Effect of Combined Cocoa Pod Ash and NPK Fertilizer on Soil Properties, Nutrient Uptake and Yield of Maize (*Zea mays*)

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Abstract: Field experiments were conducted in two cropping seasons (March and September, 2007) at two locations to determine the effect of cocoa pod ash (5 and 10 t ha^{-1}) and NPK 20:10:10 fertilizer (150 and 300 kg ha^{-1}) on soil chemical properties, nutrient uptake and yield of maize in southwest Nigeria. The experiments were sited at Adeyemi College of Education Research Farm, Ondo and Okegun both Alfisol. Ondo soil was sandy clay, deficient in OM, N, P and K while Okegun soil was clay loam, deficient in OM, N and K. The treatments were laid out in randomized complete block design with three replications. Combined cocoa pod ash and NPK 20:10:10 fertilizer significantly ($p<0.05$) increased soil OM, N, P and K at Ondo and OM, P and K at Okegun than cocoa pod ash and NPK 20:10:10 fertilizer singly applied. Plant N, P and K were also increased significantly compared with single application of cocoa pod ash and NPK20:10:10 except 300 kg ha^{-1}.at the two locations as well as plant height, grain, stover and dry root yields. At Adeyemi (sandy clay), compared with control, the percentage increase in grain yield were C10F150 (81%), F300 (74.76%), C5F150 (65.71), C10 (47.62%), C5 (38.5%) and F150 (32.28%). For Okegun (clay loam), grain yield significantly increased ($p<0.05$) by C10F150 (75.85%), F300 (54.36%), C5F150 (42.46%), C10 (8.10%), C5 (19.84%) and F150 (17.06%). Treatment C10F150 gave the highest increases in soil nutrient values and growth parameters of maize. Soil total N, available P and exchangeable K tended to increase as the level of the treatment combinations increased at both locations. Cocoa pod ash combined with reduced level of NPK 20:10:10 was more effective than single application of cocoa pod ash and NPK 20:10:10 fertilizer in both locations. Sandy clay responded to application of cocoa pod ash than clay loam in this experiment. [Journal of American Science 2010;6(3):79-84] (ISSN: 1545 - 1003)

Keyword: micronutrients, Fertilizer, macronutrients, soil, nutrient uptake, soil type

Introduction

In tropical countries, high cost, scarcity, nutrient imbalance and soil acidity are problems associated with the use of mineral fertilizer while bulkiness, low nutrient quality and late mineralization were the bottleneck to the sole use of organic manures for crop production. Some studies confirmed that combined application of organic manures and mineral fertilizers gave superior effects in terms of balanced plant nutrition and improved soil fertility (Uyovbisere and Elemo, 2000, Ayeni, 2008). Other advantages of using combined application of organic and inorganic fertilizers, is that, it reduces the need for mineral fertilizer and aids time mineralization of nutrients from organic manures.

Cocoa pod husk and its ash have not been adequately studied in plant nutrition. Ayeni *et al*., (2008a) found that cocoa pod ash contained plant nutrients as N, P, K Ca, Mg and micronutrients and is good for tomato production (Odedina *et al*., 2003). About 800,000 tones of cocoa pod husk are generated annually in Nigeria and often wasted (Egunjobi, 1976). It is advised that the husk be burnt into ash as a method of farm sanitation and for the control of black pod disease. The husk left on the farm harbours the fungus (*phytophtora palmivora*) which is the causal organism of black pod disease. Moyin Jesu (2003) after extensive literature search noted scarcity of report on use of cocoa husk in plant nutrition. Egunjobi (1976) found that ground cocoa husk applied to soil increased maize yield by 124%, and also increased uptake of P, K, and Mg. In the studies by Ajayi *et al*., (2007a, 2007b), it was found that cocoa pod husk ash increased growth and nutrient uptake by Kola seedlings and soil P, K, Ca and Mg, compared with NPK fertilizer, cocoa pod ash, at 2, 4, 6, 8 and 10 t ha^{-1} increased root N, P, K, Ca, and Mg which increased with level of ash. Ojeniyi *et al*., (2002) investigated the effect of animal manure amended cocoa pod husk on tomato. Amended husk significantly increased growth and yield of tomato, trail yield was increased by 397%.

This work studied the comparative effect of cocoa pod ash, NPK 20: 10: 10 and their combinations on soil chemical properties, nutrient uptake and yield of maize in sandy clay and clay loam of southwest Nigeria where cocoa pod is found in abundance.

Materials and methods

Soil Analysis

Before the commencement of experiment, surface (0 – 20 cm) soil samples were collected at the site of the experiment using auger, bulked, air –dried and 2mm – sieved for analysis. Samples were also

collected over each treatment plot. Analysis was done as described by Carter (1993). Organic matter (OM) was determined using wet dichromate method, total N by Kjeldahl method, available P by molybdenum blue colorimetry. Exchangeable K, Ca and Mg were extracted using ammonium acetate, K was read on flame photometer and Ca and Mg on atomic absorption spectrophotometer. Soil analysis were also carried out after the conduct of the experiment

Field experiment

Field experiments were conducted concurrently in March, 2007 and repeated in September 2007 at Adeyemi College of Education Research farm, Ondo (sandy clay) and clay loam soil of Okegun 30 km away from Ondo both Alfisol (07^{o}C 05N and 04E 55N) in the rain forest zone of southwest Nigeria. Ondo site was cultivated to maize, yam and cassava with application of various types of mineral fertilizer for many years. Okeogun soil has also been cropped with various crops with no history of the use of mineral fertilizers on the soil. The lands at both sites were manually cleared in February 2005 and heaps were made 75cm apart. There were seven manurial treatments involving a control (no treatment), NPK 20:10:10 at 300 kg ha^{-1} (F300), 150 kg ha^{-1} NPK20: 10:10 fertilizer (F150), cocoa pod ash at 5 t ha^{-1} (C5), cocoa pod ash at 10 t ha-1(C10), 5 t ha-^{1} cocoa pd ash combined with 150 kg ha^{-1} NPK 20:!0:10 fertilizer (C5F150) , 10 t ha^{-1} cocoa pod ash combined with 150 kg ha^{-1} NPK20:10:10 fertilizer (C10F150). The seven treatments were replicated three times on single stand of maize at 75 x 30 cm given a total population of 70 plants per plot of the 21 plots, each plot being 16m^2. Cocoa pod ash, NPK 20:0:10 and their combinations were applied in ring form and covered with soil to avoid evaporation at two weeks after planting. Three weeding were done with hoe at two weeks interval.

Ash and leaf analysis

The nutrient composition of cocoa husk ash was determined. With the exception of nitrogen (N), the determination of other nutrients was done using wet digestion method based on 25 – 5 – 5 ml of HNO_3 – H_2SO_4 – $HClO_4$ acids (AOAC, 1990). The methods used in soil were also used to analyze P, K, Ca and Mg. Total N was determined with Microkjedahl method.

Leaf samples collected from maize plants at 50% flowering were oven dried for 24 hrs at 70^{o}C, milled and analyzed as described by Tel and Hagarty (1984).Nutrients determination was carried out as done in cocoa pod ash.

Growth and Yield Data

At harvest (90 days after planting), five plants were uprooted per plot to determine height, stover and root dry matter. Roots were separated from the shoot. The plants were air – dried at 65 ^{0}C to constant weight to determine shoot and root dry matter yield. 40 maize plants were randomly selected from the middle row and harvested. Cobs were air –dried, shelled and grain yield determined at 12% moisture content. Grain yield per hectare were calculated. In September 2007 (second cropping season), the experiment was repeated and done as carried out in the first experiment.

Statistical analysis

The Duncan Multiple Range Test was used to compare the mean data at 5% level.

Result and Discussion

The soil physical and chemical properties used for the conduct of the experiment are shown in table1. The nutrient critical level recommended for optimum production of maze in southwest Nigeria are organic matter (OM) 3%, total N 0.15%, available P 8 – 10 g kg^{-1}, exchangeable K, Ca and Mg are 0.20, 20 and 0.26 Cmol kg $^{-1}$ respectively (Sobulo and Osiname, 1987, Adepetu *et al*., 1979, Agboola and Unamena, 1989). This indicates that soil in Ondo was deficient in OM, N, P and K while the soil use for the experiment at Okegun was adequate in P and fairly adequate in total N. The two soils were adequate in Ca and Mg. The soil at Okegun was higher in nutrient values than Ondo.

Table 2 presents data on nutrient composition of cocoa pod ash used in the conduct of the experiment. Cocoa pod ash had high K and Ca with low N and P. The low N might be as a result of volatilization during the burning process. The C/N ratio (13) is conducive enough for early mineralization of nutrients especially N for maize uptake. This is in line with the previous work of Odedina *et al*., 2003 and Ayeni *et al*., 2008b that cocoa pod ash contained N, P, K, Ca and Mg. Sobamiwa and Longe (1994) showed that cocoa pod ash contains N, P, K, Ca, Mg and micronutrients.

Table1: Initial soil physical and chemical properties

Nutrient	Okegun	Ondo
pH (1:1 H_20)	6.02	6.39
OM %	2.49	2.23
Total N %	0.14	0.10
Available P mg kg-1	8.89	5.96
Exchangeable K	0.12	0.15
Exchangeable Ca	2.35	3.38
Exchangeable Mg	0.36	0.30
Sand %	44	73
Silt	23	9
Clay	33	18
Textural class	clay loam	sandy clay

Table 2: Nutrient composition of cocoa pod ash (%)

Nutrient	values
Organic carbon	12.10
N	0.99
C/N ratio	13.00
Total P	2.50
K	12.36
Ca	3.40
Mg	0.76

Table 3 presents data on the effect of cocoa pod ash, NPK 10:10:10 fertilizer and their combinations on soil chemical properties after maize harvest in the two locations. Cocoa pod ash applied at 10 t ha^{-1} (C10), cocoa pod ash combined with NPK fertilizer rates (C5F150, C10F150) and F300 significantly ($p< 0.05$) increased soil OM, N and P in both locations. Compare with control, cocoa pod ash rates (C5, C10) and its combinations with NPK fertilizer significantly ($p<0.05$) increased exchangeable Mg at Ondo and Okegun while only Ondo had significant effect on Ca at all rates. Treatment C5 had higher OM, N and P than C10 while C10 increased OM, N and P than C5 in Okegun. The increase in OM, N and P as the level of cocoa pod ash was increased at Okegun might be as result of its texture which enhanced absorption of nutrients. The improved soil nutrient contents due to application of ash is consistent with the report of Ayeni *et al*., 2008b that application of wood ash increased soil OM, N, P, K, Ca as well as leaf N and P in the experiment conducted to show the effect of wood ash and sawdust ash on raising cocoa seedlings in the nursery. Ajayi *et al*., 2007a) also found that cocoa pod ash increased soil nutrients in the experiment performed to show the effect of cocoa husk ash in raising kola seedlings. The effectiveness of combined cocoa pod ash and NPK fertilizer over single application of cocoa pod ash and NPK 20:10:10 fertilizer might be that the materials complement each other in nutrient release for nutrient uptake. Cocoa pod ash (C5, C10) supplied higher Ca than NPK 20:10:10 fertilizer rates (F150, F300). Their values also tended to increase with the levels of cocoa pod ash in the two locations. The increases in Ca and Mg contents are attributable by cocoa pod ash. This confirmed the positive effect of ash on cationic nutrients. The higher Ca and Mg treated with C5F150 and C10F150 than F150 and F300 were therefore derived from the cocoa pod ash as indicated in the percentage composition of cocoa pod ash (Table 2).

Table 3: Effect of cocoa pod ash, poultry manure, NPK fertilizer and their combinations on soil chemical properties at Ondo and Okegun

Treatment	OM %		N %		P mg kg^{-1}		K		Ca cmol kg^{-1}		Mg	
	Ondo	Okegun	Ondo	Okegun	Ondo	Okegun	Ondo	Okegun	Ondo	Okegun	Ondo	Okegun
Control	1.07	1.21	0.02	0.09	4.16	5.62	0.17	0.19	1.00	2.11	0.33	0.47
F300	2.18	2.26	0.11	0.12	9.45	10.22	0.20	0.23	1.10	2.13	0.34	0.46
F150	1.09	2.00	0.04	0.12	4.41	7.11	0.18	0.20	1.10	2.10	0.36	0.46
C5	2.46	2.12	0.1	0.11	9.14	1973	0.29	0.22	3.02	3.32	1.50	1.00
C5F150	2.95	3.76	0.16	0.14	12.00	19.04	0.31	0.25	2.30	3.02	1.00	1.50
C10	2.43	3.25	0.12	0.15	9.03	19.49	0.36	0.23	3.84	3.00	1.62	1.15
C10F150	3.10	3.48	0.18	0.17	17.17	20.98	0.39	0.26	2.00	2.00	1.10	1.20
LSD(0.05)	0.51	0.59	0.04	0.06	3.00	4.14	0.12	0.02	0.94	1.00	0.59	0.48

Table 4 presents data on tissue N, P and K of maize in Ondo and Okegun respectively. The data are the mean for the two experiments in each location (early and late seasons). Treatment C10F150 gave the highest N and K in the two locations. F300 recorded highest P in Okegun while C10F150 had highest P in Ondo. Cocoa pod ash combined with NPK 20:10:10 fertilizer at all levels had higher N, P and K than C5, F150 and control in both locations. The value of C/N ratio of cocoa pod ash is conducive for rapid degradation and dissolution of ash as earlier stated. Hence, it is expected that the nutrients in the ash would easily be released for maize uptake. Brady and Weil (1999) recommended 2.5 – 3.5, 0.20 - .050, and 1.5 – 3% as critical levels for N, P and K plant uptake respectively. .Based on this recommendation, cocoa pod ah, NPK fertilizer applied individually and cocoa pod ash combined with NPK fertilizer at two levels had adequate plant N, P and K except control at the two locations. Treatments C10F150 and C5F150 had higher plant N than the recommended level at Okegun site. Also, treatments F300, C5, C5F150, C10 and C10F150 had K above the critical level at the two locations. The excesses might cause nutrient imbalances in other nutrients such as Ca, Mg and micronutrients that were not investigated in this experiment.

Table 5 shows data on maize height, grain yield, stover and root matter yields as affected by cocoa pod ash, NPK 20:10:10 fertilizer and their combinations. Treatment C10F150 had the tallest maize plant and grain yield, stover and root matter in the two locations. The mean increases in grain yield in the two locations followed the same trend C10F150 > F300 > C5F150 > C10 > C5 >F150 > control. The percent increases in grain yield at Ondo were higher than Okegun despite the fact that Okegun mean grain yields were higher than Ondo. This might be as a result of lower initial soil status of Ondo soil than Okegun which resulted in higher utilization of nutrients derived from the treatments applied. Also, the significance increases ($p<0.05$) in yields of all the treatments compared with control attest to the ability of these treatments in supplying plant nutrients.

Table 4: Effect of cocoa pod ash, NPK 20:10:10 and their combinations on N, P and K uptake at Ondo and Okegun (%)

Treatments	N		P		K	
	Ondo	Okegun	Ondo	Okegun	Ondo	Okegun
Control	1.14	1.18	0.14	0.29	1.24	1.26
F300	3.44	3.54	0.47	0.50	3.48	4.33
F150	1.42	2.66	0 .26	0.32	1.48	3.29
C5	2.75	2.60	0.30	0.38	3.62	3.61
C5F150	3.38	3.62	0.41	0.46	4.60	4.42
C10	2.70	2.91	0.40	0.46	4.77	4.19
C10F150	3.49	3.80	0.49	0.49	5.01	4.99
LSD 0.05	0.14	0.19	0.03	0.07	1.02	0.18

Table 5: Effect of cocoa pod ash, NPK 20:10:10 fertilizer and their combinations on agronomic parameters of maize at Ondo and Okegun

Treatment	Height cm		grain yield t ha^{-1}		% grain yield		stover yield t ha^{-1}		root dry matter t ha^{-1}	
	Ondo	Okegun	Ondo	Okeguun	Ondo	Okegun	Ondo	Okegun	Ondo	Okegun
Control	99.45	142.12	2.10	2.52	0	0	3.74	3.59	1.04	1.28
F300	69.00	170.01	3.67	3.90	75.	55	5.45	5.50	1.53	1.46
F150	103.33	166.15	2.78	2.95	32	17	2.92	4.21	1.32	1.30
C5	118.00	167.67	2.91	3.02	39	20	3.96	5.13	1.41	1.44
C5F150	163.11	173.00	3.45	3.59	66	43	5.22	5.46	1.49	1.49
C10	162.00	169.67	3.10	3.48	48	38	5.17	6.19	1.42	1.46
C10F150	172.67	179.00	3.81	4.38	81	79	5.36	6.78	1.48	2.07
LSD 0.05	12.43	14.42	0.56	059	-	-	1.59	1.44	0.47	0.61

In this experiment, yield appears dictated by plant nutrient uptake as the maize plants with highest N, P and K had the highest plant height and yields. The finding that C10F150, F300 and C5F150 gave highest increase in plant height, grain yield, stover yield and root dry matter can be related to the finding that the treatments mostly increased the N, P and K contents of maize tissue which are the most essential nutrients need by maize to complete growth and reproductive cycle.

Conclusion

Application of cocoa pod ash, NPK 20:10:10 fertilizer and their combinations increased soil organic matter and major nutrients, tissue N, P and K status as well as agronomic parameters of maize. Combined cocoa pod ash with reduced level of NPK 20:10:10 fertilizer is found to be more effective source of plant nutrients than the single application of cocoa pod ash and NPK 20:10:10 fertilizer. Treatment C10F150 gave the highest increases in soil nutrient values and growth parameters of maize. The sandy clay soil supplied more plant nutrients derived from cocoa pod ash than clay loam in this experiment.

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