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Application of Dry Cocoa Bean Shell Ash and NPK 15:15:15 for Improvement of Soil Fertility and Maize Yield on a Degraded Humid Tropical Alfisol, Southwestern Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author MRO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. While Author DBO managed the analyses and literature searches of the study. Both authors read and approved the final manuscript

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ABSTRACT

The application of dry cocoa bean shell ash (DCBSA) and NPK 15:15:15 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 2016. Four treatments of dry cocoa bean shell ash (DCBSA) at 5 tonsha-1, NPK 15:15:15 at 300 kgha-1, dry cocoa bean shell ash (DCBSA) at 2.5 tonsha-1, mixed NPK 15:15:15 at 150 kgha-1 and control (C) were used in a Randomized Complete Block Design (RCBD) with three replications. The data collected were

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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 shell ash (DCBSA) used alone can serve as a suitable alternative to inorganic fertilizer in the south western Nigeria, Especially, DCBSA has higher organic carbon than NPK dry cocoa bean shell ash (DCBSA) at 5 t ha-1, NPK 15:15:15 at 300 kg ha-1, dry cocoa bean shell ash (DCBSA) at 2.5 t ha-1, mixed NPK 15:15:15 at 150 kg ha-1 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. DCBSA 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 5.3 to 7.8 DCBSA, N levels in the soil increased from 0.06g kg-1 to 2.61g kg-1 (DCBSA) and 2.10 g kg-1 (DCBTA + NPK). Organic carbon (OC) increased from 0.07 g kg-1 to 2.87g kg-1 DCBSA plot. P level decreased from 3.7 mg dm-3 to 1.09 mg dm-3 (DCBSA) and 1.81 mg dm-3 (NPK) and 1.42 mg dm-3 (DCBSA + NPK) which was an indication of P availability to crop during growing season. Maize grain yield increased from 0.77 tonsha-1 in the control plot to 1.25 t ha-1 in DCBSA plot, 1.22 t ha-1 a in NPK plot and 1.26 t ha-1. in DCBSA + NPK plot. The study recommends an application rate of 5 t ha-1 of dry cocoa shell ash (DCBSA) alone or 2.5 t ha-1 combination each of (DCBSA + NPK) for maize yield and fertility improvement on this type of soil in this agro - ecology.

Key words: Soil fertility; potassium; soil chemical properties; integrated nutrient management; dry cocoa bean shell ash (DCBSA); soil; NPK fertilizer.

1. INTRODUCTION

Cocoa beans are seeds of the tree *Theobroma cacao*, each seed consists of two cotyledons (the nib) and a small embryo plant, all enclosed in a skin (the shell). The waste shells from cocoa processing are usually burnt for fuel or used as mulch in gardens to add nutrients to soil and to suppress weeds [1]. Cocoa bean shell can be used as mulching as it contains 2.5% nitrogen, 1% phosphate, and 3% potash, as well as natural gum which is activated when moistened. It slows moisture loss and inhibits weed growth. The texture of coca been shell also deters slugs and snail which helps prevent plant loss [1].

The importance of ameliorant fertilizers is due to the maintenance and improvement of the soil's physical, chemical and biological properties, reflecting on the performance of crops. Nutrient releases by organic fertilizers occur by the contact of soil micro-organisms with organic matrix that will reduce size and gradually release nutrients to the soil for plant growth. Complimentary use of plant nutrients from waste materials along with chemical fertilizers is of great importance for soil productivity i.e. soil structure, soil bio-activity, soil exchange capacity and water holding capacity [2].

The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) calls for focusing on efficient, small-scale agro - ecosystems with material cycles that are as closed as practicably possible [3,4]. Agroecology, nutrient recycling within the agroecosystem, and the use of locally available resources represent, therefore, agreed prerequisites for soil conservation and amelioration, and also, as a consequence, for long-term food production [5]. As a holistic farming approach to jointly manage soil, nutrients, water, crops, and vegetation in the context of sub-Saharan Africa (SSA), the IAASTD and the Food and Agricultural Organization of the United Nations (FAO) further promote integrated plant nutrient management (IPNM) [6]. When tailored to a particular cropping system, IPNM aims to provide a solution to the triple challenge of (i) sustaining soil fertility, (ii) improving land productivity, and (iii) reducing environmental degradation [6]. Applied IPNM combines the use of organic inputs, such compost, farmyard manure, mulch, etc., with mineral inputs, such as synthetic fertilizers, alongside practices including intercropping, agroforestry, liming, low-tillage, crop rotation, etc. [3].

Nitrogen, phosphorus and potassium and other nutrient elements play great physiological importance in formation of chlorophyll, nucleotides, phosphatides, alkaloids as well as in many enzymes, hormones and vitamins for optimum grain yield [7]. Nitrogen deficiency could exert a particularly marked effect on maize crop yield as the plant would remain small and rapidly turned yellow if sufficient nitrogen was not available for the construction of protein and chlorophyll. The lack of chlorophyll had been observed to diminish carbohydrate production and a restriction in the assimilating power of the plant. The source of the nutrients for plant's growth could either be organic or inorganic or from the two combined [8].

Cocoa bean shell has found its usefulness in concentrating K. It has been found to have a high level of K that is about 4.31% dry bases [9]. Cocoa shell 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, Indonesia. With the urgent need for new fertilization alternatives either sole or in combinations with inorganic fertilizer, hence the present investigation was undertaken to study the feasibility of using Dry Cocoa Shell Ash (DCBSA) as component of Integrated Plant Nutrient System with NPK fertilizer for sustaining soil productivity and crop yield as well as to evaluate its effect on some chemical properties on a degraded tropical alfisol.

2. MATERIALS AND METHODOLOGY

2.1 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' and 07º 18' and longitude 05º 09' and 05º 11' E. First cropping season was between April to July, 2016, while the second season cultivation was between August to November in 2016. 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 [10].

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 application);
b) Dry cocoa bean shell ash (DCBSA) at 5 t ha^{-1};
c) NPK 15:15:15 at 300 kg ha^{-1};
d) NPK 15:15:15 at 150 kg ha^{-1}+ Dry cocoa bean shell ash (DCBSA) at 2.5 t ha^{-1}.

All treatments were allocated to the plots in each block at random. However, control plot did not receive any application. 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 [8].

2.3 Cocoa Bean Shell Ash Preparation

The cocoa bean (Fig. 1) consists mainly of an outer shell surrounding two cotyledons. The cocoa shell (Fig. 2) is very hard and damage processing machinery. After roasting and gentle crushing of cocoa seed, a winnowing machine was used to remove the shells from the beans to leave just the nibs. The shells were collected, 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. Up till now, cocoa bean shell constitutes waste product after the beans for producing beverages were removed and many a times constitutes major environmental problem in cocoa products and processing factory located in the major communities producing in Nigeria [1].

2.3.1 Data collection

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

2.3.1.1 Plant sample collection

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

Fig. 1. Dry Cocoa Beans

Fig. 2. Dry Cocoa Beans Shell

2.3.1.2 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 [11,12] 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 [13]. The chlorophyll was determined by extraction in 80% acetone and reading the absorbance of the solution at 645, 663 and 652 nm [14].

2.3.1.3 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, 2016 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 2016 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.

2.3.1.4 soil analysis

Particle size distribution was determined by hydrometer method [15]. The soil samples collected were air dried and sieved through a 2 mm mesh and analyzed for soil chemical properties [16]. PH was determined using a glass electrode 1:1 (w/v) in de-ionized water. Organic matter was determined using method described by [17]. K, Ca, Mg, Na, P, were determined by plasma-atomic emission spectroscopy [18]. The total nitrogen was determined using micro-kjeldahl method and the available phosphorus extracted colorimetrically by the molybdenum blue method. Cation exchange capacity was determined by the summation of NH_4OAC – extractable cations plus 1.0N KCl extractable acidity.

2.4 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 cocoa bean and wood ash.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Pre-planting soil properties of the study area

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

8.4 g kg^{-1} sand and organic matter 0.08g kg^{-1}. The pH (H_20) show that the soil was slightly acidic (pH =5.3). The soil contains high organic carbon, low total nitrogen but relatively moderate phosphorus content of 0.05 gkg^{-1} and 3.6 (mg dm^{-3}) respectively. The OC was 0.08 g kg^{-1} while the cation exchange capacity was low and has the value of 3.52 $cmol_c$ kg^{-1}. The Al content of the study area was high.

3.1.2 Nutrient concentration in the Dry Cocoa Bean Shell Ash (DCBSA) and NPK

The result of the characterization of dry cocoa bean shell ash (DCBSA) is presented in Table 2. Dry cocoa bean shell ash has significantly higher values of organic carbon and nitrogen with 33.0 gkg^{-1} and 0.8 gkg^{-1} respectively. Also, phosphorus, potassium, magnesium, iron and copper in cocoa bean shell ash were significantly higher. pH value dry cocoa bean shell ash has value of 6.7.

3.1.3 Responses of plant height to the addition of Dry Cocoa Bean Shell Ash (DCBSA)

Table 3 shows that there was no significant difference in the effect dry cocoa bean shell ash (DCBSA), dry cocoa bean shell ash (DCBSA) and NPK application and control on the plant height in the week 2 and 3 after planting. At 4WAP, there was significance difference between treatments applied, with the highest values recorded in the NPK 300 at kg ha^{-1} plot and the least recorded from the control plot, however, there was no significance difference between plots treated with NPK and NPK + DCBSA and 5WAP. The plots treated with NPK + DCBSA gave the highest yield of 45.3 cm while the control plot recorded the lowest value of 15.0 cm. However, there was no significant between NPK and DCBSA at $p<0.05$ using DMRT.

3.1.4 Responses of plant diameter to the addition of Dry Cocoa Bean Shell Ash (DCBTA)

The maize stem diameter increased across all the treatments from 3, 4, and 5 weeks after planting (table 4).

At 2 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 $p<0.05$. At 5 WAP, NPK + DCBSA recorded higher value over other treatments. While control plot recorded the least value.

3.1.5 Soil chemical properties of the experimental site Affected by the application of Dry Cocoa Bean Shell Ash (DCBSA) and NPK at (7WAP)

The data shown in the table 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 (5.2) before the treatment were applied, but present values of 7.8, 5.4 and 5.8 after the application of DCBSA, NPK and DCBSA + NPK respectively (table 5). Organic carbon increased across the treated plots over the control with highest value recorded in DCBSA, while the least value was recorded from control plot. The content of N, Ca and Mg of the location improved across the whole treatment plots over the control plot. The reduction in the values of soil phosphorous from 3.7 mg dm^{-3} in the control plot to 1.09 mg dm^{-3}, 1.81 mg dm^{-3} and 1.42 mg dm^{-3} in the DCBSA, NPK and DCBSA + NPK plots respectively showed that more of P was available to the plants in a soluble form especially in the treated plots due to the presence of K. Dry Cocoa Bean Shell Ash and NPK fertilizer that increased most of the soil nutrients, however, there was no significant difference between DCBSA and DCBSA + NPK in most of the parameters measured.

3.1.6 Effect of Cocoa Bean Shell Ash and Wood Ash on leaf area, leaf area index and chlorophyll of maize plant

All treated plots recorded significantly higher values over the control plots, table 6. Dry Cocoa bean shell ash DCBSA + NPK treated plots recorded highest values for leaf are, leaf area index and chlorophyll with values of 42.44 cm^2, 2.88 and 2.99 g kg^{-1} respectively. While the lowest values of 30.08 cm^2, 0.98 and 0.89 g kg^{-1} were recorded for leaf area, leaf area index and chlorophyll respectively in the control plot. However, there was no significant difference between leaf are and leaf area index in NPK and DCBSA + NPK plots. In the same vein, chlorophyll show no significant difference in NPK, DCBSA and NPK + DCBSA.

3.1.7 Effect of Dry Cocoa Bean Shell Ash and NPK fertilizer on cob diameter, length and grain weight of maize plant

There were no significant differences in cob diameter, cob length and maize grain weight values from the treated plots. However, dry cocoa bean shell ash DCBSA + NPK fertilizer Table 7, recorded highest values for cob diameter with 6.5 cm 1.26 t ha^{-1} respectively while the lowest value of 2.6 cm was recorded in the control plot. In the same vein, dry cocoa bean shell ash (DCBSA) recorded highest value for cob diameter but statistically not significantly different from other treated plots.

Table 1. Pre -planting Physico - Chemical Properties of Soil of the Study Site

Soil Chemical Properties/macro nutrients		Particle size analysis (g kg^{-1})	
Properties	Values	Properties	Values
pH (H_2O) 1:1	5.3	Sand	8.4
TN (gkg^{-1})	0.05	Silt	0.6
OC (gkg^{-1})	0.08	Clay	1.0
Available P (mg dm^{-3})	3.6	Textural class	Sandy Loam
K ($cmol_c$ kg^{-1})	0.2		
Mg ($cmol_c$ kg^{-1})	1.9		
Ca ($cmol_c$ kg^{-1})	1.8		
Na ($cmol_c$ kg^{-1})	0.6		
CEC ($cmol_c$ kg^{-1})	3.52		
H ($cmol_c$ kg^{-1})	0.12		
Al ($cmol_c$ kg^{-1})	0.06		
Cu (mg dm^{-3})	3.15		
Fe (mg dm^{-3})	14.4		
Mn (mg dm^{-3})	6.16		

TN = total nitrogen, OC = organic carbon, C.E.C = cation exchange capacity

Table 2. Proximate Analysis of Dry Cocoa Bean Shell Ash

Properties	Dry Cocoa Bean Shell Ash (DCBSA) gkg^{-1}
Organic carbon	33.0
Nitrogen	0.8
Phosphorus	0.35
Potassium	25.8
Calcium	0.74
Magnesium	15.5
Iron (mg dm^{-3})	2.7
Copper (mg dm^{-3})	8.9
pH	6.7

Note: 1 g kg^{-1} = 0.1%Note: 1 g kg^{-1} = 0.1%

Table 3. Responses of Plant Height to the addition of Dry Cocoa Bean Shell Ash (DCBTA)

Treatments	WAP (cm)			
	2	3	4	5
Control	11.8a	11.9a	13.7c	15c
NPK at 300 kg ha^{-1}	13.3a	13.7a	22.5a	43.4b
CBSA at 5t ha^{-1}	11.7a	12.3a	20.5b	42.8b
NPK at 150 kg ha^{-1} + CBSA at 2.5 t ha^{-1}	12.3a	14.9a	21.8a	45.3a

WAP- Weeks after planting CBSA- Cocoa bean shell ash NPK - Complete fertilizer NPK
Means in the same column followed by the same letters are not significantly different by DMRT at $p<0.05$

Table 4. Responses of plant diameter to the addition of dry cocoa bean shell ash (DCBTA)

Treatments	WAP (cm)			
	2	3	4	5
Control	0.47a	0.60b	0.71b	1.15c
NPK at 300 kg ha^{-1}	0.52a	0.82a	0.97a	2.61a
CBSA at 5t ha^{-1}	0.53a	0.80a	0.99a	2.40b
NPK at 150 kg ha^{-1} + CBSA at 2.5 t ha^{-1}	0.52a	0.88a	1.02a	2.65a

WAP - weeks after planting DCBSA - dry cocoa bean shell ash NPK - NPK fertilizer
Means in the same column followed by the letters are not significantly different by DMRT at p<0.05

Table 5. Soil chemical properties of study site affected by the application of dry cocoa bean shell ash and NPK fertilizer at (7WAP)

Treatments	pH(H_2O)	OC (g kg^{-1})	N(g kg^{-1})	P(mgdm^{-3})	K(cmol$_c$ kg^{-1})	Ca (cmol$_c$ kg^{-1})	Mg (cmol$_c$ kg^{-1})
Control	5.2d	0.070d	0.06c	3.70a	0.30b	1.8c	1.88c
DCBSA	7.8a	2.87a	2.61a	1.09d	0.81a	12.50a	3.55a
NPK	5.4c	0.13c	2.10a	1.81b	0.97a	3.67c	2.20b
DCBSA+ NPK	5.8b	1.20b	2.10a	1.42c	1.02a	12.95a	4.20a

DCBSA = dry cocoa bean shell ash NPK = NPK fertilizer Means in the same column followed by the letters are not significantly different by DMRT at p<0.05

Table 6. Effect of cocoa bean shell ash and NPK on leaf area and chlorophyll of maize plant (7WAP)

Treatments	Leaf Area (cm^2)	Leaf Area index	Chlorophyll (g kg^{-1})
Control	30.08c	0.98c	0.89c
NPK at 300 kg ha^{-1}	39.05ab	2.87a	2.96a
DCBSA 5 t ha^{-1}	38.97b	2.79a	2.89a
NPK at 300 kg ha^{-1} + DCBSA 2.5 t ha^{-1}	42.44a	2.88a	2.99a

DCBSA - Dry Cocoa bean shell ash DCSA+NPK - Cocoa bean shell ash + NPK fertilizer NPK = NPK fertilizer

Table 7. Effect of dry cocoa bean shell ash and NPK fertilizer on cob diameter, length and maize grain weight

Treatments	Cob Diameter (cm)	Cob Length (cm)	Maize grain weight (t ha^{-1})
Control	2.6b	12.58c	0.74c
CBSA	6.4a	24.08a	1.25a
NPK	6.2a	22.25a	1.22a
CBSA + NPK	6.5a	23.75a	1.26a

DCBSA - Dry cocoa bean shell ash NPK - NPK fertilizer
Means in the same column followed by the letters are not significantly different by DMRT at p<0.05

3.2 DISCUSSION

3.2.1 Pre- planting physico - chemical properties of Soil of the study 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 [19] Table 1, Smyth and Montgomery, 1962 [19] 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 [20]; Adekayode and Olojugba, 2010 [8]. N, P, K, Ca, Mg and Na were low in the study area. This may be due to the over cropping, texture of the soil which may lead to leaching of soluble cations, soil erosion as well as lack of proper land management practices in the area, Tisdale et al. 2003 [21] 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 was largely responsible for the development of acidity in the soil. The texture of the soil may be the reason why there was low value of organic matter in the area and also may be due to continuous cropping without the addition of organic manure Adekayode and Olojugba, 2010 [8].

3.2.2 Nutrient Concentration in Dry Cocoa Bean Shell Ash (DCBSA) used for the experiment

The value of organic carbon in both DCBSA showed that it is a good source organic matter for soil fertility regeneration, crop growth and yield, however, the higher value of organic carbon in DCBSA over it might be better source of organic carbon. Dry cocoa bean shell ash (DCBSA) has pH of 6.7, it shows that more nutrients would be more available and soluble if DCBSA is used to fertilize soil. This is in agreement with the findings of Pagani and Mallarino, 2015 [22]. They were of the opinion that more nutrients such as N, P, K, S, Ca, Mg are more soluble, less toxic to crops and available between pH 6.5 to 7.5. Also, high proportion of OC, N and K in DCBSA shows that it might be a better source of OC, N and K Adeoye et al. 2001 [9], Afoakwa et al, 2014 [1]. The plots mulched with NPK + DCBSA and NPK had low pH, which lead to more acidic condition (Table 2) as compared with plot mulched with DCBSA. This may be due to other organic acid products by decomposition of organic material, production of hydrogen ions by exchange with corresponding release of OH^- from aluminum and iron oxides as well as production of H^{-1} from mineral fertilizer (NPK) Opala, 2011 [23].

3.2.3 Responses of growth parameters (height and diameter) to the addition of Dry Cocoa Bean Shell Ash (DCBTA) and NPK

The significantly higher values of maize length and diameter in the dry cocoa bean shell ash (DCBSA), NPK, DCBSA + NPK treated plots over that of the control plot may be due to the concentration of essential minerals in OC, N, K 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 [24], 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 from DCBSA and DCBSA+ NPK plots might be due to the concentration of OC, N, K in the treatments Adeoye et al. 2001 [15], Afoakwa et al, 2014 [1]]. Mirza et al, 2018 [25] found out that among the plant nutrients, 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, water and photosynthesis. Potassium regulates the biosynthesis, conversion, and allocation of metabolites that ultimately increases the yield. Many researches work strongly supported the notion that K is directly or indirectly responsible for higher yield of crops Islam and Muttaleb, 2016 [26], Uddin et al, 2013 [27].

3.2.4 Changes in leaf area, leaf area index and chlorophyll as aresult of addition of dry Cocoa Bean Shell Ash (CBSA) and NPK

The order of size of total leaf area the leaf area index and chlorophyll values which were significantly higher in Dry cocoa bean shell ash plus NPK (DCBTA + NPK) and dry cocoa bean shell ash (DCBTA) plots might be due to higher values of K and organic carbon in DCBSA as opposed to NPK plot that has N, P and K only 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 [28]. In the same vein, Subedi and Ma, 2005 [29], maintained that leaf area was essential for simulation of light interception and photosynthetic 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 [25], Lu et al, 2016 [30].

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 [25], Lu et al, 2016 [30].

3.2.5 Changes in some soil chemical properties as a result of addition of Dry Cocoa Bean Shell Ash (DCBSA) and NPK

Dry cocoa bean shell ash (DCBSA), NPK and DCBSA + NPK significantly improved the soil chemical properties over the control plots. The finding was in time with the earlier assertion of Upanwansa, 1997 [31]. He was of the opinion that the integrated nutrients management has combined effect on soil conservation nutrient enhancement and biological activities improvements. The higher pH value of 7.8 in dry cocoa bean shell ash (DCBSA) plots might due to the liming effects of K and high concentration of OC in DCBSA Opalla, 2011 [23]; Adeoye et al. 2001 [15]. Marcel et al, 2016 [24] submitted that the pH increases can be attributed mainly to the release of potassium carbonat by reaction of ash in the soil. Also, Demeyer et al. 2001[32] and Lickaaz 2002 [33] 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 [32]. The significant higher in nitrogen and potassium in DCBSA as well as DCBSA + NPK may be due to higher quantities of N, P and K found in DCBSA Table 2, the modification of soil pH following ash amendment especially in the DCBSA treated plots 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 [34]. An increase in pH favors the release of those occluded phosphorus forms into the soil solution and increase phosphorus availability DeBano & Klopatek, 1988 [35]. Rani and Kalpana, 2010 [36] also reported that application of fly ash to soil increased the nutrient availability such as nitrogen, phosphorus, and other micro nutrients.

3.2.6 Effect of Dry Cocoa Bean Shell Ash (DCBSA) and NPK on maize yield parameters

The significantly higher values of all yield parameters (cob diameter, cob length and maize grain yield) in all treated plots over the control plot. This may be due to favourable pH, which influences solubility and availability of plant nutrients between pH 6.5-7.5. Higher OC in DCBSA plots which serves as store house for most plant nutrients coupled with better soil aggregate stability which enhances better soil aeration, water holding capacity and nutrient availability Opalla, 2011 [23]. The highest grain yield values of 1.26 tha^{-1} obtained in dry cocoa bean testa ash (DCBSA) and NPK compared with other treatments of DCBSA ability to increase crop yield alone or in combination with inorganic manure. The trend observed might be due to high concentration of K and OC in DCBSA, according to Cheema et al 2012 [28] 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. Khanna et al., 1994 [37] reported that the extent to which these are dissolved and the rate at which they are made plant available varies between elements. Oxides and hydroxides of K are normally dissolved quickly, while the dissolution of Ca and Mg depends on the dilution (faster when ash/water ratio is low), this phenomenon translates to absorption of K and subsequently increase the maize grain yield. 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 [7]. Uddin et al. 2013 [27] 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 [38] reported that K 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 [25], K has a role in the xylem and phloem transport system. Consequently, Ca^{2+}, Mg^{2+}, NO_3^-, and PO_4^{3-} as well as plant hormones and enzymes cannot be translocated, if K is deficient.

4. CONCLUSION

It was observed that dry cocoa bean shell ash (DCBSA) alone can serve as a suitable alternative to the use of NPK 15:15:15 fertilizer for soil fertility improvement and maize grain yield. The improvement of soil fertility and subsequent higher maize grain yield obtained in 5 t ha^{-1} DCBSA and 2.5 t ha^{-1} DCBSA + NPK 15:15:15 at 150 kg ha^{-1} confirmed that a combination of both DCBSA + NPK gave higher maize grain yield. Also, Dry Cocoa bean shell ash (DCBSA) contained higher quantity of K and organic carbon which made it to perform better than NPK in improving soil fertility in term of pH increment as well as other nutrients such as N, P, Ca, Mg and Na. DCBSA also increased maize grain better than NPK, although, not significantly different. Application of DCBSA and NPK appeared to have performed better in both soil fertility improvement and maize grain yield due to higher concentrations of K and OM in DCBSA and high K in NPK. As K has been proved to be vital for plant survival under both physiological and stress conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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