other nutrients such as N, P, Ca, Mg and Na. DCBTA also increased maize grain better than WA. Application of DCBTA and WA appeared to have performed better in both soil fertility improvement and maize grain yield due to higher concentrations of potassium (K) and organic matter in DCBTA and high calcium in WA. As potassium (K) 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.

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