Nigerian Journal of Soil Science
Journal homepage:www.soilsjournalnigeria.com

SOIL PROPERTIES AND COCOA (*Theobroma cacao L.*) NUTRIENT UPTAKE AS AFFECTED BY ORGANIC AND INORGANIC BASED FERTILIZERS IN SOUTHWESTERN NIGERIA

Adejobi, K,B.[1], Agele, S.O.[2] and Ewulo, B.S.[2]
[1]*Agronomy Section, Cocoa Research Institute of Nigeria, PMB 5244, Ibadan, Nigeria.*
[2]*Department of Crop, Soil and Pest Management, Federal University of Technology Akure, Nigeria.*
**Corresponding author: E-mail: jobikayode@gmail.com.*

ABSTRACT

Low soil fertility is a major problem for cocoa establishment on the field; however, cocoa (*Theobroma cacao* L) is characterized by high nutrient demand particularly N, P, K, Ca and Mg during its early growth. In this study, the effects of organic and inorganic fertilizers on soil properties and nutrient uptake of cocoa in Ibadan and Owena soils of Southwestern Nigeria were investigated in 2011. The experiments were 4 x 4 factorial fitted into Randomized Complete Block Design (RCBD) with three replications. The fertilizers were: Goat Dung (GD), Sunshine Organic (OF) and Organo -Mineral Fertilizers (OMF) and NPK 15:15:15 and the rates of application were: 0, 200, 400 and 600 kg/ha. Four hundred and thirty two (432) plantain suckers were planted at 3 x 3 m spacing while 432 cocoa seedlings (F3 Amazon) were also transplanted at 3 x 3 m respectively at each experimental site. Top soil samples were collected randomly from each experimental sites using soil auger. The samples were bulked, air dried and subjected to routine laboratory analysis for physical (sand, silt, clay, bulk density, moisture) and chemical properties (SOM, pH, N, P, K, Mg, Ca, and Na). Two grammes (2g) each of the organic fertilizers used were also analyzed for their nutrients composition. The fertilizers were applied to treatment plots one month after cocoa seedlings were transplanted using ring method. Leaf samples (4tI leaf) which were collected from 4 tagged cocoa seedlings at 12 months after transplanting were analyzed in the laboratory for chemical compositions. The experiments were monitored for 36 months (144 weeks) after planting. Soil samples were collected from treatment plots processed and analyzed using standard procedures. Data collected were subjected to statistical analysis using Analysis of variance (ANOVA) and significant means separated by Tukey's HSD ($P < 0.05$) test. Goat dung (GD), Organo-mineral fertilizer (OMF) and organic fertilizers (OF) had pH of 8.17, 7.00 and 7.30 respectively. They contained in similar order 2.86, 0.63 and 3.64 g/kg OC, 4.80, 1.09 and 6.27 OM, 1.26, 0.06 and 2.16% N, 113.24, 138.06 and 7.08 cmol/kg P, 2.60, 2.00, and 13.10 cmol/kg Ca, 0.38, 0.18, and 2.30 cmol/kg Na respectively. Application of 200 kg OMF, 600kg/ha GD and 400 kg/ha GD, 400 kg/ha OF significantly increased soil moisture contents in both Ibadan and Owena experiments. Application of GD, OMF and OF significantly reduced soil bulk density compared with NPK 15:15:15 and the control. In addition, these treatments enhanced soil and leaf chemical properties at 15 MAT at both locations.

Key words: Cocoa, Fertilizers, Soils Properties and Nutrient Uptake.

INTRODUCTION

In Nigeria, cocoa occupies about 0.6 million hectares and production stands at 383,000 tonnes in 2012 (FAOSTAT, 2014). The average cocoa yield in West Africa is about 0.5 tonnes/ha while for Nigeria it is around 0.4 tonnes/ha. This suggests that yield in Nigeria is low compared to the world average. After its introduction into the zone of West Africa sub- region in 1890, the area planted to cocoa increased rapidly to its present 0.7 million hectares and yield increased to peak of 310,000 tons in 1965 (Daramola, 2004). However, as early as 1940 manifestation of deficiency symptoms necessitated the need for research on the need to balance soil nutrients.

From 1966, yield declined gradually to its present 383,000 tons (FAOSTAT, 2014). Many workers have attributed this yield decline essentially to soil nutrients imbalance (Ayanlaja, 2002; Ojeniyi, *et al.,* 2010). Cocoa remains the highest foreign exchange earner of all agricultural export crops in Nigeria. Cocoa output has declined one of the factors responsible for this was the fact that soils of cocoa growing agro-ecologies are inherently poor in fertility, has rapid degradation of properties, acidic due to the nature of their parent materials, high rainfall intensity enhanced leaching of nutrients and weathering. These soils are often deficient in essential plant nutrients due to continuous cropping without application of fertilizers. There is therefore, the need for sustainable manuring via application programme. Observation of many workers between 1959-69 revealed gross micro-nutrient deficiencies and comparison of soil nutrient contents under cocoa and virgin forest revealed that organic carbon and major nutrients were higher in virgin forest soils than adjacent cocoa soils. This indicated gradual soil nutrient depletion under cocoa, and that litter decomposition and nutrient recycling are not adequate to maintain nutrient balance (Ayanlaja, 2002). One way of combating this problem of soil nutrients imbalance in cocoa soil is via sustainable organic and management of fertilizers. However, African farmers use very little fertilizer (8 kg/ha) compared to their counterparts in other parts of the agrarian world (Ogunlade and Iloyanomon, 2009). Hence, Africa's soils are increasingly depleted of nutrients (IFDC, 2008/2009). This is particularly true with cocoa farmers in Nigeria. Ogunlade and Iloyanomon (2009), reported that more than 85 % of cocoa farmers in Nigeria do not use fertilizers on cocoa. Reasons for this low usage of fertilizers vary from lack of farmers' knowledge of the nutrients status of their soils to scarcity and high cost of fertilizers where available. The need to pay attention to soil fertilization is now almost as important as the control of capsids and black-pod disease in cocoa. Ayanlaja (2002), Adejobi *et al.* (2011 a, b, c, d) and CRIN Annual Reports (2005) reported the use of organic residues such as animal manures, urban refuse, agro-industrial processing wastes, animal dung, refuse dump compost, pit latrine compost, foot of the hill compost, mulching, passive refuse dump in home gardens and alley cropping with appropriate nitrogen fixing shrubs, have been found capable of increasing and balancing soil nutrients, improving soil properties with consequential increase in crop performance. The objective of this study was to examine the effects of fertilizers on soil physical, chemical properties and leaf nutrient composition cocoa seedlings on the field.

MATERIALS AND METHODS

Experimental sites and condition

Field experiments were conducted at Ibadan, Headquarters of the Cocoa Research Institute of Nigeria (CRIN), and in Owena, a CRIN Sub-station in Ondo State.

Ibadan experimental location

Ibadan, Oyo State, is located on latitude 07° 10' N and longitude 03° 52'E, and an altitude of about 122 meters above sea level in the humid tropical rain forest zone of Nigeria. The annual rainfall is between 1200-1500 mm. The maximum temperature ranges between 26 to 35°C with an average of about 30.1°C. Relative humidity is high throughout the year and ranges from 50 to 89 % with an average of 79 %. There are seasonal variations in the values of relative humidity, which varies from 65 to 89 % during the rainy season and 46 to 70 % during the dry season.

Owena experimental location

The Owena sub-Station of the Cocoa Research Institute of Nigeria, Ondo State, lies on latitude 07° N and longitude 05°, 7'E and at an altitude of about 22.5 meters above sea level. Owena is situated at about 21 kilometres south — east of Akure between Akure and Ondo. The average rainfall ranges between 1500 — 1600 mm per annum. The maximum temperature in Owena is usually between 28 and 34° C while the daily minimum temperature ranges between 18 and 23° C. The relative humidity during the rainy season ranges from 69 to 80 %, and between 56 and 64 % during the dry season.

Acquisition and preparation of experimental materials

Cocoa F3 Amazon genotype seedlings were collected from CRIN Seed Garden, while plantain suckers were collected from the experimental plots in both Ibadan and Owena. Sunshine organic and organo-minerals fertilizers used for the experiments in Ondo State were obtained from the Ministry of Agriculture, while the N.P.K. 15:15:15 was obtained at Ayedaade Local Government Gbongan, Osun State. Goat dung manure was obtained from Ilesha Garage Akure, Ondo State. The goat dung was collected dried and carefully sorted to remove foreign materials and packed in 50 kg bags for application on the field.

Treatments and experimental design

Field experiments were conducted in two stations of the Cocoa Research Institute of Nigeria (CR1N), Ibadan Headquarters and Owena Sub-Station, Ondo State. The experiments were conducted between June, 2011 and June, 2014. The experiments were 4 x 4 factorial scheme fitted into Randomized Complete Block Design (RCBD) with 3 replications. The 4 fertilizers were: Goat Dung (GD), Sunshine Organic and Organo-Mineral Fertilizers (OF and OMF) and NPK 15:15:15 and the rates of application were: 0, 200, 400 and 600 kg/ha. Lay-out of each experimental site (Measurement, pegging and holing) was carried out before planting. Four hundred and thirty two (432) plantain suckers were planted at the spacing of 3 x 3 m in each of the experimental sites in Ibadan and Owena between second and third week of June, 2011 Four hundred and thirty two (432) five month-old cocoa seedlings (F3 Amazon) of average height of 46 cm (already raised in the nursery) were transplanted at the spacing of 3 x 3 m on each of the sites in Ibadan and Owena, four plants were randomly tagged for data collection. Top soil samples were collected randomly from each experimental site (Ibadan and Owena) using soil auger. The samples were bulked and air dried before being subjected to routine laboratory analysis. Particle size analysis was determined by the hydrometer method (Kettler *et al.,* 2001) and organic carbon content (OC) by the potassium dichromate oxidation method (Zhang *et al.,* 2001). Soil pH was read on pH meter (1:1 water). Organic matter was determined by the Murphy blue coloration and determined on a spectronic 20 at 882um (Murphy and Riley, 1962). Soil potassium (K), calcium (Ca) and Magnesium (Mg) were extracted with 1M NH_4OAc, PH7 and were determined with flame photometer; Mg was determined with an atomic absorption spectrophotometer. The total nitrogen (N) was determined by the Microkjedahl method (AOAC, 1990).

Two grammes (2g) each of the organic fertilizers used were also analyzed for nutrient composition. The fertilizers were applied to treatment plots one month after transplanting using ring method of fertilizer application at 5 cm away from the base of cocoa (July, 2011). Leaf samples (4th leaf) were collected from the four tagged cocoa seedlings at 12 months after transplanting; dried in an oven at 70^0 C for 72 hours (to ensure there was no N loss). The oven- dried plant materials were then milled with the aid of a Glen Creston Mill equipped with stainless steel grind chamber. The materials obtained were then analyzed for the nutrient contents according to standard procedures (IITA, 1992).

The experiments were monitored for 36 months (144 weeks after planting). At 15 months after transplanting, soil samples were collected from treatment plots and were processed and analyzed for physical properties (sand silt, clay, soil moisture content and soil bulk density), chemical properties (soil organic matter, soil pH, N, P. K, Mg, Ca, and Na) using standard procedures.

Soil samples collection and analysis

Top soil samples were collected randomly from each of the experimental sites at both locations (Ibadan and Owena) with the aid of soil auger at 30 cm depth. For the pre-cropping analysis, the samples were bulked together and mixed thoroughly, air dried at room temperature and analysed for various elements. Particle analysis was carried out using the hydrometer method as described by Bouyoucos (1951).

The pH was determined in water (1:1 soil: water ratio) using a pH meter with glass electrode as described by Jackson, (1965). Total Nitrogen was determined using Kjeldahl procedure as described by Jackson (1965). Organic carbon content was determined using the Walkey-Black method (Nelson and Sommers, 1982). Phosphorus determination was done by the Bray method as described by Bray and Kurtz, (1945).

Exchangeable K, Ca, Mg and Na were determined by extraction with ammonium acetate and the amounts of K, Ca and Na in the filtrate were determined using flame photometer with appropriate filter while Mg was determined using a perking Elmer Atomic Absorption Spectro photometer (AAS).

Statistical analysis

Analysis of variance was performed on all data to test the treatment effect on different parameters and significant means were separated using Tukey's Honest Significant Difference (HSD) ($P < 0.05$).

RESULTS AND DISCUSSION

The pre-planting soil physio-chemical properties of the organic wastes used for the experiments were presented in Tables l and 2.The results of the particle-size analysis of the soils of both Ibadan and Owena experimental sites showed that the soils were sandy loam and Alfisols (Soil Survey Staff, 1999). The silt + clay contents of the soils at Ibadan and Owena (23.98 % and 27.9 %) experiments were below the 32 % estimated to be adequate for soils considered to be ideal for tree crops production especially cocoa (Egbe *et al.*, 1989). Based on the established critical levels for soils in Southwestern Nigeria, the soils at Ibadan and Owena were acidic with pH ranging between 4.56 — 5.76 and low in organic matter (0.99 —2.51 %) compared to the reported critical levels of 3 % organic matter (Agboola and Corey, 1973). The total nitrogen of Owena soil was less than 0.15 % which is considered optimal for most crops including cocoa and the soil also had low CEC (Ogunwale *et*

Table 1: Physical and chemical characteristics of the soils of the experimental sites before planting in Ibadan and Owena experiments

Soil Properties	Ibadan Site	Owena Site
Sand (%)	76.1	72.1
Silt (%)	16.3	18.2
Clay (%)	7.6	9.7
Textural class	Sandy loam	Sandy loam
pH (1:1in H_20)	5.44	5.76
Organic carbon (g/kg)	2.20	0.57
Organic matter (%)	2.51	0.99
Nitrogen (%)	0.32	0.06
Available P (cmol/kg)	11.67	9.96
K^+ (cmol/kg)	0.28	0.22
Ca^{++} (cmol/kg)	6.60	1.00
Mg^{++} (cmol/kg)	3.40	0.40
Na^+ (cmol/kg)	2.87	0.16
Al^{+++}	1.22	2.36
H+(cmol/kg)	6.32	7.89
ECEC	14.37	4.14

al., 2002). This suggests the need to improve on the soil organic matter and hence the CEC for enhanced nutrient retention and the release of same to crops upon external fertilizer application (Agboola and Omueti, 1982). The improvement of soil organic matter (SOM) can be achieved by organic fertilizer application, either as sole or in combination with inorganic fertilizers as organo-mineral fertilizer (OMF). The application of inorganic fertilizer to a soil with low organic matter content is a waste of resources and time (Agboola and Obigbesan, 1975). Hence there is need for proper SOM management on Ibadan and Owena soils to reduce the deleterious effects on soil physical and

Table 2: Chemical composition of Goat dung, organo-mineral and organic fertilizers used in the experiment

Properties	Goat dung (GD)	Organo-mineral fertilizer (OMF)	Organic fertilizer (OF)
pH (1: 1 in water)	8.17	7.00	7.30
Organic carbon (g/kg)	2.86	0.63	3.64
Organic matter (%)	4.80	1.09	6.27
Total nitrogen (%)	1.26	0.06	2.16
Available P (cmol/kg)	113.24	138.06	7.08
K^+ (cmol/kg)	0.41	0.19	5.56
Mg^{++} (cmol/kg)	1.20	1.00	6.00
Ca^{++} cmol/kg)	2.60	2.00	13.10
Na^+ (cmol/kg)	0.38	0.18	2.30
C:N	1:4	1:1	1:6

chemical properties. Available P was also low; this level of available P is considered inadequate for cocoa (Wessel, 1971; Egbe *et al*., 1989). Also, the exchangeable potassium and calcium fell below the critical values of 0.3 and 5 cmol/kg required for cocoa. At both locations with the exception of Owena experiment, the exchangeable Mg was adequate for cocoa production. Obatolu, (1991) earlier observed the general low Mg nutrient contents of these soils. The low nutrient contents of the soils implied the need for external input of nutrients in order to meet the requirements for optimal cocoa growth. It is obvious that the soils of both Ibadan and Owena were inherently low in fertility and were therefore expected to show positive response to soil amendment. The insufficient levels of the major nutrients in the soils in both locations showed that the soils were depleted in nutrients and would not be able to meet the nutritional needs of cocoa plants unless external nutrients supply is made to support optimum growth of cocoa plants. Among the organic fertilizers applied, goat dung (GD) had the highest p1-I, though all the organic and organo-mineral fertilizers had pH above 5 (acidity levels) which indicated that they could be effective as liming materials. The organo-mineral fertilizer (OMF) had the highest available P followed by GD and organic fertilizer (OF) had highest percentage N. The results were in agreement with the works of Adejobi *et al.* (201la) who found out that GD, OMF and OF were as effective as NPK fertilizer which can be used as effective sources of plant nutrients. In particular, OF had the highest OM, K, Mg, Ca and Na concentrations relative to other organic fertilizers, this implied that OF could be a good source of these nutrients for plant growth.

Effects of fertilizer types and rates on soil moisture content measured at 15 MAT in Ibadan and Owena are presented in Table 3 .The general observation that the lowest percentage soil moisture contents were recorded for the control plots followed by NPK fertilizer plots in both Ibadan and Owena experiments could be due to low SOM contents and consequent low soil moisture retention capacity [Maurya and Lal, 1979; Ghuman and Lal, 1984 and Agbede and Kalu, 1995]. Another possible reason for high moisture status in organic fertilizer plots than NPK and control plots could be due to high SOM that enhanced soil structure and lower porosity. Low porosity is known to reduce turbulent movement of atmospheric air into the soil which enhances water evaporation (Ojeniyi and Dexter, 1984. Application of 200 kg/ha OMF gave significantly higher soil moisture content than other treatments and the control plot at Ibadan experiment. In Owena experiment, 600 kg/ha GD significantly increased soil moisture content relative to all other treatments and the control plots. Application of both GD, OMF and OF improved

Table 3: Effects of organic and inorganic fertilizer types and rates on soil moisture content 15 MAT (September) in Ibadan and Owena (2011 experiments)

Treatments (kg)	Soil moisture content (%) Ibadan Soil	Owena Soil
Goat dung 600	48.85b	59.70a
400	50.08b	42.21b
200	48.97b	43.50b
	26.54d	20.98d
Control		
OMF 600	41.89bc	44.64b
400	47.25b	43.33b
200	56.75a	41.22b
	26.54d	20.54d
Control		
OF 600	49.37b	41.00b
400	50.24b	45.45b
200	46.70b	43.43b
Control	26.54d	21.67d
NPK 600	34.28c	33.82c
400	37.93c	31.63c
200	37.12c	33.48c
Control	25.43d	20.57d

Treatment means within each column followed by the same letters are not significantly different from each other using Tukey's HSD at 5% level

soil physical properties; soil structure, porosity and soil water infiltration and retention (Akanni *et al.,* 2011 and Makinde *et al.,* 2011).

Bulk density of the soil as affected by fertilizer types and rates in both Ibadan and Owena experiments is presented in Table 4. The organic fertilizer types and rates applied significantly reduced (P<O.05) the soil bulk density relative to levels of NPK 15:15:15 applied and the control for both Ibadan and Owena. OMF applied at 600 kg/ha and 200 kg/ha gave the lowest soil bulk density, 600 kg/ha OF reduced soil bulk density relative to other treatments in Owena experiment. This shows that application of OF, OMF and GD obliterated effect of high bulk density, it could also be attributable to increased soil OM, Ca and other macro and micro- nutrients following manure application. Both organic colloid and Ca are cementing and stabilizing agents in soil aggregation (Ojeniyi *et al.,* 2012). Improved aggregation leads to reduction in bulk density and increased in water infiltration and retention.

Soil chemical compositions of cocoa seedlings as affected by organic and inorganic fertilizer types and rates at 15 MAT in Ibadan and Owena experiments are presented in tables 5 and 6. At both locations, soil pH at 15 MAT increased across the fertilizer treatments above the initial value 11 — 27 % and 6 — 18 % in Ibadan and Owena respectively. The higher soil pH in soil treated with 600 kg/ha OF and 200 kg/ha OF in Ibadan and Owena compared with NPK and control was as a result of build-up of SOM which released basic cations into the soil system from the break- down of soil organic materials (Helling *et al.,* 1964). Application of 600 kg/ha OF produced build up of SOM in Ibadan while 200 kg/ha OMF resulted in higher SOM in Owena soil than NPK and the control. This is expected because of the high organic carbon contents of the organic materials used for soil amendments

Table 4: Effects of organic and inorganic fertilizer types and rates on soil bulk density (g/cm-3) 15 MAT in Ibadan and Owena (2011 experiments)

Treatments (kg)		Soil bulk density (g/cm-3) Ibadan Soil	Owena Soil
Goat dung	600	0.35c	0.31b
	400	0.34c	0.27b
	200	0.36c	0.29b
Control		0.94a	0.83a
OMF	600	0.29c	0.33b
	400	0.31c	0.30b
	200	0.45b	0.29b
Control		0.95a	0.81a
OF	600	0.38c	0.27b
	400	0.36c	0.35b
	200	0.32c	0.32b
Control		0.92a	0.81a
NPK	600	0.89a	0.60a
	400	0.85a	0.77a
	200	0.81a	0.72a
Control		0.94a	0.82a

Treatment means within each column followed by the same letters are not significantly different from each other using Tukey's HSD at 5% level

Table 5: Soil chemical properties of cacao seedlings as affected by organic and inorganic fertilizer types and rates at 15 MAT in Ibadan (2011experiment)

Treatments (kg)		Soil pH	OC (g/kg)	OM (%)	N (g/kg)	P mg/kg	K	Mg	Ca	Na
							(cmol/kg)			
GD	600	6.75e	5.87c	1.49j	1.08g	13.14h	0.23ef	2.11c	5.31c	0.10a
	400	6.72e	5.63c	2.82c	1.15c	10.46i	0.22ef	1.18h	4.02g	0.19a
	200	7.07c	5.33g	2.26f	1.12de	21.25g	0.23ef	2.31b	6.00c	0.48a
	Control	5.66j	2.86l	1.50j	0.07h	8.43l	0.13f	1.89e	2.08l	0.44a
OMF	600	6.08i	5.59d	2.74d	1.15c	33.43c	0.28cd	1.31g	13.00a	0.14a
	400	6.32h	5.76b	3.06b	1.15c	7.61k	0.23ef	1.41f	3.50h	0.44a
	200	6.94d	5.29h	2.22f	1.10ef	9.11j	0.19f	1.21h	2.71i	0.09a
	Control	5.64j	2.84l	1.49j	0.08h	7.12l	0.12f	1.91e	2.07l	0.49a
OF	600	7.43a	6.94a	3.14a	1.17a	24.25e	0.36b	2.03d	5.44d	0.12a
	400	6.93d	5.48f	2.55e	1.14cd	21.31g	0.42a	1.91e	4.21f	0.11a
	200	6.62f	5.14j	1.96h	1.12de	24.65d	0.22ef	1.00j	2.63ij	0.16a
	Control	5.54j	2.67l	1.50j	0.07h	7.30l	0.12f	1.89l	2.04l	0.46a
NPK	600	5.89j	4.06k	1.81i	1.11gf	62.14b	0.26de	1.07i	2.57j	0.12a
	400	5.94j	4.21i	2.08g	1.01ef	116.12a	0.32c	1.00j	2.43k	0.11a
	200	5.60j	4.81e	3.13a	0.10ef	23.23f	0.24de	3.00a	6.50b	0.14a
	Control	5.65j	2.85l	1.49j	0.06h	7.32l	0.13f	1.91e	2.05l	0.47a

Treatment means within each column followed by the same letters are not significantly different from each other using Tukey's HSD at 5% level

(Allison, 1973; Ogunlade, 2008). However, there was increase in total N values across the fertilizer treatments compared to the initial total N value of 0.32 % at Ibadan; the same trend went for Owena experiment. Soil N at both locations appeared to be sufficient to meet the N requirement of cocoa seedlings. The fertilizer types and rates also resulted in higher soil available P at both locations than the control with the exception of OF applied at 600, 400 and 200 kg/ha in Owena. The control treatment led to decrease in available P values at both locations. It indicated high P released from the organic and inorganic materials as the soil available P was higher than the pre-planting (initial) value after uptake by the cocoa seedlings for fifteen months on the field. Application of OF at 400 kg/ha and 200 kg/ha significantly enhanced the soil K in both Ibadan and Owena respectively compared with the control. The soil Mg and Ca in all the fertilizer types and rates were reduced when compared to the initial soil values at the end of fifteen months with the exception of 600 kg/ha OMF in Ibadan which increased soil Ca above the initial soil value. There were therefore, increases in soil Mg and Ca at Owena when compared to the initial soil value at 15 MAT. There were reductions in Mg and Ca despite application of fertilizers in Ibadan experiment; Wilson and Lal, (1983) made similar observations when cynodon and various other organic materials were incorporated in to the soil. The higher soil Ca and Mg in NPK treated soil compared with the control implied that NPK must have enhanced the release of Mg and Ca from the soil mineral contents by creating favourable condition for it. There was no significant difference among soil Na when fertilizer type rates and the control in Ibadan experiment. However, OF applied at 200 kg/ha enhanced soil Na higher than other treatments and control at fifteen MAT in Owena experiment. Similarly, Wilson and Lal, (1983), reported release of K, Ca and Mg among other elements when cynodon and various other organic materials were used to ameliorate the soil in Ibadan. However, the soil Na decreased considerably at both locations across the different fertilizer treatments at the end of 15 MAT of cocoa

Table 6: Soil chemical composition of cacao seedlings as affected by organic and inorganic fertilizer types and rates 15 MAT Owena experiment

treatment (kg)		Soil pH	OC (g/kg)	OM (%)	N g/kg	P mg/kg	K	Mg	Ca	Na
							(cmol/kg)			
GD	600	6.28ab	1.17h	2.00g	0.10h	15.29g	0.28b	1.00b	2.08i	0.11b
	400	6.28ab	1.04j	1.85h	0.10h	16.69f	0.26b	0.90b	2.00j	0.13b
	200	6.84ab	1.06j	1.85h	0.11h	14.77h	0.22b	1.20b	3.08d	0.23b
	Control	5.10bc	1.43h	1.40i	0.01i	13.30h	0.13c	0.40c	2.00j	0.10b
OMF	600	6.75ab	1.48g	2.55f	0.14g	19.38d	0.18b	1.00b	2.50f	0.10b
	400	6.94ab	1.55f	2.67e	0.14g	19.12e	0.26b	1.53ab	3.55c	0.16b
	200	6.62ab	2.77a	4.72a	0.51a	19.43d	0.27b	1.21b	4.04b	0.13b
	Control	5.12bc	1.45h	1.40i	0.01i	13.30h	0.13c	0.38c	2.00j	0.10b
OF	600	6.82ab	2.72b	4.68a	0.34d	5.90k	0.14b	2.01ab	4.52a	0.09b
	400	6.10ab	1.81e	3.10d	0.16f	7.92j	0.24b	3.07a	2.00j	0.10b
	200	7.00a	0.94k	1.60i	0.08i	8.78i	0.81a	1.20b	2.20h	0.77a
	Control	5.12bc	1.45h	1.45i	0.01i	13.35h	0.12c	0.38c	2.00j	0.10b
NPK	600	5.87bc	1.94d	3.34c	0.21e	42.78c	0.20b	1.04b	2.10i	0.17b
	400	5.28bc	2.36c	4.10b	0.37c	73.18a	0.18b	1.26b	2.81e	0.11b
	200	5.18bc	2.70b	4.70a	0.41b	56.06b	0.16b	1.07b	2.31g	0.13b
	Control	5.10bc	1.44h	1.40i	0.01i	13.37h	0.12c	0.39c	2.00j	0.10b

Treatment means within each column followed by the same letters are not significantly different from each other using Turkey's HSD at 5% level

seedlings. The decrease might not be unconnected with plant uptake and leaching: - losses from crop root zone.

Nutrient contents of cocoa leaves seedlings at Ibadan and Owena experiments 15 MAT are presented in tables 7 and 8. The enhanced N contents of cocoa leaves at 15 MAT in Ibadan with the application of 400 kg/ha GD and at Owena with application of 400 kg/ha OF could be due to the high N content of OF and GD presumably from protein content of roughage fed to goat (Agboola *et al.*, 1981). The differences in N values arising from the different treatments suggested that differences should occur in the quantity of the materials to be applied to cocoa in order to supply equal amount of N. The available P content of cocoa leaves at Ibadan at the end of fifteen months after transplanting was enhanced by 600 kg/ha OF relative to the control. While 600 kg/ha OMF had higher available P than other treatments and the control in Owena. The higher leaf K content recorded when OMF was applied at 200 kg/ha than NPK fertilizer rates and control plots in both Ibadan and Owena was due to its higher nutrient contents (NPK) which encouraged vegetative growth. Nitrogen is known to be responsible for plant growth and protein synthesis (Ojeniyi and Adejobi, 2002) while P and K are essential for promotion of meristematic tissue and carbohydrate formation (Moyin-Jesu, 2012). The Mg contents of cocoa leaves under the control treatments at Ibadan were significantly higher than NPK fertilizer treatments. The higher Mg contents for the control plots indicated that for a longer time, the cocoa plants would not show leaf Mg deficiency as a result of short supply from the leaf. This observation was also supported by the findings of Folorunso *et al.* (1995), who reported that high soil K resulted in nutrient imbalance with Ca and Mg thereby affecting their availability to maize crop. The cocoa highest leaf Ca contents were also obtained under 600 kg/ha GD and 600 kg/ha OF at Ibadan and 600 kg/ha OF in Owena

Table 7: Leaf chemical composition of cacao seedlings as affected by organic and inorganic fertilizer types and rates 15 MAT in Ibadan (2011experiment)

Treatments (kg)		N g/kg	P mg/kg	K	Mg (cmol/kg)	Ca	Na
GD	600	2.80bc	30.14c	5.99d	5.74b	16.59a	2.21g
	400	2.93a	31.69b	6.81b	4.95d	10.12f	2.32g
	200	2.47e	25.83f	6.64cd	6.31a	15.24b	4.43b
	Control	2.57d	20.45h	3.71g	4.41e	12.68e	1.89h
OMF	600	1.97f	19.66i	5.11f	4.27ef	12.77e	2.72e
	400	2.79bc	22.56g	6.47c	4.85d	14.29c	4.70a
	200	2.40g	25.92f	5.17f	5.24c	13.28d	2.81de
	Control	2.60d	20.42h	3.67g	4.42e	12.65e	1.85h
OF	600	2.92a	32.96a	5.33ef	5.74b	16.32a	2.61ef
	400	2.81b	30.74c	7.55a	2.93h	9.77g	2.41gf
	200	2.55de	27.15e	5.41e	6.22a	15.26b	3.15c
	Control	2.45d	20.21h	3.72g	4.39e	12.21e	1.67h
NPK	600	2.53de	22.36g	5.44e	3.16g	8.34h	3.02c
	400	2.52de	28.26d	6.07d	4.24f	13.24d	2.73e
	200	2.73c	28.73d	5.24ef	2.81h	6.96i	3.04c
	Control	2.59d	20.48h	3.70g	4.41e	12.67e	1.87h

Treatment means within each column followed by the same letters are not significantly different from each other using Tukey's HSD at 5% level

while 400 kg/ha OMF significantly enhanced Na contents of cocoa leaves higher than other fertilizers and control treatments at Ibadan. But 600 kg/ha GD gave the highest Na contents than the control plot in Owena.

In general, the residual effects of fertilizer treatments on cocoa leaf nutrients show that the organic manures promoted leaf nutrient contents than the organo-minerals (OMF), while the organo-minerals were better than NPK. The enhancement of leaf nutrient contents by organic manures compared to OMF and NPK suggested more frequent application is needed in the use of OMF than the organic manures and much more frequency for NPK than OMF. However, this practice has cost implication. The extra cost would stem from costing procurement and labour for fertilizer application at every application time. Therefore, any fertilizer type that would reduce frequency of application, with optimal manurial effects on cocoa growth and on soil physical and chemical properties would be ideal for sustainable management of soil for cocoa production.

CONCLUSION

Soil is the main source of nutrient supply to cocoa trees like any other crop; therefore, the use of fertilizer to address soil fertility problem in cocoa production can not be over emphasised. This research work explored the effects of Goat Dung (GD), Sunshine Organic and Organo-Mineral Fertilizers (OF and OMF) and NPK 15:15:15 on soil properties and nutrient uptake of cocoa in 2011 at Ibadan and Owena in Nigeria. The soils of the experimental sites were acidic, low in organic matter and total N. The available P was less than the critical level (10 cmollkg) at both Owena and Ibadan. The silt ± clay contents of both sites were below the 32 % estimated to be adequate for soil considered ideal for tree crop production, especially cocoa. The insufficient levels of the major nutrients in the soil in both locations showed that the

Table 8: Leaf chemical composition of cacao seedlings as affected by organic and inorganic fertilizer types and rates at 15 MAT in Owena (2011 experiment)

Treatments (kg)		N g/kg	P mg/kg	K	Mg (cmol/kg)	Ca	Na
GD	600	2.22e	23.14e	5.22g	3.26g	6.92i	2.07a
	400	2.77b	25.78c	5.66de	4.83bc	10.23d	1.51de
	200	2.37d	24.70	5.40gf	5.06ab	12.07b	1.71cd
	Control	2.52c	18.60g	6.04ab	3.34fg	7.76g	1.72abcd
OMF	600	2.29ed	29.84a	5.85bcd	2.33i	5.07k	1.87abc
	400	2.81b	27.60b	3.44i	3.49gf	9.22e	1.81abcd
	200	2.47c	28.18b	6.12a	4.04d	7.74 g	1.24e
	Control	2.42c	18.21g	5.99ab	3.36g	7.54g	1.56abcd
OF	600	2.47c	27.82b	5.71dce	5.18a	14.22a	1.91abc
	400	2.96a	27.88b	5.60ef	3.85ed	8.49f	2.04ab
	200	2.31d	29.53a	5.41gf	4.54c	12.82c	1.68cd
	Control	2.49c	17.89g	5.99ab	3.36.fg	7.34g	1.71abcd
NPK	600	2.37d	29.30a	5.91abc	4.91ab	10.07d	1.50de
	400	2.81b	21.48f	4.93h	2.81h	6.21j	1.90abc
	200	2.92a	26.55c	5.55ef	3.61ef	6.21j	2.07a
	Control	2.52c	18.61g	6.07ab	3.37fg	7.76g	1.73abcd

Treatment means within each column followed by the same letters are not significantly different from each other using Tukey's HSD at 5% level

soils were depleted of nutrients and would not be able to meet the nutritional needs of cocoa unless externally supplied for optimum growth of cocoa plants. Goat dung (GD), Organo-mineral fertilizer (OMF) and Organic fertilizer (OF) increased soil pH above 5 (acidity level). This indicated that these materials are effective as liming materials in addition to their contents of essential nutrients needed for cocoa growth.

Application of 200 and 400 kg/ha OMF, and 600 and 400 kg/ha GD significantly increased soil moisture relative to other treatments and the control at Ibadan and Owena. The lowest percentage soil moisture was recorded for the control plots, followed by NPK fertilizer, in both locations. In Ibadan, 600, 400, 200 kg/ha OMF and 600 kg/ha OF gave the lowest soil bulk density but the highest bulk density was recorded for the control followed by 600 kg/ha NPK. There were no significant differences (P=0.05) in soil bulk densities among rates of organic fertilizers applied at Owena . At the locations, soil pH, organic matter, N, P, K, at 15 MAT increased across the fertilizer treatments above the initial values by 11 — 27 % and 6 — 18 % respectively. There were reductions in Mg and Ca despite application of fertilizers in Ibadan.

Application of 400 kg/ha GD and 600 kg/ha OF enhanced N contents of cocoa leaves in Ibadan. The trend was similar at Owena where cocoa seedlings under the application of 400 kg/ha OF had the highest N content. This implied that OF and GD released nitrogen for cocoa seedlings growth. The available P content of cocoa leaves was enhanced by 600 kg/ha OF relative to the control in Ibadan. 600 kg/ha OMF had higher available P than other treatments and the control in Owena. 600 kg/ha GD significantly increased the soil available P values compared with other fertilizer treatments and the control at both Ibadan and Owena experiments. Higher leaf content of K was recorded for 200 kg/ha OMF than NPK fertilizer rates and control in both Ibadan and Owena experiments.

In general, the effects of fertilizer treatments showed that the organic manures promoted leaf nutrient contents than the organo-minerals (OMF), while the organo-minerals were better than NPK. These results have clearly shown that organic fertilizers (GD, OF and OMF) supplied cocoa nutrients and stabilize soil physical conditions.

REFERENCES

Adejobi, K. B., Famaye, A.O., Adeniyi, D.O., Akanbi, O. S. O. and Orisajo, S.B. (201la). Comparative effect of organo-mineral fertilizer and cocoa pod husk ash on the soil, leaf chemical composition and growth performance of cocoa (*Theobroma cacao L.*) in South western Nigeria. *Obeche Journal 29 (1): 212-217.*

Adejobi, K. B., Famaye, A.O,, Oloyede, A.A., Oyedokun, A.V., Adeniyi, D.O. and Adeosun, S.A. (2011b). Effects of organo-mineral fertilizer and cocoa pod husk ash on the soil, leaf chemical composition and growth performance of coffee in Nigeria. *Nigerian Journal of Soil Science.* Vol. 21(2) 45-5lpp.

Adejobi, K. B., Famaye, A. 0., Adeniyi, D. 0., Orisajo, S. B. and Adeyemi, E. A. (2011c). Effect of cocoa pod husk ash and goat dung on nutrient content and growth performance of cashew (*Anacardium occidentale* L.). *Advances in Environmental Biology.* 5(7); 1536 — 1542.

Adejobi, K. B., Adeniyi, D. 0., Famaye, A. 0., Adenuga, 0. 0., Ayegboyin, K. 0. (2011d). Evaluation of the effectiveness of goat dung manure and kola pod husk ash on nutrient composition and growth performance of coffee (*Coffea arabica*) in Nigeria. *Journal of Applied Biosciences* 44:2987-2993.

Agbede, 0.0. and B. A. Kalu (1995). Constraints of small-scale farmers in increasing crop yields farm size and fertilizer supply. *Nigerian Journal Soil Science.* Vol.11:139-152.

Agboola, A.A. and J.A.I. Omueti (1982). Soil fertility problems and its management in tropical Africa. In: *International Conference on land clearing and development Proceedings.* Vol. 2: IITA, Ibadan, Nigeria.

Agboola, A.A. and R.B. Corey (1973). The relationship between soil pH, organic matter, available P, exchangeable K, Calcium, Magnesium and nine elements in the maize tissues. *Soil Science.* 115: 367-375.

Agboola, A.A. and G.O. Obigbesan (1975). Interrelations between organic and mineral fertilizer in tropical rainforest of Western Nigeria. In: *Organic materials as fertilizers*. FAO, Rome.

Agboola, A.A., Omueti, J.A.I. and Titiloye, 0. (1981). Chemical composition of industrial and agricultural waste products contaminating water resources. *Proceedings of 2 National Conference on Water Polution*, P 198-210. Fixation and organic matter in the tropic. IL mt. soil cong Symposium: 198 - 202.

Akanni, D. I., S.O. Ojeniyi and M. A. Awodun (2011). Soil properties growth yield and nutrient content of maize, pepper and amaranthus as influenced by organic and organomineral fertilizer. *Journal of Agricuirural Technology* Al, 1074-1 078 (USA).

Allison, F. E. (1973). Soil organic matter and its role in crop production. Elsvier Scientific Publ. co., Amsterdam, *The Netherlands.* Pp. 247-251.

Ayanlaja, S. A. (2002). Soil nutrient management research in the humid forest zone of Nigeria for Cocoa production between 1940 and 2000; missing gaps. 17th WCSS. *Thailand Symposium* No 16, paper No 1503.

A.O.A.C.(1990). *Official Methods of Analysis* 12th ed. Association of Official Analytical Chemistry, Washington, D.C. USA.

Bouyoucous, G. J. (1951). Hydrometer methods improved for making particle size analysis of Soils. *Agronomy Journal* 54:465.

Bray, R. H. and Kurtz, L.T. (1945). Determination of total, organic and available form of Phosphorus in soils, *Soil Science*. 59:45-59.

CRIN Annual Reports (2005). *Annual Reports of the Cocoa Research Institute of Nigeria,* Pp 28-35.

Daramola, A,G. (2004). Competitiveness of Nigeria Agriculture in a Global Economy and Dividends of Democracy. *Inaugural Lectures series* 36, FUTA, 2nd March 2004. 34p.

Egbe, N. E., Ayodele, E. A. and Obatolu, C.R. (1989). Soil and Nutrition of cocoa, Coffee, Kola, Cashew and Tea. In: *Progress in tree crop research in Nigeria*. 2edl Ed. CRIN, Ibadan. pp 27-38.

FAOSTAT (2014). Food and Agricultural Organization World Food Balance Sheet. *www.faostat.fao.org.*

Folorunso, O. O., A. A. Agboola and G.O. Adeoye (1995). Use of Fractional Recovery (FR) to calculate the K needs of maize (*Zea mays*). *Journal of Technological Education* 2 (1):65-75

Ghurnan, B.S. and Lal, R. (1984). Water percolation in a tropical alfisol under conventional ploughing and no-till systems of management. *Soil and Tillage Research* 4, 263-276.

Helling, C.S, Chesters, O. and Corey, H.B. (1964). Contributions of organic matter and clay to soil cation exchange capacity as affected by pH of the saturating solution. *Soil Science Society of America Proceedings* 28:517-520.

IFDC (2008/2009). International Fertilizer Development Centre, *Annual Reports* 2008/2009. *ifdccommunications@ifdc.org*

IITA (1992). I*nternational Institute of Tropical Agriculture Annual Report for 1992.* Ibadan, Nigeria.

Jakson, M. L. (1965). American Society Agronomy Monograph No.9. *Methods of Soil Analysis*.45pp.

Kettler, T.A. Doran, J.W. and Gilbert, T.L (2001). Simplified method for soil particle-size determination to accompany soil-quality. USDA Agricultral Research Service. Lincoln. Nebraka Pp 849-852.

Makinde, E. A., L.S. Ayeni and S.O. Ojeniyi (2011). Effects of Organic, Organomineral and NPK fertilizers treatment on the nutrient uptake of *Amaranthus cruentus* on two soil types in Lagos Nigeria. *Journal of Central European Agriculture* 12 (1), 114-123.

Maurya, P.R. and Lal, R.(1979). Effect of bulk density and soil moisture on radicle elongation of some tropical crops. In: R. Lal and Greenland (editors) *Soil Physical Properties and Crop Production in the Tropics*, Wiley, New York NY Pp339-347.

Moyin-Jesu, I. E. (2012). Simple and Blended Organic Fertilizers Improve Fertility of Degraded Nursery Soils for Production of Kolanut (*Cola acuminata*) seedlings in Nigeria. *Soil Fertility Improvement and Integrated Nutrient Management — A Global Perspective.* ISBN 978-307-945-5. Publisher In Tech. Pp293-306.

Murphy, J. and Riley, J.P. (1962). A modified single solution method for the determination of phosphate in water. *Analytical Chemisry Acta*

9: 69-82.

Nelson, D.W. and Sommers, L.E. (1982). Organic carbon and soil extracts. In: *Methods of Soil Analysis. Part 2- Chemical and Microbiological Properties.* Agronomy Monograph No. 9 (2ed Edition). American Society of Agronomy, Soil Science Society of America, Madison, WI, USA. Pp 539-579.

Obatolu, C.R. (1991). Growth and Nutrient uptake of coffee (*Coffea* spp) Seedlings grown on different organic materials, *Ph.D Thesis*, University of Ibadan. 276.pp.

Ogunlade, M.O. (2008). Seedling establishment under old cocoa plantation using neem fortified cocoa pod husk fertilizer at Ibadan and Owena, western Nigeria. *Ph.D.Thesis,* Agronomy Department, University of Ibadan, Ibadan l32pp

Ogunlade, M.O. and Iloyanomon, C.I. (2009). Leaf litter fall and soil nutrient status under cocoa plantation of different ages in Ibadan, Nigeria. *Nigerian Journal of Soil Science* 19(1):25-28.

Ogunwale, J.A., Olaniyan, J.O. and Aduloju, M.O. (2002). Morphological, Physico-chemical and Clay mineralogical properties of soils overlaying basement complex rocks in Ilorin East, Nigeria. *Moor Journal of Agricultural Research*. Vol. 3(2): 147-154.

Ojeniyi, S.O. and Dexter, A.R. (1984). Effect of Soil Structure on Soil Water Status. *Soil and Tillage Research* 4,371-379.

Ojeniyi, S. 0. and K. B. Adejobi (2002). Effect of Ash and Goat Dung Manure on Leaf Nutrient Composition, Growth and Yield of Amaranthus. *Niger Agric. J* 33:46-57.

Ojeniyi, S.O., Awonlenhen, B. E. and Adejoro, S. A. (2010). Soil Plant Nutrients and Maize Performance as influenced by Oil-palm Bunch Ash plus NPK Fertilizer: *Journal of American Science* 6 (12) pp. 456 — 460

Ojeniyi, S.0., S. A. Odedina and T.M. Agbede. (2012). Soil productivity improving attributes of Mexican Sunflower (*Tithonia diversifolia*) and siam weed (*Chromolaena odorata*). *Emirate Journal of Food and Agriculture* 24 (3), 243-24 7,

Soil Survey Staff (1999). *Soil Taxonomy. A basic system for soil classification for making and interpreting soil surveys.* USDA. Hand book, No. 436, Washington D.C.

Wessel, M. (1971). Soil aspects of cocoa rehabilitation in Nigeria. *Proceedings of 3rd International Cocoa Research Conference*, Accra, Ghana. 1969:81-5.

Wilson, G.P. and R. Lal (1983). New Concepts for Post clearing land management in Tropics. Lecture presented at the soil management in the humic tropics training course at IITA. 30th May—June 17th 1983. 23pp.

Zhang, M.H., Cederwall, R.T., Yio, J.J., Xie, S.C. and Lin, J. L. (2001). Objective Analysis of ARM. lOP Data; Method and Sensitivity. Lawrence Livermore National Laboratory, Liver more California. Pp 295-311.