International Research Journal of Agricultural Science and Soil Science Vol. 1(3) pp.077-082 May 2011
Available online @http://www.interesjournals.org/IRJAS

Full Length Research Paper

Effect of Sole and Combined Cocoa Pod Ash, Poultry Manure and NPK 20:10:10 Fertilizer on Soil Organic Carbon, Available P and Forms of Nitrogen on Alfisols in Southwestern Nigeria

Ayeni LS

Department of Agricultural Science, Adeyemi College of Education, PMB 520, Ondo, Ondo State, Nigeria
E-mail: leye_sam@yahoo.com

Accepted 11 May, 2011

A laboratory incubation study was conducted in 2009 to investigate the effects of cocoa pod ash (CPA) (0, 5 and 10 t ha^{-1}), poultry manure (PM) (0, 5 and 10 t ha^{-1}), NPK 20:10:10 fertilizer (NPKF) (0, 100 and 200kg ha^{-1}) and their various combinations on the rate of nutrients release with soil constituents in southwestern Nigeria. The soil used was slightly acidic, low in OM, N, P and K. The twenty eight treatments were incubated for 90 days using completely randomized design and were replicated three times. Among the combinations CPA+NPKF, PM+NPKF and PM+CPA+ NPKF had higher OC, NH_4-N, NO_3-N and available P than CPA+PM showing enhancement of NPKF in nutrient mineralization. The combinations also had higher cations and available S under study than the single application of the fertilizer materials. Cocoa pod ash applied at high rate of 10t ha^{-1} had lower OC, N and NO_3-N than when 5t ha^{-1} CPA was applied alone or combined with PM and NPKF. Cocoa pod ash combined with either poultry manure or NPK fertilizer or both increased soil nutrients above critical levels required for optimum production of crops especially arable crops in southwestern Nigeria.

Key words: Soil nutrients, nitrate nitrogen, ammonium nitrogen, available phosphorus and sulphur.

INTRODUCTION

Fertile and well-managed soils form the basis for efficient crop production. The three most important elements-(anions) needed for crop production are nitrogen (N), phosphorus (P) and sulphur (S). Nitrogen (N) is a vitally important plant nutrient and is the most frequently deficient of all nutrients. N is absorbed by crops as nitrate-nitrogen and ammonium – nitrogen. An adequate supply of N is associated with high photosynthetic activity and vigorous synthetic growth if N is used properly in conjunction with other needed fertility inputs. It can speed the maturity of crop such as maize and other cereals. The supply of S is related to carbohydrate utilization. When N supply is insufficient, carbohydrate will be deposited in vegetative cells causing them to thicken. Large quantities of P are found in seed and fruit, and it is considered essential for seed formation and energy transfer (Adenosine di – and triphosphate ADP and ATP). Also, a good supply of P is associated with increased root growth. An adequate supply of P is associated with greater straw strength in cereals. The quality of certain fruits, forage, vegetables and green crops is improved and disease resistance when these crops have satisfactorily P nutrition (Anonymous, 1999). Sulphur (S) in protein helps in formation of disulphide bonds between peptide chains and also a vital part of ferrodoxine which has significant role in nitrite reduction. Though organic matter (OM) is not a plant nutrient per se, it is a store house for plant nutrients and also helps to improve soil physical properties.

Before these elements can function well, they must be adequately supplied and readily available in the agricultural soils, likewise their availability must not hinder other conditions of soil fertility and nutrients uptake by plants. In southwestern Nigeria, the critical levels of OM, N, NO_3-N, P and S recommended for most arable crops are 2.2 – 3%, 0.15%, 30, 8 – 10 and 8 mg kg^{-1} respectively. (Sobulo and Osiname 1981, Oluwatosin and Ogunkunle, 1991), while N recommended for tree crops such as cocoa is 0.9 g kg^{-1} N (Egbe, 1989). Continuous addition of mineral fertilizers such as NPK in different formulations negatively affect other conditions of plant growth such as increase in soil bulk density, nutrient imbalance and low soil organic matter content; and NPKs cannot be totally depended upon for optimum crop production. Many researchers (Agbim and Adeoye, 1999; Ayeni, 2010; Kulkarne and Kulkarne, 1982) have actually demonstrated the use of animal manures and agrowastes for soil fertility maintenance, but they are low in nutrient quality and bulky. Since total eradication of mineral fertilizers is not possible, there is need to integrate them with organic residues for sustainable crop production. Nottidge *et al.* (2005a) showed that wood ash, pea nut residues and NPK combinations gave higher dry matter yields and leaf N, K, Ca and Mg contents compared with each treatment when applied alone. In another experiment, Nottidge *et al.* (2005) showed that ash and peanut combined reduced soil bulk density and increased aggregate stability and porosity. Application of combined use of organic based fertilizer (OBF) and urea at 2 t ha^{-1} OBF and 90 kg ha^{-1} urea was more superior to application of either of the fertilizer alone (Adediran, *et al.,* 1999). Also, the effectiveness of cow dung, poultry dropping, oil palm sludge, calcium ammonium nitrate (CAN) and urea with their combinations on soil chemical properties have been reported (Opara –Nnadi *et al.,* 2000). Ayeni 2010 and Ayeni and Adeleye 2010 conducted various experiments on the uses of cocoa pod ash, poultry manure and NPK20:10:10 on soil chemical and maize yields but the cumulative sole and combined application of coca pod ash, poultry manure and NPK fertilizer on anions in southwestern Nigeria has not been adequately studied. Hence, the objective of this study was to determine the cumulative nutrients release from sole and combined cocoa pod ash, poultry manure and NPK fertilizer in southwestern Nigeria.

MATERIALS AND METHODS

Soil Analysis

The soil samples collected from Ondo, rain forest zone of Nigeria were bulked, air-dried and sieved through 2mm sieved mesh. Part of the soil samples was used for routine soil analysis to show both macro and micro nutrient status of the soil used for the experiment and the remaining for laboratory incubation study. The physical and chemical properties of the soil used for the incubation study were determined in order to know the characteristics of the soil and their effects.

The pH of the soil was determined in 1:1 soil/water suspension and 2:1 $CaCl_2$ / soil suspension using a glass electrode pH meter. Organic matter was determined by the Walkley and Black (1934) dichromate oxidation method. Total N was determined by the Kjedahl method. NO_3-N and NH_4-N were extracted with 1 M KCl solution and determined using steam distillation technique (Bremner, 1965).

Available phosphorus was extracted by 0.03M NH4F +0.025M HCl, the P in the extractant was determined by colorimeter. Exchangeable bases (Na, Ca, K and Mg) were extracted with 1N ammonium acetate at pH 7.0. Potassium and Na were read using flame photometer, while Ca and Mg were determined by AAS.

The exchangeable acidity was determined from 0.1M KCl extracts and titrated with 0.1M HCl. Effective cation exchange capacity (ECEC) was established as the summation of the exchangeable cations (K, Ca, Mg and Na). Available S was extracted using $Ca(H_2PO_4)_2$ and determined turbidimetrically as $BaSO_4$ (Chesnin and Yien, 1951). The micronutrients (Fe, Cu, Zn and Mn) were determined by extracting them with 0.1N HCl and the extracts were measured on Perkin Elmer 20 atomic absorption spectrophotometer (AAS) (AOAC, 1990).

Organic Materials Analysis

The nutrient composition of powdered poultry manure and cocoa husk ash were determined. Total N was determined by Kjedahl method. For other nutrients, ground samples were subjected to wet digestion using 25 – 5 – 5 ml of HNO_3 – H_2SO_4 – $HClO_4$ acids (A.O.A.C, 1990). The filtrate was used for nutrients determination as done in routine soil analysis. Total P was determined by colorimeter, K by flame photometer and Ca, Mg, Fe, Cu, Zn and Mn by AAS.

Incubation Study

A laboratory incubation study to determine the interactions of cocoa pod ash, poultry manure, NPK 20:10:10 fertilizer and their various combinations with soil constituents at 90 days was carried out at the laboratory of the Adeyemi College of Education, Ondo in January, 2009. The soil sample used for the conduct of the experiment was collected from the students research farm of Adeyemi College of Education, Ondo.

Five hundred grams of soil sample in jars were used for the incubation study. The treatments applied consisted of cocoa pod ash at 0, 1.25 and 2.5 g, poultry manure at 0, 1.25 and 2.5 g to represent 0, 5 and 10 t ha^{-1} respectively. NPK 20:10:10 fertilizer consisted of 0, 0.25

Table 1. physical property of incubated soil

Particle size	g kg^{-1}
Sand	820
Silt	110
Clay	70
Textural Class	loamy sand

and 0.5 g to represent 0, 100 and 200 kg ha^{-1}. The treatments were replicated three times. The soil samples were arranged on a flat platform in the laboratory in completely randomized design. The experiment was in the laboratory for 90 days. This is the period for vegetative and reproductive cycles of most arable crops in Nigeria.

Soil samples were analyzed before and after the incubation period for organic matter, N, NO3-N, NH4-N, P, K, Ca, Mg and S as previously described. Organic carbon was multiplied by 1.74 to get organic matter. Organic matter was determined by walkely dichromate oxidation method, total N by Kjedahl method, NH3-N and NH4-N by steam distillation technique after extraction with 1M KCl, available P by Bray - 1 – method, extractable S by Chesnin and Yien (1951) method, exchangeable K by photometer, while Ca and Mg were determined by Absorption Atomic Spectrophotometer (AAS) after extraction with 1N ammonium acetate.

RESULT

Fertility Status of the Incubated Soil

The chemical and physical characteristics of the soil used for the conduct of the experiments are presented in tables 1 and 2. The soil had sandy loam texture with high proportion of coarse sand (82%). The soil was slightly acidic and low in organic matter, total percent N, NO_3-N and available P. The exchangeable cations K and Mg values were low, while Ca was adequate. Routine soil analysis also showed that ECEC and percentage base saturation values were low. The micronutrients such as Fe^{2+}, Cu^{2+} and Mn^{2+} were high, while Zn^{2+} was low in the soil.

Effects of cocoa pod ash (CPA), poultry manure (PM), NPK 20:10:10 (NPKF) and their combinations on soil total N, available NO_3-N, NH_4-N and P are presented in Table 4.

Application of 10 t ha^{-1} of poultry manure and their combinations increased soil organic carbon relative to the control. Poultry manure combined with NPK 20:10:10 fertilizer ($P_{10}F_{100}$, $P_{10}F_{200}$, P_5F_{100} and P_5F_{200}) after 90 days of incubation gave the highest values of organic carbon and were statistically different at 5% level.

Treatments F_{200} and F_{100} did not increase organic carbon appreciably relative to control. Among the soil samples treated with the sole cocoa pod ash, poultry manure and NPK 20:10:10 fertilizer, poultry manure significantly increased soil organic carbon than cocoa pod ash and NPK 20:10:10 fertilizer.

Application of NPK 20:10:10 fertilizer, poultry manure, cocoa pod ash applied individually and their combinations with or without NPK fertilizer increased soil total N relative to the control except 5 t ha^{-1} of cocoa pod ash (C_5). Treatments $P_{10}F_{200}$, F_{200}, $P_{10}F_{100}$, $C_{10}P_{10}$, P_5F_{100} recorded the highest increase in soil total N followed by treatments $C_5P_5F_{100}$, $C_{10}F_{100}$, $C_{10}P_{10}F_{200}$ and C_5P_5 within 90 days of incubation. The treatments with NPK 20:10:10 fertilizer at 100 or 200 kg ha^{-1} had significant effect on total N when the two organic materials were combined.

Generally, application of cocoa pod ash alone, poultry manure alone and their combinations with NPK 20:10:10 fertilizer or NPK 20:10:10 fertilizer applied alone increased soil available NO_3 – N (Table 4). However, when cocoa pod ash alone was used at 5 or 10 t ha^{-1} , it did not have appreciable effect on NO_3 –N. The $C_5P_5F_{100}$, C_5F_{200}, $C_5P_{10}F_{200}$, C_5F_{100}, $C_{10}F_{100}$, $C_{10}F_{200}$ and $P_{10}F_{200}$ respectively had highest level of NO_3-N at 90 days of incubation. Comparison of $P_{10}F_{100}$, $P_{10}F_{200}$, P_5F_{100} and P_5F_{200} show that addition of NPK 20:10:10 fertilizer to poultry manure increased soil NO_3 – N relative to poultry manure without combination.

Also, comparison of C_5F_{100}, C_5F_{200}, $C_{10}F_{100}$ and $C_{10}F_{200}$ with cocoa pod ash alone or NPK 20 10:10 fertilizer applied alone, the combinations were statistically different except $C_{10}F_{100}$. Among the triple combinations, $C_5P_5F_{200}$ had the highest NO_3 – N.

Relative to control, NPK20: 10:10 fertilizer, poultry manure and cocoa pod ash used alone or combined increased NH_4 – N above the absolute control except F_{100} (Table 4). The treatment with NPK 20:10:10 fertilizer had higher value of NH_4 – N especially when the three materials were combined. Without NPK 20:10:10 fertilizer, the values of NH_4 – N were reduced. Treatments $C_{10}P_{10}F_{200}$, $P_{10}F_{200}$, $C_{10}P_{10}F_{100}$, $C_5P_5F_{200}$, $C_5P_5F_{100}$, $P_{10}F_{100}$, $C_{10}F_{200}$ and $C_{10}F_{100}$ gave highest values of NH_4 – N within 90 days of incubation. When cocoa pod ash and poultry manure were applied

Table 2. Incubated soil chemical properties

Soil properties	value
pH (1:1H_2O suspension)	5.79
pH (2: 1.0.1M $CaCl_2$ suspension)	5.56
Organic carbon (g kg^{-1})	7.6
Organic matter (g kg^{-1})	13.1
Total Nitrogen (g kg^{-1})	0.6
C/N ratio	12.67
Available P (mg kg^{-1})	4.88
Available NO_3-N (mg kg^{-1})	25.58
Available S (mg kg^{-1})	7.46
Exchangeable bases (c mol kg^{-1})	
Ca^{2+} ;	2.32
Na^{+} ;	0.37
K^{+} ;	0.16
Mg^{2+} ;	0.20
Exchangeable acidity (c mol kg^{-1})	1.36
Base saturation (%)	69.19
Effective cation exchange capacity(c mol kg^{-1})	4.41
Fe^{2+} ;	2.44
Cu^{2+} ;	0.41
Mn^{2+} ;	4.20
Zn^{2+}	3.30

Table 3. Nutrient concentration (%) of poultry manure and cocoa pod ash used in laboratory, pot and field experiments

Parameters	Poultry manure	Cocoa pod Ash
Organic carbon	21.70	16.56
Nitrogen	3.70	1.23
C/N ratio	6	14
S	0.82	0.31
Total P	2.72	1.01
K “	2.91	12.52
Ca “	2.80	3.74
Mg “	0.80	1.00
Zn “	0.40	0.13
Cu “	0.10	0.33
Fe “	2.66	1.22
Mn “	1.48	1.22

individually, the NH_4 - N were lower than when they were combined. For example, treatments C_5, C_{10}, P_5 and P_{10} were not significantly different from the control. Compared with control, cocoa pod ash, poultry manure, NPK 20:10:10 fertilizer and their combinations increased soil available P (Table 4). The $P_{10}F_{200}$ gave highest value followed by $P_{10}F_{100}$. The treatments with triple combinations (combined cocoa pod ash, poultry manure and NPK 20:10:10 fertilizer) had the next higher value of soil available P. The treatments were $C_5P_5F_{100}$, $C_5P_{10}F_{100}$ and $C_5P_5F_{200}$. These were followed by $C_5P_{10}F_{200}$, $C_{10}P_5F_{200}$ and $C_{10}P_5F_{100}$. These were followed by 5 t ha^{-1} of poultry manure combined with NPK 20:10:10 fertilizer (P_5F_{100} and P_5F_{200}) or cocoa pod ash combined with NPK20:10:10 fertilizer (C_5F_{100} and C_5F_{200}). Also, $C_{10}P_5$ and $C_{10}P_{10}$ fall into this category especially when 10 t ha^{-1} of cocoa pod ash was included in the formulation. The use of the organic materials alone without NPK 20:10:10 fertilizer gave lower available P except 10 t ha^{-1} poultry manure. Compared with control, NPK fertilizer, cocoa pod ash, poultry manure and their combinations significantly increased extractable soil S Treatments $C_5P_{10}F_{100}$, $C_5P_5F_{100}$, $C_{10}F_{200}$, $C_{10}F_{100}$, $P_{10}F_{100}$, $C_{10}P_{10}F_{100}$ and $C_{10}P_{10}F_{200}$ gave the highest soil S.

The mean values of OC, N, NH_4-N, NO_3-N, P and S for CPA alone were 1.35 – 1.67%, 0.12 – 0.14%, 17.2 – 39.2mg kg^{-1}, 49.1 – 55.5,mg kg^{-1}, 7.8 – 9.6mg kg^{-1} and 12.03 -12.49 respectively. The values of OC, N, NH_4-N, NO_3-N, P and S for PM rates were 1.61 – 1.73%, 0.14-0.15%, 15.6-18.9mg kg^{-1}, 97.6 -120.2mg kg^{-1}, 7.5 – 21.0

Table 4. Effect of cocoa pod ash, poultry manure and NPK 20:10:10 fertilizer combinations on soil OC, total N, available NH_4-N, NO_3-N, P and S

Treatment	OC	N	NH_4-N	NO_3-N	P	S
	-----------%--------------		-------------- mg kg^{-1} --------------------			
Control	1.09c	0.10c	14.9d	33.2d	4.6i	8.72c
F_{100}	1.10c	0.13bc	22.4d	93.9c	7.8h	24.90b
F_{200}	1.15c	0.21a	43.2c	135.4bc	21.3a	32.70b
C_5	1.35c	0.12c	39.2c	49.1d	7.8h	12.03c
C_5F_{100}	1.79a	0.17b	64.7c	150.0b	11.3f	21.04c
C_5F_{200}	1.86a	0.17b	31.5c	150.3b	11.5f	22.31c
C_{10}	1.67b	0.14b	17.2d	55.5d	9.6g	12.49c
$C_{10}F_{100}$	1.97a	0.20a	110.9b	134.2c	13.7e	69.07a
$C_{10}F_{200}$	1.85a	0.17b	114.9b	142.5b	14.7e	74.87a
P_5	1.73a	0.14b	15.6d	97.6c	7.5h	14.78c
P_5F_{100}	2.44a	0.21a	51.5c	159.9b	18.7d	19.67c
P_5F_{200}	2.43a	0.21a	42.5c	155.9b	19.5c	20.37c
P_{10}	1.61b	0.15b	18.9d	120.2c	21.0c	23.83c
$P_{10}F_{100}$	2.72a	0.19ab	130.8a	253.0a	26.1a	41.50b
$P_{10}F_{200}$	2.72a	0.25a	158.7a	259.8a	26.4a	40.10b
C_5P_5	2.22a	0.19ab	56.3c	132.7c	12.0f	19.19c
$C_5P_5F_{100}$	2.33a	0.21a	134.0a	197.8b	20.3c	28.83b
$C_5P_5F_{200}$	1.90b	0.17b	135.1a	198.1b	21.1b	28.20b
C_5P_{10}	1.88b	0.16b	48.4c	169.2b	20.1b	26.93b
$C_5P_{10}F_{100}$	1.74ab	0.16b	57.2c	175.2b	19.0cd	82.90a
$C_5P_{10}F_{200}$	2.04a	0.16b	57.9c	227.6a	20.4bc	57.60a
$C_{10}P_5$	1.40bc	0.12c	31.4c	49.1d	10.5f	41.46b
$C_{10}P_5F_{100}$	1.96a	0.17b	56.5c	128.6c	20.2c	45.57b
$C_{10}P_5F_{200}$	1.92a	0.17b	125.8ab	175.9b	21.1b	59.70a
$C_{10}P_{10}$	1.86b	0.16b	62.8c	168.8b	6.8h	34.85b
$C_{10}P_{10}F_{100}$	1.88b	0.18b	142.1a	183.4b	17.9d	65.00a
$C_{10}P_{10}F_{200}$	2.03a	0.20a	160.3a	190.1b	18.3d	48.70ab

mg kg-^{1} and 14.78 – 23.83 mg kg^{-1} respectively. The values of OM and N for NPKF rates were 1.88 – 3.20% and 0.10 – 0.25% respectively. The values obtained for NH_4-N, NO_3-N, P and S were 14.93-158.74, 33.70 – 259.84, 4.60 – 26.36 and 8.62 – 82.90 mg kg^{-1}, respectively. The values of CPA +NPK fertilizer rates for OM and N were 1.67-1.73% and 0.17 – 0.2% respectively. The values obtained for NH_4-N, NO_3-N, P and S were 31.50 -114.90, 134.20 – 150.3, 7.50 – 11.50 and 12.49 – 74.87 mg kg^{-1} respectively. NPKF + PM rates recorded 2.43 – 2.73%, 0.21 - 0.25%, 42.50 - 158.70mg kg^{-1}, 120.2 – 259.80mg kg^{-1}, 18.70 - 26.40mg kg^{-1} and 19.67 – 40.10mg kg^{-1} for OC, N, NO_3,N, NH_4-N, P and S respectively. CPA + PM had 1.40-2.22%, 0.12 – 0.19%, 31.4 62.80, 49.1-169.2, 6.80-20.1 and 19.19 – 45.57 $mgkg^{-1}$ respectively. CPA + PM+ NPKF had 1.88 – 2.04%, 0.16 – 0.21%, 56.5-135.10, 183.4 -227.6, 19.0 - 21.1 and 45.57 – 82.90 mg kg^{-1} for OC, N, NO_3-N, NH_4-N, P and S.

DISCUSSION

The low C/N ratio experienced by NPKF might have enhanced faster decomposition of poultry manure (Titiloye, 1992), and thereby enhanced more and quick release of N and P. However, the combined use of cocoa pod ash and poultry manure were found to be more beneficial than sole use of either of them in terms of nutrient supply and balanced nutrition since poultry manure mainly supplied N and P, while cocoa pod ash supplied K and Ca in this experiment. This finding is in line with the work of Adu – Dapaah *et al*. (1994), who effectively used cocoa pod ash as K source for maize in Ghana. The incubation study also showed that application of NPK 20:10:10, cocoa pod ash, poultry manure and their combinations increased soil OM, N, $N0_3$-N, NH_4-N, P and S. This finding is consistent with the earlier finding of Mba and Mbagwu (2006), Ano and

Agwu, 2006 and Ewulo (2005 in their incubation studies that animal manures and plant residues increased soil nutrients. The slower release of nutrients especially N and P from cocoa pod ash and poultry manure compared with NPK 20: 10:10 fertilizer was observed in this study. This is because organic materials would need to decompose before the organic nutrients could be mineralized. Hence, NPK fertilizer was quicker source of N and P. It is established fact that organic matter positively influences both physical and chemical properties of soils. Since there were increases in organic matter, N and P in the soils treated with both poultry manure and cocoa pod ash in this experiment, it could be deduced that agrowastes used would have improved the physical and chemical properties of the soil which could enhance its productivity.

Arable crops like maize, tomato, millet require N and P in their early stage and any shortage especially at this early stage may reduce root growth, nutrient uptake and also affects the crop for the rest of its life cycle. The timely mineralization of N, NO_3-N, NH_4-N and P within 90 days of incubation shows that plants can successfully utilize them to complete their vegetative and reproductive cycles. The lower N and P recorded in the control than single application of cocoa pod ash, poultry manure, NPK fertilizer and their combinations showed the ability of the fertilizer materials in supplying N and P to the soil. Crops require moderate pH, adequate nutrients and favourable soil conditions. The combination of the three fertilizer materials is found to supply these conditions of plant growth. The best treatment that supplied adequate plant nutrition is combining low level of cocoa pod ash (5t ha^{-1}), poultry manure 5 or 10 t ha^{-1} and NPK fertilizer (100 or 200 kg ha^{-1}).

CONCLUSION

Results have shown that combined cocoa pod ash, poultry manure and NPK 20:10:10 fertilizer increased soil organic carbon, total N, NH_4-N, NO_3-N, available P and S. Application of cocoa pod ash and poultry manure could be used to reduce the acidic effect of NPK 20:10:10 fertilizer, supply organic matter that can improve the physical condition of the soil and also supply adequate nutrients. The common problems associated with both chemical fertilizer and organic manure when applied alone could be eliminated by integrating the good qualities in each material in order to achieve a better interaction effects. Cost reduction is ensured under the integrated fertility management approach because only small quantity of chemical fertilizers is required with animal manure.

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