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SOIL CHEMICAL PROPERTIES AND GROWTH OF MAIZE (*Zea mays* L.) AS AFFECTED BY COCOA POD COMPOST BASED N AND P FERTILIZER

[1]Atere, C. T. and [1]Olayinka, A.
[1]*Department of Soil Science and Land Resources Management,*
Obafemi Awolowo University (OAU), Ile-Ife, Nigeria.
Corresponding author: cornelatere@oauife.edu.ng

ABSTRACT

A greenhouse soil culture experiment was carried out to investigate the effects of organo-mineral fertilizers on soil chemical properties, growth, dry matter yield and tissue nutrient contents of maize (*Zea mays* L.). The organo-mineral fertilizers consisted of cocoa (*Theobroma cacao*) pod compost fortified with inorganic N and P. Five (5) kilogramme portions of an ultisol obtained from an uncultivated plot were amended with cocoa pod compost at the rates of 0, 2.5 and 5.0 t/ha, respectively, with and without N (0 and 25 kg/ha urea) and P (0 and 26 kg/ha single superphosphate - SSP). Maize was grown for two consecutive 8-week periods and the following parameters were determined: plant heights, dry matter yield, soil reaction (pH), organic carbon, soil and tissue contents of N, P, Mg, Ca, K and Na. The results showed that plant heights and dry matter yields were significantly ($p<0.05$) enhanced in the following order: 5 t/ha cocoa pod + N and P (CC2F) > 5.0 t/ha cocoa pod compost (CC2) > 2.5 t/ha cocoa pod + N and P (CC1F). The soil pH, OM, P, Mg, K as well as tissue contents of P, K, Ca and Mg were significantly ($p<0.05$) increased thus: CC2 > CC2F > CC1> CC1F. Other parameters such as exchangeable Ca and Na, and tissue N content were not significantly ($p>0.5$) affected by the treatments. It was, therefore, concluded that the application of cocoa pod compost at the rate of 5.0 t/ha with and without N and P improved some soil chemical properties, growth and tissue nutrient contents of maize.

Key words: ultisol, cocoa pod compost, N and P, dry matter yield.

INTRODUCTION

Soil degradation and nutrient depletion have become serious threats to agricultural productivity in Nigeria and most parts of sub-Saharan Africa (Madukwe *et al.*, 2008; Ramaru *et al.*, 2008). These degradative processes and concomitant decline in soil quality decrease the capacity of soils to produce adequate yields of healthy and nutritious crops (Parr *et al*., 1989; FAO, 1990; Ayoub, 1991). However, it has been authenticated that the maintenance of soil organic matter (SOM) is the basis of sustainable crop production in Nigeria and the tropics in general (Agboola, 1990; Oladipo *et al.*, 2005). With continuous cultivation, SOM content declines, and nutrients are detached and leached out of the rooting zones (Agboola, 1990). Apart from the high cost, the sustainability of heavy mineral fertilizer use without organic manure application in cropping systems is widely questioned. Regular application of organic manure not only supplies all the various macro and micro-nutrients, although in small quantities, but also improves soil physical and biological properties (Batiano and Mokwunye, 1991; Moyin-Jesu, 2002, 2008; Saviozzi *et al*., 1997; Olayinka, 2009). Morafa (2007), in a study with *Gliricidia*, sewage and poultry wastes and NPK fertilizer, found that the cost of fertilizer input was higher than for the organic materials, and the marginal rate of return was less for the fertilizer. Therefore, the complementary use of organic manure and mineral fertilizer has proved a sound soil fertility management strategy in the fragile soils of tropical Africa. Apart from enhancing crop yield, the practice has a greater beneficial residual effect than can be derived from the application of either inorganic fertilizer or organic manure alone (Egarva, 1975). The complimentary application of organic manures and composts with inorganic fertilizers is, therefore, gaining increasing interest. Spent cocoa pods are normally left to rot in heaps in cocoa plantations. This study, therefore, assessed soil chemical properties and growth of maize as affected by cocoa pod compost based N and P fertilizer.

MATERIALS AND METHODS

Sampling preparation and soil amendment

Top soil sample (0-20 cm) of Itagunmodi soil series (an Ultisol) was obtained from an uncultivated plot, bulked, air-dried, and sieved using 2 mm sieve, to remove extraneous materials. Spent cacao pods were composted over a period of 3 months. Thereafter, portions of the compost were fortified with N (0 and 25 kg/ha urea) and P (0 and 26 kg/ha SSP), mixed and further composted for 1 month to obtain sole cocoa pod compost and cocoa pod compost fortified with N and P.

Soil physical and chemical analyses

Soil particle size distribution and water holding-capacity were determined using the hydrometer method (Bouyoucos, 1962) and the core sampling method (Blake and Hartge, 1986), respectively, while soil pH was determined potentiometrically in a soil-solution ratio of 1: 2 in 0.01 M $CaCl_2$ using a glass electrode pH meter (Peech *et al*., 1953). Available phosphorus (P) was determined using the Bray-1 method (Bray and Kurtz, 1945) and read at 660 nm wavelength after the development of the molybdenum blue colour. Exchangeable cations were extracted with 1 N ammonium acetate (NH_4OAc) at pH 7; sodium (Na), calcium (Ca), and potassium (K) were determined using flame photometer while magnesium (Mg) was determined using the ethylenediaminetetraacetic acid (EDTA) titration method (Page *et al*., 1982). The organic carbon (OC) and the total nitrogen (N) were determined using the chromic acid digestion method (Allison, 1965) and the micro-Kjeldahl digestion and distillation process (Bremner and Mulvaney, 1982), respectively.

Chemical analyses of fresh and composted cocoa pod

Some portions of the fresh and composted cocoa pod were oven-dried at 65^{o}C and ground with stainless steel mill. The ground samples were digested using concentrated H_2SO_4 and 30 % H_2O_2, after which the samples' contents of cations were read: K, Na, and Ca with flame photometer; Mg and heavy metals (Cd, Pb, Zn, As, and Cu) with Atomic Absorption Spectrophotometer (AAS). The organic carbon (OC) and total N contents of the organic materials were also determined as earlier described.

Amending the soil samples

Five kilogrammes (5 kg) portions of soil were amended with cocoa pod compost with and without N and P fortification. The treatments were the following:

1. Soil only (Control)
2. Soi + N (25 kg/ha) + P (26 kg/ha) (F)
3. Soil + 2.5 t/ha cocoa pod compost (CC1)
4. Soil + CC1 + N (25 kg/ha) + P (26 kg/ha) (CC1F)

5. Soil + 5.0 t/ha cocoa pod compost (CC2)
6. Soil + CC2 + N (25 kg/ha) + P (26 kg/ha) (CC2F)

Where, CC= cocoa pod compost; F= Inorganic N and P; 1= 2.5 t/ha; 2 = 5.0 t/ha.

Greenhouse soil culture experiment

The treatments, in triplicates, were transferred to plastic pots arranged in a Completely Randomized Design (CRD) and wetted to 70 % of the soil's water holding capacity. Four (4) maize (*Zea mays* L.) seeds were planted per pot and later thinned to 2 at two weeks after planting. The plants were harvested at the end of eight (8) weeks. The plant heights were measured using meter rule and thereafter, the shoots and the roots were carefully harvested. The experiment was repeated to evaluate the residual effects of the amendments.

Plant tissue analyses

The shoots and roots were later oven-dried in paper bags at 65^{o}C to constant weight and the dry matter yields determined after which they were ground in a micro-hammer stainless steel mill prior to chemical analyses. The tissues were later digested with concentrated H_2SO_4 and 30 % H_2O_2, after which the contents of cations were read; K and Ca with flame photometer and the Mg content with Atomic Absorption Spectrophotometer (AAS). The total N was determined using micro-Kjeldahl digestion and distillation process (Bremner and Mulvaney, 1982).

Data analyses

The data collected were analyzed using the ANOVA technique and means were separated using the Duncan's New Multiple Range Test (DNMRT) at 5% level of probability with the SAS Software Package.

RESULTS AND DISCUSSION

Properties of the soil and organic amendments

Table 1 shows the physical and chemical properties of the soil used for the greenhouse soil culture experiment. The chemical properties of the fresh and composted cocoa pod are presented in Table 2. The textural classification of the soil is clay, made up of 310 gkg^{-1} sand, 230 gkg^{-1} silt and 460 gkg^{-1} clay. The pH (0.01 M $CaCl_2$) showed acidic reaction. The cocoa pod compost (CC) contained 21.8 % OC compared with the soil which had 11 gkg^{-1} and within the medium fertility range (Sobulo and Adepetu, 1981; Adepetu, 1990). The compost also had higher total N content (0.88%) than the soil with 5.8 gkg^{-1} N which was above the critical minimum of 1.1 gkg^{-1} for Nigerian soils (Adepetu and Adebusuyi, 1985; Adepetu, 1990). The compost was also high in available P, with a value of 0.58 % P while the soil only had 21.34 mg/kg available P which, however, was within the high fertility range (Sobulo and Osiname, 1981; Adeoye, and Agboola, 1985). The compost contained 7.21 % K, 0.6 % Ca, 0.02 % Mg and 0.31 % Na. These were much higher than those of the soil with the following values of extractable cations (in Cmol/Kg); Ca – 5.1, K – 0.21 (medium fertility range), Mg – 3.21 (high fertility range) and Na – 0.28. Comparing the fresh and composted cocoa pods, the composted material was richer in virtually all the nutrients than the fresh materials. The compost in addition had lower C:N ratio, thereby making mineralization of nutrients possible and faster. The heavy metal contents (Cd, Pb, Zn, As, and Cu) of the compost were also analyzed in order to ascertain their suitability as sources of plant nutrients without constituting health hazard to man in the long run. The values obtained as shown in Table 2, were, however, lower than the maximum permissible levels in sewage sludge used in agriculture (Lixandru *et al*., 2010).

Effects of treatments on heights and dry matter yields of maize

At the end of the first cropping, maize plant heights were significantly ($p<0.05$) increased by CC2F and CC2 over the control while the remaining treatments were not significantly different from the control (Table 3). The treatments, however, had no significant ($p>0.05$) effect at the end of the second planting. The maize dry matter yield was significantly ($p<0.05$) increased by CC2F, CC1F and CC2, respectively, over the control at the end of both the first and the second plantings.

The cocoa pod compost was rich in plant nutrients especially N, P and K as shown in Table 2. This, combined with its low C:N ratio (25:1) ensured that these nutrients were available for plant uptake. The agronomic parameters of the test crop were thus improved by the compost application especially at the higher application rate of 5 t/ha. Ayeni (2010), reported increased plant, grain, stover and dry root yields of maize with the combined application of cocoa pod ash and NPK 20:10:10. Some other studies confirmed the superior effects of combined applications of organic manure and mineral fertilizers in terms of balanced plant nutrition and improved soil fertility (Uyovbisere and Elemo, 2000; Ayeni, 2008). In this study, however, there was no added advantage in terms of maize heights and dry matter yields, of adding N and P to cocoa pod composts applied at the rates of 2.5 and 5.0 t/ha. This implies that the added N and P were immobilized (Olayinka, 2001). Olayinka (2001) and Olayinka and Ailenubhi (2004), working with cow dung and $(NH_4)SO_4$, therefore, suggested that inorganic nutrients and organic amendments should be applied separately.

Effects of treatments on soil pH, SOM and available P contents

The pH values obtained with CC2F and CC2 at the end of the first planting were significantly ($p<0.05$) higher than in all other treatments including the control (Table 4). At the end of the second planting, however, the pH values were not significantly affected by the treatments. The increases in pH observed at the end of the first planting can be attributed to the release of basic cations by the organic amendments (Ramaswami and Son, 1996; Olayinka *et al*., 1998).

The SOM contents were significantly ($p<0.05$) affected by the treatments at the end of both the first and the second plantings. The CC2 and CC2F significantly ($p<0.05$) increased the SOM contents over the control at the end of both the first and the second croppings. While at the end of the first planting, the SOM content obtained in the control was significantly ($p<0.05$) higher than in other treatments (except CC2 and CC2F), at the end of the second planting, it was significantly ($p<0.05$) lower than in other treatments except F and CC1F. In addition, the SOM contents were generally higher in the first cropping than in the second cropping. This result showed that CC2 and CC2F supplied more organic matter to the soil compared with other treatments. Increasing the organic matter contents of soils through incorporation of organic materials such as plant residues has been well-documented (Brady and Weil, 2002; Adediran *et al*., 2003; Adeoye *et al*., 2005). Also, the treatments without inorganic fertilizer (F) fortification yielded higher SOM contents than those containing inorganic fertilizer. This may be due to the fact that inorganic nutrients enhance rapid mineralization of the native SOM (Agboola, 1990).

At the end of the first planting, the available P was only significantly ($p<0.05$) increased over the control by CC2F while it was not significantly affected by the treatments at the end of the second planting. This may be due to the cumulative effects of the high P content (0.56 %) of the cocoa-pod compost, the initially high available P in soil (21.34 mg/kg) coupled with the P added to fortify the compost.

Effects of treatments on exchangeable cation (K, Ca, Mg and Na) contents

The contents of exchangeable cations at the end of the first and second 8 week cropping of maize are presented in Table 5. Compared with the initial contents, the contents of all the exchangeable cations decreased at the end of both croppings. The soil exchangeable K was significantly ($p<0.05$) increased by CC2 and CC2F over the control and F, but significantly different from all other treatments at the end of the first and second cropping. The exchangeable Ca and Na were, however, not significantly ($p>0.05$) different at the end of both croppings. While at the end of the first cropping the exchangeable Mg contents were not significantly ($p>0.05$) different, it was increased significantly ($p<0.05$) over the control by CC2 at the end of the second cropping.

The decrease in the contents of exchangeable cations with cropping can be attributed to their uptake by the maize plant. This was in line with the findings of others who reported increases in the contents of exchangeable cations with the applications of organic wastes applied individually or combined with inorganic fertilizers (Olayinka and Adebayo, 1983; Olayinka, 1990; Odedina *et al*., 2007; Ayeni, 2008; Ayeni, 2010; Oladipo *et al*., 2010). The trend obtained with CC2 regarding exchangeable K and Mg was, therefore, in line with the findings of others. The lower but not significantly ($p>0.05$) different exchangeable K and Mg contents of CC2F compared with CC2 might be attributed to the concomitant uptake of these macronutrients that were not initially added to the cocoa pod compost. The lack of significant differences between treatments with respect to exchangeable Ca and Na at the end of both croppings may be due to the fact that they are secondary macronutrients.

Effects of treatments on tissue contents of N, P and cations (K, Ca and Mg).

As shown in Table 6, the tissue total N contents were not significantly ($p<0.05$) affected by the treatments at the ends of both the first and the second cropping. While tissue P was significantly ($p<0.05$) increased in all treatments over the control at the end of the first cropping, there were no significant differences at the end of the second. The tissue contents of K and Ca were significantly ($p<0.05$) increased by CC2 over the control at the end of the first cropping. At the end of the second cropping, however, only the tissue content of K was significantly ($p<0.05$) increased by CC2. At the end of the first cropping, while the tissue contents of Mg were not significantly ($p>0.05$) different, those obtained with CC2 and CC2F were significantly ($p<0.05$) higher than in the control only, at the end of the second cropping.

The lack of significant difference in the tissue N contents at the end of both plantings can be attributed to the initial medium content of SOM which on being mineralized supplied inorganic N for plant uptake. The lower tissue P content in the control compared with the other treatments at the end of the first cropping was expected as these treatments received either inorganic fertilizer and/or cocoa pod compost. The generally higher K, Ca and Mg contents obtained with CC2 and non-significantly with CC2F compared with the control could be due to the release of these nutrients at the higher rate of cocoa pod compost addition (5 t/ha). Cocoa pod ash alone had been reported to compare favourably with cocoa pod ash fortified with NPK fertilizer in increasing the leaf N, P, K, Mg and Ca contents of tomato as well as maize tissue N, P and K (Odedina *et al*., 2007; Ayeni, 2008; Ayeni, 2010). The applications of 5.0 t/ha cocoa pod compost with and without N and P could, therefore, be said to be effective in enhancing the tissue contents of cations of the maize plant.

CONCLUSION

In conclusion, the application of cocoa pod compost effectively improved soil chemical properties as well as the growth of maize. The applications of 5 t/ha cocoa pod compost with and without N and P addition did not only significantly improve the soil chemical properties (pH, OM, P, K and Mg), but also increased the plant agronomic parameters (plant heights and dry matter yield), tissue contents of cations (K, Ca and Mg) and P.

Table 1: Physical and chemical properties of the soil used for the greenhouse study

Property	**Value**
Sand (gkg^{-1})	310
Silt (gkg^{-1})	230
Clay (gkg^{-1})	460
Textural class	Clay
FMC (%)	22.3
pH ((H_2O)	4.4
pH (0.01 M $CaCl_2$)	4.1
Organic carbon (gkg^{-1})	11
Total N (gkg^{-1})	5.8
Available P (mg/kg)	21.34
Exchangeable cations (cmol/kg)	
Ca	5.1
K	0.21
Mg	3.21
Na	0.28

Table 2: Chemical properties of fresh and composted cocoa pod (dry weight basis) used for the study

Properties	**Cocoa pod**		**Maximum permissible levels (mg/kg)**		
	Fresh	**composted**	**Romania (Ord. 344/2004)**	**EU86/278/ECC**	**USA(EPA 503/1999)**
C (%)	33.6	21.8			
N (%)	0.49	0.88			
P (%)	0.36	0.56			
K (%)	4.06	7.28			
Ca (%)	0.3	0.60			
Mg (%)	0.03	0.02			
Na (%)	0.24	0.31			
C:N	69	25			
Cd (mg/kg)	2.50	3.25	10	20-40	85
Pb (mg/kg)	13.88	25.25	300	750-1200	840
Zn (mg/kg)	45.50	47.00	2000	2500-4000	7500
As (mg/kg)	5.50	6.25	10	-	-
Cu (mg/kg)	70.25	72.50	500	1000-1750	4300

Table 3: Maize *(Zea mays* L.) plant heights and dry matter yields at the end of the first (a) and second (b) 8-week croppings in the greenhouse

(a)

	Plant heights (c)		**Dry matter yields (g/plant)**	
Treatments	**A**	**B**	**a**	**b**
Control	75.00b*	114.00	6.26b	4.09b
Fertilizer(F)	93.83ab	88	7.34ab	7.36ab
CC1	86.17ab		7.22ab	7.98ab
CC1F	100.67ab	105.17	9.63a	8.75a
CC2	94.83a	104.67	9.89a	9.11a
CC2F	104.67a	111.67	10.49a	9.25a
		NS		

*Means in a column with similar letter(s) are not significantly different (p<0.05) according to Duncan's New Multiple Range Test. Where, CC = cocoa pod compost; 1 = 2.5 t/ha; 2 = 5.0 t/ha.

Table 4: Soil pH, organic matter and available P contents at the end of the first (a) and second (b) 8-week croppings of maize (*Zea mays* L.) in the greenhouse

Treatments	**pH**		**OM (%)**		**P (mg/kg)**	
	A	**b**	**A**	**b**	**a**	**B**
Control	4.53b*	4.27	1.25c	1.04d	23.06b	22.96
Fertilizer(F)	4.50b	4.23	1.07e	1.03d	24.83b	25.05
CC1	4.70b	4.17	1.11d	1.07c	28.21ab	20.42
CC1F	4.57b	4.27	1.08e	1.05cd	26.28ab	20.65
C2	4.90a	4.30	1.73a	1.61a	26.52ab	19.37
CC2F	4.80a	4.27	1.63b	1.51b	33.77a	23.43
		NS				NS

*Means in a column with similar letter(s) are not significantly different (p<0.05) according, to Duncan's New Multiple Range Test. Where, CC = cocoa pod compost; 1= 2.5 t/ha; 2 = 5.0 t/ha.

Table 5: The contents of exchangeable cations at the end of the first (a) and second (b) 8-week croppings of maize (*Zea mays* L.) in the greenhouse

(a)

	K	Ca	Mg	Na
Treatments	←	Cmol/kg		→
Control	0.14bc*	3.53	2.37	0.17
Fertilizer(F)	0.12c	3.33	1.52	0.16
CC1	0.35abc	3.40	1.86	0.17
CC1F	0.34abc	3.53	1.86	0.16
CC2	0.53a	3.60	2.03	0.18
CC2F	0.40ab	3.57	2.20	0.18
		NS	NS	NS
(b)				
Control	0.12cd	2.70	0.41b	0.18
Fertilizer(F)	0.08d	2.37	0.74ab	0.18
CC1	0.20abc	2.30	1.15ab	0.15
CC1F	0.15bcd	2.40	0.88ab	0.15
CC2	0.29a	2.53	1.42a	0.17
CC2F	0.24ab	2.47	1.29ab	0.16
		NS		NS

* Mean in a coloumn with similar letter(s) are not significantly different (p<0.05) according to Duncan's New Multiple Range Test. Where, CC = cocoa pod compost; 1 = 2.5 t/ha; 2 = 5.0 t/ha.

Table 6: Maize (*Zea mays* L.) Tissue contents of N, P and cations at the end of the first (a) and second (b) 8-week croppings of maize (*Zea mays* L.) in the greenhouse.

Treatment	Total N	P	K	Ca	Mg
	←		%		→
(a)					
Control	1.07*	0.58b	1.35b	0.12b	0.22
Fertilizer(F)	1.23	0.66a	1.48b	0.13ab	0.23
CC1	1.42	0.67a	1.92ab	0.13ab	0.24
CC1F	1.14	0.63a	1.85ab	0.17ab	0.26
CC2	0.86	0.68a	2.15a	0.23a	0.23
CC2F	1.24	0.68a	1.96ab	0.15ab	0.25
	NS				NS
(b)					
Control	1.17	0.59	0.85b	0.05	0.08b
Fertilizer(F)	1.24	0.60	1.25b	0.05	0.12ab
CC1	0.84	0.51	2.29b	0.05	0.13ab
CC1F	1.03	0.52	2.02ab	0.07	0.14ab
CC2	1.26	0.56	3.42a	0.08	0.16a
CC2F	1.26	0.56	2,71ab	0.08	0.15a
	NS	NS		NS	

* Mean in a coloumn with similar letter(s) are not significantly different ($p<0.05$) according to Duncan's New Multiple Range Test. Where, CC = cocoa pod compost; s1 = 2.5 t/ha; 2 = 5.0 t/ha.

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