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Full Length Research Paper

Cumulative effect of combined cocoa pod ash, poultry manure, NPK 20:10:10 fertilizer on major cations release for crop production in southwestern Nigeria

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A laboratory incubation study was conducted on Alfisol to investigate the effect of cocoa pod ash (0, 5 and 10 t ha^{-1}), poultry manure (0, 5 and 10 t ha^{-1}), NPK 20:10:10 fertilizer (0,100 and 200 kg ha^{-1}) and their combinations on soil pH and cations release for sustainable crop production. Compared with control, cocoa pod ash and poultry manure applied singly or in combination with NPK 20:10:10 fertilizer increased soil pH, available K, Ca and Mg from 5.89-7.23, 0.17-0.94, 2.17-6.10 and 0.47-2.97 C mol kg^{-1} respectively. Compared with control, Cation exchange capacity (CEC) and Percent Base Saturation (%BS) were significantly increased ($p>0.05$) with corresponding decrease in Exchange Acidity (EA). Cautions must be exercised in combining 10 t ha^{-1} cocoa pod ash with poultry manure to avoid overliming as their combinations tended to increase soil pH above the level favourable to crop production in southwestern Nigeria.

Keywords: Exchange acidity, mineral fertilizer, organic fertilizer, percent base saturation.

INTRODUCTION

Good fertilizer do not only supply plant nutrient to the soil but also supply the nutrients in proper amount and in proper balance. The presence of soil organic matter (OM), cation exchange capacity (CEC), high percent base saturation (%BS) as well as suitable pH is the major determining fertility factors for crop production. The higher the OM, CEC and %BS, it is expected that the higher the productivity status of the soil would be. In some cases, CEC in the soil may be high yet the soil may be unproductive. A soil that contains high exchange acidity (Al^{2+} + H^{+}) may have high CEC but may be unproductive due to the negative interaction between the Al^{2+} + H^{+} with other nutrients. For example, high EA in soil tends to reduce P availability.

Among the constituents of CEC, Ca and Mg make up the bulk of the cation attracted to the soil colloids. It is known that Ca^{2+} flocculates soil while Mg^{2+} coagulates it. A balance between the two soil nutrients is needed to maintain ideal nutrients for plants uptake likewise improvement in soil physical properties such as soil structure. The productive capacity of a soil also depends on the interaction between its biological and physical properties. It is asserted that soil with high levels of Ca or K will typically produce less Mg to crops (Samuel et al., 2003). Integrated application of agro wastes and mineral fertilizers have been found to increase productive capacity of the soil (Bhattacharyya et al., 2008; Ghosh et al., 2009; Liu et al., 2009; Adeleye and Ayeni, 2010; Ayeni, 2011; Carvalho et al., 2011). Excess Mg is known to be in competition with other major cations such as Ca^{2+}, K^{+}, Na^{+}, NH_4^{+}, Fe^{2+} and Al^{3+}.

Many researches have been conducted on the combined effect of cocoa pod ash, poultry manure and NPK 20:10:10 fertilizer on soil chemical properties and crop yield (Ayeni, 2010; Ayeni, 2011) but there is scanty information on their effects on nutrient interactions. Hence, the objective of this study was to determine the rate of nutrients release from cocoa pod ash rates, poultry manure rate, NPK fertilizer rates and their combined effect on nutrient release and interactions.

MATERIALS AND METHODS

Soil samples used in this experiment was collected from the 0 – 20 cm depth of Adeyemi College of Education student research farm. The soil is classified as Alfisol (oxic tropuldalf) and sandy clay. The soil used for this experiment has been previously described by Ayeni (2011). The soil contained 82% sand, 11% silt and 70% clay. The soil had been cropped for more than ten years with application of different types of fertilizers before it was sampled for this experiment.

Experimental Design

500 gram of air-dried sieved soil were mixed with three levels of cocoa pod ash (C) and three levels of poultry manure (P) at 0, 5 and 10 t ha^{-1} and three levels of NPK 20:10:10 fertilizer (F) at 0, 100 and 200 kg ha^{-1}, cocoa pod ash rates were singly applied or combined with either poultry manure or NPK fertilizer or both to give 27 treatments. The treatments were replicated three times. The soil – cocoa pod ash – poultry manure – NPK fertilizer admixtures were placed in cups for ninety days. Perforated asbestos was used to cover each cup and moistened with equal amount of water at two weeks interval.

Soil Analysis

The treatments were analysed at 90 days of incubation. Soil pH was determined on 1:2 soil/water ratio. Exchangeable K, Ca, Mg and Na were extracted with IN ammonium acetate at pH 7. Potassium and Na were quantified with flame photometer while Ca and Mg were determined on the atomic absorption spectrophotometer (AOAC, 1999). Exchange acidity was determined by titration method.

CEC was determined as the summation of cations. Percent base saturation was determined as CEC minus exchange acidity divided by CEC and then multiplied by 100. Percent base saturation (%BS) = ((CEC – EA)/CEC) x100. Exchange percent sodium (ESP) = (Na x 100)/CEC.

Statistical Analysis

Data were subjected to analysis of variance using General Linear Model (GLM) (SAS 1990), using Duncan Multiple Range Test.

RESULT

Cocoa pod ash used in this experiment contained higher amount of cations (L, Ca and Mg) than poultry manure (Table 1). Application of cocoa pod ash, poultry manure alone or the two organic materials combined with NPK 20:10:10 fertilizer at 100 or 200 kg ha^{-1} significantly ($p<0.05$) increased soil pH relative to the control. The pH of the control or NPK 20:10:10 fertilizer at 100 and 200 $kgha^{-1}$ was not significantly different at 5% level. Cocoa pod ash combined with NPK 20:10:10 fertilizer or poultry manure combined with NPK 20:10:10 fertilizer at all levels of combination were statistically higher ($p<0.05$) than NPK 20:10:10 fertilizer applied individually. Highest pH was recorded when 10 t ha^{-1} of cocoa pod ash was combined with 10 t ha^{-1} of poultry manure ($C_{10}P_{10}$).

Compare with control, except F100, cocoa pod ash; NPK 20:10:10 fertilizer and their combinations significantly ($p<0.05$) increased exchangeable soil K. Five treatments had pronounced increase in exchangeable K among the treatments. The $C_{10}P_5F_{100}$, $P_{10}F_{200}$, $C_{10}P_5$, $C_{10}P_5F_{200}$, C_{10} and $C_5P_{10}F_{200}$ respectively gave highest soil exchangeable K (Table 1).

Relative to control, and NPK 20:10:10 fertilizer, cocoa pod ash, poultry manure and their combinations with or without fertilizer increased soil exchangeable Ca though, treatments F_{100}, F_{200}, C_5, C_5F_{100} and C_5F_{200} were not significant at 5% level (Table 1). Treatments $C_{10}P_{10}F_{100}$, $C_{10}P_5F_{100}$, $C_{10}P_5$, C_{10}, C_5P_5, $C_{10}F_{100}$ and $C_5P_5F_{100}$ had the highest Ca followed by $C_5P_5F_{100}$ and C_5P_{10}, $C_5P_{10}F_{100}$, $C_{10}F_{100}$, $C_5P_5F_{200}$ and $C_{10}F_{200}$ respectively tended to have higher value of Ca than any of the treatments. Addition of 10 t ha^{-1} of cocoa pod ash and poultry manure or its triple combinations that included 10 t ha^{-1} of cocoa pod ash gave the highest increased soil exchangeable Ca.

Relative to control, and NPK 20:10:10 fertilizer, cocoa pod ash, poultry manure and their combinations with or without NPK fertilizer significantly increased exchangeable Mg with the highest values recorded for the treatments in the following $C_{10}P_5$, $C_{10}P_{10}$, $C_{10}P_{10}F_{100}$ and $C_{10}P_{10}F_{200.}$ These were also followed by C_{10}, $C_5P_5F_{100}$, $C_5P_{10}F_{200}$, P_{10}, $C_5P_5F_{200}$, $C_{10}F_{100}$, $C_{10}F_{200}$, P_5F_{200} and $C_5P_{10}F_{100}$ (Table 1). Poultry manure combined with NPK 20:10:10 fertilizer at all levels were not significantly different from poultry manure applied at 5 t ha^{-1} in soil exchangeable Mg. Cocoa pod ash applied at 10 t ha^{-1} compared favourably with cocoa pod ash combined with NPK 20:10:10 fertilizer ($C_{10}F_{100}$, $C_{10}F_{200}$, $C5F_{100}$ and $C5F_{200}$).

The treatments that had 5 t ha^{-1} cocoa pod ash combined with poultry manure , NPK fertilizer or both (C_5P_5, C_5P_{10}, $C_5P_5F_{100}$, $C_5P_5F_{200}$, $C_5P_{10}F_{100}$ and $C_5P_{10}F_{200}$,) had low exchangeable Mg compared with treatments without cocoa pod ash in their formulations (P5F100, P5F200, P10F100 and P10F200) but were significantly higher than NPK 20:10:10 fertilizer applied

Table 1. Effect of cocoa pod ash, poultry manure, NPK 20:10:10 fertilizer and their combinations on soil exchangeable pH, ECEC and EA within 90 days of incubation.

Treatment	pH	K	Ca	Na	Mg	EA	ECEC
Control	5.89i	0.17d	2.67d	0.35c	0.47e	2.05b	5.56c
F_{100}	5.88i	0.21d	2.66d	0.35c	0.41e	2.05b	5.68c
F_{200}	5.86i	0.26cd	2.62d	0.36c	0.38e	2.04b	5.66c
C_5	6.09h	0.43c	3.07d	0.90b	1.20d	1.24b	6.93c
C_5F_{100}	6.02h	0.44c	3.02d	0.96b	1.26d	1.26b	6.09c
C_5F_{200}	6.03h	0.53b	3.00d	0.58c	1.30d	1.26b	10.59b
C_{10}	6.94b	0.68b	5.67a	1.26a	2.40b	1.21b	9.19b
$C_{10}F_{100}$	6.77c	0.66b	4.45b	0.95b	1.61c	1.3b	8.7b
$C_{10}F_{200}$	6.47c	0.66b	4.22b	0.91b	1.57c	1.31b	6.84c
P_5	6.35f	0.43c	3.06d	0.36c	1.13d	1.31b	6.2c
P_5F_{100}	6.19g	0.46bc	3.03d	0.76b	1.06d	1.31b	7.09c
P_5F_{200}	6.07g	0.45c	3.00d	0.63c	1.57c	1.28b	8.24b
P_{10}	6.45e	0.48b	4.00c	0.98b	1.85c	1.28b	8.22b
$P_{10}F_{100}$	6.17h	0.57b	3.20d	0.93b	1.23d	1.3b	7.23bc
$P_{10}F_{200}$	6.15g	0.62b	3.20d	0.66c	1.09d	1.22b	6.79c
C_5P_5	6.67c	0.58b	4.89ab	0.11b	2.03bc	1.2b	9.81b
$C_5P_5F_{100}$	6.62c	0.66b	4.70b	1.0a	1.91c	1.32b	9.59b
$C_5P_5F_{200}$	6.37e	0.69b	4.36b	0.46c	1.82c	1.10b	8.43b
C_5P_{10}	6.65d	0.60b	4.63b	1.07a	1.42cd	1.27b	8.99b
$C_5P_{10}F_{100}$	6.60d	0.70ab	4.50b	1.1b	1.56c	1.21b	9.07b
$C_5P_{10}F_{200}$	6.43f	0.72a	4.34b	1.0b	1.46d	0.96c	8.62b
$C_{10}P_5$	6.97b	0.69b	5.73a	1.29a	2.72a	0.98c	9.14b
$C_{10}P_5F_{100}$	7.01ab	0.94a	5.87a	1.54a	2.79a	1.0c	12.14a
$C_{10}P_5F_{200}$	6.69c	0.69b	4.07b	1.34a	2.87c	0.9c	8.91b
$C_{10}P_{10}$	7.23a	0.66b	6.10a	1.56a	2.97a	1.0c	12.38a
$C_{10}P_{10}F_{100}$	7.20a	0.68b	5.99a	1.20a	2.90a	1.0c	11.97a
$C_{10}P_{10}F_{200}$	7.10a	0.79a	5.90a	1.48a	2.83a	2.08b	13.08a

Means with the same letters are not significantly different at 5% level using Duncan Multiple Range Test.
Abbreviations: C = cocoa pod ash, P = poultry manure, F = NPK 20:10:10 fertilizer.

alone (F_{100} and F_{200}) (Table 1).

The soil samples treated with fertilizer rates F_{100}, F_{200} and control had the highest exchange acidity (EA) compared with other treatments (Table 1). Treatments $C_{10}P_5$, $C_{10}P_{10}$, $C_5P_{10}F_{200}$, $C_{10}P_5F_{100}$, $C_{10}P_5F_{200}$, $C_{10}P_{10}F_{100}$ and $C_{10}P_{10}F_{200}$ were significantly higher ($p>0.05$) than the control and NPK fertilizer rates (F_{100} and F_{200}). Though, other treatments were significantly different from the control and NPK fertilizer rates but they had lower EA. Treatment $C_{10}P_5F_{100}$ had the lowest EA.

All the treatments were significantly higher than control in relation to effective cation exchange capacity (ECEC) except F_{100}, F_{200}, C_5 and C_5F_{100}. Treatments $C_{10}P_{10}F_{100}$, $C_{10}P_{10}$, $C_{10}P_{10}F_{200}$ and $C_{10}P_5F_{100}$ were relatively high in ECEC (Table 1).

The soil samples without treatment and NPK fertilizer singly applied had lower percent base saturation (%BS) than the combined treatments. Generally, the combined treatments had higher %BS than the single application of cocoa pod ash, poultry manure and NPK 20:10:10 at all rates. The treatments in which 10 t ha^{-1} of cocoa pod ash was included in their formulations recorded the highest %BS (Table 2).

The soil samples treated with NPK fertilizer without addition of organic wastes (F_{100} and $F_{200)}$), had the widest Ca/Mg and Ca/K ratios among all the treatments. Treatment $C_{10}P_{10}F_{200}$ had the lowest Ca/Mg ratio. Except control, and F100, the Ca/Mg ratios of all other treatments fell between the range of 2 and 3 (Table 2). The two treatments that had the highest rate of cocoa pod ash, poultry manure and NPK fertilizer in their formulations ($C_{10}P_{10}F_{200}$ and $C_{10}P_{10}F_{100}$) recorded the widest Mg/K ratio.

Among the combinations, P_5F_{200} had the lowest Ca/Mg ratio while F200 had the highest Ca/Mg ratio.

Table 2. Effect of cocoa pod ash poultry manure, NPK 20:10:10 fertilizer on cation ratios

	Ca/Mg	Mg/K	%BS	Ca/K	ESP
Control	5.68	2.76	63	15.71	6.29
F_{100}	6.49	1.95	63	12.67	6.16
F_{200}	6.89	1.46	64	10.08	6.36
C_5	2.56	2.79	82	7.14	12.98
C_5F_{100}	2.39	2.86	79	6.86	15.76
C_5F_{200}	2.31	2.45	88	5.66	5.48
C_{10}	2.36	3.53	86	8.34	13.71
$C_{10}F_{100}$	2.76	2.44	85	6.74	10.91
$C_{10}F_{200}$	2.69	2.37	81	6.39	13.30
P_5	2.71	2.63	79	7.12	5.787
P_5F_{100}	2.86	2.30	79	6.58	10.71
P_5F_{200}	2.91	3.49	83	6.67	7.645
P_{10}	2.16	3.85	85	8.33	11.92
$P_{10}F_{100}$	2.60	2.16	84	5.61	12.86
$P_{10}F_{200}$	2.94	1.76	83	5.16	9.72
C_5P_5	2.41	3.5	88	8.43	11.13
$C_5P_5F_{100}$	2.46	2.89	86	7.12	10.42
$C_5P_5F_{200}$	2.39	2.64	87	6.32	5.46
C_5P_{10}	3.26	2.39	86	7.2	11.90
$C_5P_{10}F_{100}$	2.88	2.23	87	6.23	12.12
$C_5P_{10}F_{200}$	2.97	2.03	89	6.03	11.60
$C_{10}P_5$	2.11	3.94	90	8.30	14.11
$C_{10}P_5F_{100}$	2.10	2.97	92	6.24	12.68
$C_{10}P_5F_{200}$	2.17	2.71	90	5.89	15.03
$C_{10}P_{10}$	2.15	4.2	92	4.5	13.32
$C_{10}P_{10}F_{100}$	2.07	8.8	92	4.3	10.02
$C_{10}P_{10}F_{200}$	2.08	7.47	84	3.6	11.31

Treatment $C_{10}P_{10}F_{100}$ had the highest Mg/K while F_{200} had the lowest Mg/K. Also, treatment $C_{10}P_{10}F_{100}$ had the lowest Ca/K ratio while the control had the highest Ca/K ratio.

Exchange percent sodium (ESP) was generally higher in soil samples treated with cocoa pod ash rates; poultry manure rates and their combinations except P_5, C_5F_{200} and $C_5P_5F_{200}$. Treatment F100 had the lowest ESP while $C_{10}P_5F_{200}$ had the highest ESP.

DISCUSSION

The increase in the pH of the soil samples treated with cocoa pod ash and poultry manure above the control and mineral fertilizer could be attributed to the buffering from carbonates and organic acids in the amendments as noted by Whalen et al. (2000). The mechanism given by Ano and Ubochi (2007) that best explained the neutralization reaction was found to be microbial decarboxylation of calcium-organic matter complex leading to the release and subsequent hydrolysis of calcium ions. The hydroxyl ions released in the hydrolytic reaction then reacts with both the exchangeable hydrogen and aluminum ions to form water and insoluble aluminum hydroxide (Al(OH)3) respectively.

The poultry manure composed of macronutrients with little micronutrients (Adeniyan, 1999; Adeniyan and Ojeniyi, 2005, 2006; Carvalho et al., 2011). The organic acids with carboxyl and phenolic hydroxyl groups have important roles in buffering soil acidity and increasing the pH of acid soils amended with poultry manure Carvalho et al. 2011). Also, the ability of poultry manure, cocoa pod ash and their combinations to increased soil pH in this work can be aligned with supply of K, Ca, Mg and Na

The increase in soil pH with addition of cocoa pod ash, poultry manure and their combinations varied between 6.02 and 7.01. The pH range for optimum arable production in South Western Nigeria ranged between 6 and 8. The pH of the cocoa pod ash rates, poultry manure rates and their combinations still fall within the critical range and it is not likely to have deleterious effect

Table 3. Nutrient composition of poultry manure (PM) and cocoa pod ash (CPA) (%)

Nutrient	K	Ca	Mg	Na
CPA	12.52	3.74	1.00	ND
PM	2.91	2.80	0.80	ND

Source: Ayeni, 2011

on arable crop production. The result showed that the release of Ca, K and Mg were high within the treatment that had pH 6 - 7.01 range. The high Ca released by the treatments might have caused the decrease in exchange acidity. The release of available K, Ca and Mg in cocoa pod ash rates, poultry manure rates and their combinations might be as a result of favourable soil pH (Cavallaro et al., 1993). It is presumed that with this pH range (6.02-7.01) other nutrients antagonizing Nitrogen (N) might not come up as N could be mineralized at wide range of pH. Phosphorus might partially be antagonized by Ca as the pH increased. Therefore, caution must be taken in applying cocoa pod ash as 10 t ha^{-1} of cocoa pod ash combined with 10 t ha^{-1} poultry manure might result in soil alkalinity.

The Ca/Mg and Mg/K ratios of the treatments fall within the critical range of 3:1 – 4-1, 13:1 and 2:1 respectively (Ogban and Ibia, 2006). Though there is no established usefulness of nutrient ratios for optimum crop yield but the ratios could influence nutrients interactions or release to the soil.for crop uptake (Spectrum, 2003). Also Ca/Mg ratio can help in identifying soil structure problems (Graig, 2009). The critical level recommended for Ca and Mg are 2.5 and 0.45 C mol Kg^{-1} respectively. Though the Mg level of the soil samples treated with the soil and combined agrowastes increased the soil Mg level compared with control, only the combinations that involved 10 t ha^{-1} cocoa pod ash ($C_{10}P_5$, $C_{10}P_5F_{100}$, $C_{10}P_{10}$, $C_{10}P_{10}F_{100}$ and $C_{10}P_{10}F_{200}$) increased soil Mg slightly above the critical level. With the use of combined cocoa pod ash and poultry manure, availability of K may not be a problem in southwest Nigeria as the soil samples treated with cocoa pod ash, poultry manure and their combinations increased K above the critical level of 0.20 cm/kg^{-1} (Adebusuyi, 1985). Carvalho et al., 2011 observed that the addition of poultry litter increased levels of K in the soil.

The soil ECEC was high with high percent base saturation (%BS) with corresponding decrease in EA. The high %BS implied that the soil was able to hold nutrients that were applied through cocoa pod ash, poultry manure and their combination with NPK 20:10:10 fertilizer. Hence, there would be availability of nutrients for plants use. It could be also deduced that availability of the cations in cocoa pod ash and poultry manure might have caused the reduction in exchange acidity as high cations are known to reduce H^+ and Al^{3+} concentration. This shows the ability of these organic wastes to act as liming material. The agrowastes and their combinations with NPK fertilizer increased soil ECEC and therefore, the treated soils were expected to be more productive because of the low Al^{3+} and H^+ in this experiment. In this study is also in line with the work Liu et al. (2009).

Critical level 0.23 C mol kg^{-1} was recommended for Ca (Adebusuyi, 1985). The recommended Ca/Mg, Ca/K and Mg/K in Nigeria were 3:1, 13:1 and 2:1 respectively as earlier stated (Ogban and Ibig, 2006) but Johntson (2006) got the values range of 37:1.and 9:1 for Ca/Mg ratio. Going by Ogbam and Ibian (2006) assertion, the soils without organic amendment but with NPK rates were too high in Ca/Mg ratio. This shows the ability of organic wastes applied to reduce Ca/Mg ratio there by reducing the need for Ca and Mg fertilization.

The Ca/K range was lower than the critical level (13:1) in all the soil samples except the control. This means Ca might antagonize K release in the soil and possibly hinder its uptake by crops. Sodium concentration might not pose problem due to addition of the two organic wastes at 5 and 10 t ha^{-1} as the exchange sodium percent (ESP) fell below 16 recommended by (Clemson, 2000). The antagonized relationship between Na and Ca has been documented (Idown and Aduayi, 1999). At high concentration of Na, there may be breakdown in the Ca regime of the soil resulting in insufficiency of Ca availability as a plant nutrient. The level of Na in the soil samples may still be tolerable for arable crops and may not cause soil structure deterioration. It is ascertained that Na is not an essential plant nutrient but is usually considered in light of its effect on the physical condition of the soil. Soil that is high in ESP may cause adverse physical and chemical condition to develop in the soil, which may prevent the growth of plants.

CONCLUSION

The burnt cocoa pod, poultry manure and their integration with NPK 20:10:10 fertilizer improves soil cations as well as balance of nutrients in the soil for optimum crop production.

Cocoa pod ash can successfully reduce exchange acidity for better crop production.

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