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Fertilizer, lime and manure amendments for ultisols formed on coastal plain sands of southern Nigeria

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Abstract: The highly weathered and leached soils formed on Coastal Plain Sands under excessive rainfall regime in southern Nigeria are Ultisols. The appropriate management practices with which to obtain high crop yields in these soils, characterized by high acidity, nutrient deficiencies and imbalances, should be developed. Surface layer (0-15 cm) samples of soils with extreme acidity (pH 4.0-4.6) formed on Coastal Plain Sands were collected from four locations in southern Nigeria and grown to maize (SUWAN 1-SR-Y) in pots for two cycles of six weeks each to measure the direct and residual effects of applied fertilizer (90 kg N+ 36 kg P+ 60 kg K.ha^{-1}), 2.5 MT.ha^{-1} lime, 10 MT.ha^{-1} farm yard manure (FYM) compared to a control. The direct effect of FYM produced the highest dry matter yield while fertilizer and lime did not differ significantly from the control. The residual effects were significant in dry matter yield for FYM in all the soils and for lime in three soils. Lime and FYM increased soil pH and exchangeable bases, reduced iron, manganese and aluminium; fertilizer and FYM raised available P while only FYM increased soil organic matter contents. Application of lime, fertilizer and FYM in all possible combinations compared to the control in one soil showed that FYM + Fertilizer gave the highest maize dry matter yield, improved soil characteristics and would be the recommended nutrient management practice for these acid soils.

Keywords: Ultisols, Acidity, Dry Matter, Nutrient Uptake, Residual Effects

1. Introduction

One of the remaining frontiers whose contribution can be substantial for global food security is the vast humid tropical region whose soils have potentials that can be exploited for arable crop production (Sanchez and Buol, 1975; Ofori *et al.*, 1986; Buol *et al.*, 2011). Unfortunately, most of the soils are acidic, low-base status Oxisols and Ultisols characterized by poor crop growth and yields. This is because high soil-solution hydrogen ion (H^+) concentration affects the availability and uptake of several metallic ions, causes the deficiencies of calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P) and molybdenum (Mo) and presence of aluminium (Al), iron (Fe) and manganese (Mn) at high to (Fageria and Baligar, 2008). Besides, clay, Al and Fe ions and oxides convert native and applied P to insoluble forms through fixation processes (Brady and Weil, 2002). Ultisols are extensive in Nigeria, being located mainly in the south where the Coastal Plain Sands parent materials and excessive rainfall regime produce highly weathered and leached soils with low organic matter and cation exchange capacity as a reflection of the kaolinitic and Fe, Al-oxide (low activity clay) mineralogy (Juo and Wilding, 1996). The major challenge is to overcome acid soil infertility, indicated by low nutrient status (deficiencies) and nutrient imbalances, through the development of realistic management systems the farmers would adopt to obtain reasonable and sustained high crop yields.

Lime application has been recognized and used as the main practice for ameliorating strong acidity which curtails the availability of nutrients required at high amounts in soils for maximum yields (Fageria and Baligar, 2008). Liming based on the quantity needed to neutralize exchangeable Al which is the principal factor responsible for poor crop growth in acid soils, and also supply Ca and Mg (Haynes and Naidu, 1998) was beneficial to yield in soils with pH <5.5 but not in moderately acid soils or when liming targeted pH= 7.0 or more (Sumner and Yamada, 2002). Also, lime efficiency decreases at high rates and over-liming has detrimental effects on the availability of micronutrients, especially zinc (Zn) and copper (Martini and Mutters, 1989).

Fertilizer use is promoted as a vital component of the improved technology that farmers must adopt to attain high yields in crops. Unfortunately, the humid areas where acid soils are common features have a poor fertilizer use history in relation to the dominant multi-storey tree crop agroforestry systems that rely on somewhat closed nutrient cycles to maintain soil productivity (Agboola, 2002). Fertilizers have become scarce and expensive in Nigeria as a result of economic structural adjustment policies adopted by government that necessitated subsidy reduction/withdrawal which substantially reduced fertilizer use (Banful *et al.*, 2010; Liverpool-Tasie *et al.*, 2010) and the resultant low total nutrient content is inadequate for open arable crop production systems. Besides, declining yields have often been observed where fertilizer was used alone while continuous application at high rates increased soil acidification (Juo *et al.*, 1996) as one of the general effects on environmental degradation.

Manure application increases crop growth and yields in acid soils (Bouwer and Powel, 1995) because of added nutrients and the ability to neutralize acidity that may arise from fertilizer use through the suppression of Al solubility. Organic manure added to the soil over one season changed pH from acidic to near neutral after 90 days (Evelyn *et al.*, 2004). Hargrove and Thomas (1981) had observed that the benefit of increased P availability was because the metabolic products of microbial decomposition of the manure form stable complexes with Al, Fe and Mn which are responsible for P sorption or fixation through anion exchange. The phenolic and alcoholic functional groups of the organic acids (humates and fulvates) form complexes with these metal ions or compete with P on the exchange sites (Haynes and Mokolobate, 2001; Yang *et al.*, 2013). Annual application of 5-10 metric tonnes (MT).hectare (ha^{-1}) improved soil physical properties, increased organic matter level and sustained yields in permanently cultivated sub-humid Alfisols (Mokwunye, 1980) but larger rates would probably be needed in the humid tropics with predominant Ultisols. The larger rates are compatible with applications at longer intervals which are more effective than treating soils frequently with small amounts (Müller-Sämann and Kotschi, 1994).

The potentials of these management options for ameliorating acid soil conditions to enhance the productivity of some arable crops in Nigeria have been indicated since the 1970s. Maize, seed cotton, and sorghum yields increased with organic matter application but liming only changed the soil pH and level of exchangeable Al (Heathcote, 1970). Maize growth and yield increased through liming only when nitrogen (N), P, K, Mg, sulphur and organic manure were also applied (Fore and Okigbo, 1973). The implication is that balanced nutrition through the application of lime, manure and fertilizer, to provide the nutrients whose optimum levels are needed to obtain high crop yield and responses to fertilizers in acid soils, should be considered in the development of appropriate management packages. The objective of this study is to evaluate the potentials of fertilizer, lime and manure as components of the management recommendations to be adopted for increased performance of maize in Ultisols represented by four surface soil samples taken from farmers' plots in Edo and Delta States of Nigeria.

2. Materials and Methods

The study was carried out between March and June 2011. Surface (0-15 cm) samples of soils were taken from four locations in Southern Nigeria- Oko and Ugbogiobo in Edo State; Agbarho and Effurum in Delta State- representing the upland and lowland areas of soils developed on unconsolidated sands and sandstones (Coastal Plain Sands) grouped as reddish brown soils of the Benin fasc and yellow to yellowish brown soils of Calabar fasc, respectively (Vine, 1970). The soils at Ugbogiobo and Oko were classified as Oxic Kandiudult and Arenic Kandiudult while at Oleh and Agbarho the soils belonged to Aquic Kandiudult (Ojanuga et al., 1981; FDALR, 1990).

There were two experiments involving 3 kg of air-dried and sieved (<2 mm) soil samples weighed into 5 litre plastic pots. The first experiment was an evaluation of the effects of fertilizer, lime, manure and a control on the four soils in three replicates and arranged in a split-plot design with the soils as main plots and the amendments as subplots. The amendments were 2.5 metric tonnes (MT).hectare (ha^{-1}) of lime (as 100 mesh quicklime, CaO), fertilizer (90 kg N, 30 kg P and 60 kg $K.ha^{-1}$ supplied as urea, single superphosphate and muriate of potash, respectively) and 10 $MT.ha^{-1}$ sawdust/cow dung compost (manure- 3.32% N, 0.58% P, 1.24% K, 0.94% Ca and 0.39% Mg). These amendments were thoroughly mixed with the soils and the mixture was watered and kept moist for seven days. Maize (SUWAN 1-SR-Y variety) seeds were sown and the seedlings thinned to $two.pot^{-1}$ after emergence. The plants were watered daily and grown for 42 days after which the top-growth was harvested from the soil surface, oven-dried at 60°C for 48 hours and weighed. The soils were allowed to air-dry for about two weeks, sampled and cropped to maize for another cycle of 42 days, to evaluate the residual effects of the amendments.

The second experiment was a randomized complete block design of the following treatments: control, fertilizer (90 kg N, 30 kg P and 60 kg $K.ha^{-1}$), 10 $MT.ha^{-1}$ manure, 2.5 $MT.ha^{-1}$ lime, manure + fertilizer, manure + lime, lime + fertilizer, lime + fertilizer + manure applied to the soil from Oko in three replicates. Two seedlings of maize were grown in each pot for 42 days and the top-growth was harvested, oven-dried and weighed.

The soil samples were analyzed for selected physical and chemical properties using the laboratory procedures described in IITA (1979): particle size distribution (Bouyoucos' hydrometer method); pH in 1: 2 (w/v) soil-water suspension and measured by pH meter; organic carbon (Walkley-Black wet dichromate oxidation method); total N (macro-Kjeldahl digestion and titration); available P (Bray's P-1 extraction and molybdenum blue method and colour intensity read on a spectrophotometer); exchangeable cations (extraction with neutral 1N ammonium acetate, determination of Na, K and Ca with flame photometer and Mg with atomic absorption spectrophotometer); and exchangeable acidity (1N KCl extraction and titration with NaOH). The sum of total exchangeable bases and exchangeable acidity were used to calculate the effective CEC and base saturation. Available Mn and Fe were extracted with 0.1NHCl and determined with atomic absorption spectrophotometer. The soil samples taken after the first and second cropping were analyzed for pH, organic carbon, exchangeable cations and available P, Mn and Fe.

Dried plant samples were ground in a Wiley mill and digested in a mixture of concentrated nitric, perchloric and sulphuric acids (25-5-5 v/v). Total Ca, Mg, Mn and Fe in the digests were determined with atomic absorption spectrophotometer while total P was determined by the vanado-molybdate yellow method.

Data of maize top-growth dry matter yield from the direct and residual effects of the amendments were subjected to analysis of variance (ANOVA) and treatment means separated using the least significant difference (LSD) (P= 0.05) as described in Steel *et al*. (1997). Changes in soil chemical properties after adding amendments and each cropping were determined by subtraction relative to the initial values.

3. Results

Table 1. *Physiographic features of the locations where soil samples were collected*

	Oleh	Agbarho	Oko	Ugbogiobo
Location	5°25'N, 6°08'E	5°34'N, 5°52'E	6°25'N, 5°30'E	6°33'N, 5°37'E
Land Use	Citrus farm mixed with plantain and pineapple. Fertilizer use not practiced; water table was about 1 m to soil surface.	Multiplication Farm for SPDC Nig. Ltd. Agric Projects and Extension Services, used for cultivation of arable crops with regular fertilization; water table within 1 m of soil surface.	ADP On-Station Research Farm for cultivation of arable crops; the previous crop was maize with regular use of fertilizer.	Oil palm nursery site cleared from >7 year fallow; no fertilizers used in the site before.
Vegetation	Seasonal swamp forest	Seasonal swamp forest	Moist lowland forest	Moist lowland forest
Rainfall	2649 mm	2386 mm	2257 mm	2242 mm
Landform	Sombreiro-Warri deltaic plains	Sombreiro-Warri deltaic plains	Nearly level coastal plain terraces, long slopes with coarse-textured dendtritic drainage pattern	Undulating coastal plain terraces dissected by deep gullies and long slopes
Soil group	Yellowish brown soils of Calabar fasc	Yellowish brown soils of Calabar fasc	Reddish brown soils of Benin fasc	Reddish brown soils of Benin fasc
Soil unit	Fresh water-swamp soils	Fresh water-swamp soils	Nearly level plains on Coastal Plain Sands	Nearly level plains on Coastal Plain Sands
Soil type	Typic Tropaquent/ Aquic Kandiudult	Typic Tropaquent/ Aquic Kandiudult	Arenic Kandiudult	Oxic Kandiudult

Sources: FDALR (1990)

Table 1 shows some properties of the surface (0-15 cm) soils used for the studies. The soils were extremely acidic (pH 4.0-4.6) sandy loams to sands with medium organic matter content and very low exchangeable basic cations. Available P varied was 2.1-5.3 mg.kg^{-1} in three soils and 17.5mg.kg^{-1} in the soil from Ugbogiobo.

The top growth dry matter yields of maize during the first and second cropping are shown in Table 2. The main effects of locations and amendments were significant (P=0.05) in the first cropping. The soils from Oleh and Ugbogiobo gave the highest yields (16.97 and 15.46 g respectively) which did not differ while the soils from Agbarho and Oko gave significantly (P=0.05) lower yields. Manure application gave the highest yield (27.39 g) which was superior to the other amendments. The soil x amendment interaction was significant (P=0.05). Lime produced higher dry matter yields in the soils from Agbarho and Oko compared to the control but the increase was not significant. Responses to fertilizer varied among the soils with calculated yield increases low in Ugbogiobo (5.2%) and Agbarho (21.9%), high in Oko (77.4%) and negative in Oleh (-27.2%). Manure was the best amendment in all the soils. Maize dry matter yield was lower in the second cropping with the soils from Oleh and Ugbogiobo still significantly (P=0.05) higher. Fertilizer application reduced maize dry matter yield the most in soils from Ugbogiobo and Agbarho; lime had significant residual effects in soils from Agbarho, Oleh and Ugbogiobo while manure was beneficial in all the soils.

Table 2. *Properties of soils developed on Coastal Plain Sands used for the study*

Properties	Oleh	Agbarho	Oko	Ugbogiobo
Sand, %	88.6	83.4	82.6	84.6
Silt, %	4.8	6.4	3.8	3.2
Clay, %	6.6	10.2	14.6	12.2
Textural class	S	LS	LS	LS
pH (water)	4.3	4.1	4.0	4.6
Organic carbon, %	0.92	1.06	0.72	1.12
Total N,%	0.09	0.10	0.07	0.12
Available P, mg.kg^{-1}	2.4	4.9	3.2	16.4
Exchangeable cations, cmol.kg^{-1}				
K	0.11	0.06	0.08	0.24
Ca	0.63	0.17	0.20	0.94
Mg	0.34	0.38	0.19	0.83
Na	0.02	1.31	0.34	0.53
Acidity	3.98	3.41	3.88	2.70
CEC	5.08	5.33	4.69	5.24
Base saturation, %	21.65	36.02	17.27	48.47
Al, mg.kg^{-1}	12.2	24.3	23.0	7.3
Fe, mg.kg^{-1}	1.4	1.7	1.1	2.5
Mn, mg.kg^{-1}	22.0	14.0	21.9	28.0

S = Sand; LS = Loamy sand
CEC = Cation exchange capacity

Table 3. *Dry matter yield of maize top-growth as affected by soil amendments*

Amendments					
Soils	**Control**	**Fertilizer**	**Lime**	**Manure**	**Mean**
1st Cropping					
Agbarho	2.24u	2.73u	4.06u	26.47q	8.88b
Oko	2.03u	3.67u	3.75u	22.21r	7.91b
Oleh	12.54s	9.13t	11.60s	34.60p	16.97a
Ugbogiobo	12.42s	12.52s	10.61st	26.30q	15.46a
Mean	7.31y	7.01y	7.51y	27.39x	
SE = 0.94					
2nd Cropping					
Agbarho	1.88w	1.62w	4.04rst	4.55qr	3.02b
Oko	1.65w	1.76w	1.53w	3.05u	2.00c
Oleh	3.74st	3.85st	4.55qr	5.09pq	4.31a
Ugbogiobo	3.61tu	2.40v	4.47qrs	5.53p	4.00a
Mean	2.72z	2.41z	3.65y	4.55x	
SE = 0.21					

Means for the soils and amendments in each cropping followed by same letters do not differ significantly (P=0.05)

The direct and residual effects of the amendments on maize nutrient content are shown in Table 3. Fertilizer and manure application significantly (P=0.05) increased %P in all soils during the first cropping compared to very low and similar values from lime and the control treatments. Manure still increased maize tissue %P in all soils during the second cropping while the increase from fertilizer was obvious only in the soils from Oko and Oleh. Lime increased %Ca significantly (P=0.05) and the effect was more pronounced during the second cropping while it caused highest reduction of Mn content in the first and second cropping. Fertilizer reduced Mn and Fe content compared to the control while manure application decreased Mn but gave inconsistent results for Fe content.

Table 4 shows the changes in soil properties caused by amendments after the first and second cropping compared to pre-cropping conditions. Lime increased soil pH after the first cropping and the effect was highest (3.1 units) in the soil from Oko and the least (1.8 units) in Agbarho. Lime also increased exchangeable Ca the most but the effects on available P, organic matter and exchangeable Mg were inconsistent while Al, Mn and Fe decreased in all soils. Fertilizer slightly increased soil pH in three soils (0.1-0.6 units) but decreased it in soil from Ugbogiobo (-0.3 units). It increased available P and exchangeable Ca and Mg in all soils and increased exchangeable Al and Mn in Oleh and Ugbogiobo. Manure increased soil pH, organic matter, available P and the exchangeable cations but reduced the levels of Mn, Fe and Al. The increase in available P compared to the initial values was very large. The calculated increase ranged from 780% in Ugbogiobo to 6,500% in the soil from Agbarho. Successive cropping sustained or magnified the changes in soil chemical properties as shown by the slight increase in pH and large increases in available P in all soils after the second cropping, increase in exchangeable Ca and Mg, reduction in organic matter in soils from Oko and Ugbogiobo, and the decrease in Al, Mn and Fe. Soil organic matter decreased after the second cropping compared to the previous levels attained.

Table 4. *Effect of soil amendments on nutrient content of maize grown on Ultisols developed on Coastal Plain Sands*

		P		**Ca**		**Mn**		**Fe**	
		%				**mg.kg-1**			
Locations	**Treatments**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**
Oleh	Control	0.10c	0.21c	0.44b	0.85b	194b	295a	1110b	1740a
	Fertilizer	0.23b	0.35b	0.32c	0.35d	285a	321a	580d	720c
	Lime	0.12c	0.16c	0.80a	1.09a	70c	150b	805c	1620b
	Manure	0.31a	0.54a	0.30c	0.62c	194b	183b	1660a	475d
Agbarho	Control	0.10c	0.14b	0.40b	0.57b	604a	812a	1400a	1800a
	Fertilizer	0.28a	0.19ab	0.31c	0.30c	285b	320b	590c	730c
	Lime	0.11c	0.16b	0.89a	1.11a	121d	130c	890b	1650b
	Manure	0.24b	0.27a	0.26c	0.70b	160c	350b	480d	456d
Oko	Control	0.14c	0.16bc	0.46b	0.70b	700a	1035a	1630a	1800a
	Fertilizer	0.44a	0.25b	0.35c	0.33c	350b	645b	702b	625c
	Lime	0.08c	0.14c	0.90a	1.14a	70d	165d	570c	630c
	Manure	0.27b	0.42a	0.37c	0.68b	130c	265c	230d	1330b
Ugbogiobo	Control	0.14c	0.20b	0.44b	0.72b	365a	335a	1600a	1650b
	Fertilizer	0.21b	0.10b	0.42b	0.32d	161b	145b	430c	750d
	Lime	0.12d	0.23b	0.88a	0.91a	130b	150b	960b	1870a
	Manure	0.28a	0.52a	0.31c	0.62c	325a	130b	445c	1475c
	S.E.	0.01	0.04	0.01	0.02	12.9	24.2	12.9	24.9

Values in each column followed by the same letters do not differ significantly (P=0.05)
I = First Cropping
II = Second Cropping

Table 5. *Changes caused by application of amendments and successive cropping on some chemical properties of Ultisols developed on Coastal Plain Sands*

		Organic						Exchangeable Bases									
		pH		matter		Available P		Ca		Mg		Al		Mn		Fe	
Soils	**Treatments**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**
Oleh	Control	0.7	0.7	0.70	0.51	1.08	-0.77	0.85	0.80	0.10	0.20	-2.75	-2.75	-2.75	-4.76	-0.56	-0.23
	Fertilizer	0.6	0.3	-	-	4.70	4.65	1.23	0.80	1.92	1.71	5.40	10.80	8.24	-2.75	-0.56	-0.28
	Lime	2.7	2.7	0.42	0.20	1.05	1.10	3.50	3.55	-0.10	-0.05	-11.66	-11.66	-16.98	-16.98	-0.76	-0.76
	Manure	1.8	1,8	1.65	1.04	155.30	202.20	2.20	2.15	1.10	1.05	-11.66	-11.66	-16.98	-16.98	-0.76	-0.76
Agbarho	Control	0.3	0.4	0.44	0.41	1.88	1.91	0.30	0.25	-0.24	0.00	-4.10	-1.20	-3.98	-3.98	-0.44	-0.39
	Fertilizer	0.1	0.1	-	-	11.50	10.40	0.23	0.17	0.14	0.15	-14.85	-13.50	-17.60	-23.09	-0.55	-0.27
	Lime	1.8	1.8	1.43	1.40	2.09	3.80	3.60	3.35	-0.20	-0.05	-22.95	-23.76	-4.09	-10.99	-0.86	-1.17
	Manure	1.5	1.6	1.85	1.19	145.91	225.40	2.00	2.35	1.05	1.35 -	22.68	-23.76	-5.00	-0.24	-0.92	-0.50
Oko	Control	0.3	0.4	-0.32	-0.33	-0.94	-0.57	0.15	0.40	0.00	0.00	-3.24	-1.62	-8.00	-0.55	-0.42	-0.11
	Fertilizer	0.1	0.1	-	-	-1.66	-0.60	0.25	0.23	0.39	0.30	-6.75	-2.70	-10.90	-13.65	-0.56	0.00
	Lime	3.1	3.1	-0.12	-0.25	-1.63	0.57	3.95	4.20	-0.05	0.10 -	22.41	-22.41	-18.99	-16.98	-0.76	-0.56
	Manure	2.0	2.3	1.23	0.62	152.43	198.43	2.30	2.00	1.50	1.35 -	22.41	-22.41	-3.00	-16.98	-0.48	-0.20
Ugbogiobo	Control	0.2	0.3	-0.26	-0.31	-2.04	-6.00	0.10	0.10	-0.25	-0.10	-0.54	-0.54	-14.23	-2.01	-0.13	-0.44
	Fertilizer	-0.3	-0.3	-	-	3.00	3.00	0.29	0.10	0.82	0.60	-0.54	-0.54	21.97	10.98	-0.55	0.00
	Lime	2.4	2.6	-0.13	0.30	-5.88	-7.60	3.20	3.30	-0.45	-0.35	-6.75	-6.75	-20.86	-19.98	-1.22	-1.22
	Manure	1.4	1.6	0.34	0.24	136.50	182.50	1.35	1.50	1.25	1.10	-6.75	-5.67	-3.99	-19.98	-0.63	-0.86

The effects of all possible combinations of the amendments added to the soil from Oko on maize dry matter yields are shown in Table 5. Lime or fertilizer alone gave similar dry matter yield (6.40 g) which was 78% increase above the control (3.60 g) but was significantly lower than manure application (17.44 g). Manure + Fertilizer produced the highest dry matter yield (26.13 g) that was significantly different (P=0.05) from other treatments and represented 95% increase over the treatment that contained the three amendments. All treatments, except fertilizer alone, increased soil pH to slightly acid status after cropping. Lime + fertilizer and manure treatments gave the highest maize tissue %P concentration. The presence of lime in the treatments increased %Ca, manure and lime decreased Mn and Fe content while application of fertilizer alone gave the highest values.

Table 6. *Effect of possible fertilizer, lime and manure combinations on maize dry matter yield and nutrient content in an Ultisol (pH=4.0)*

Treatments	**Final**	**Dry matter**	**P**	**Ca**	**Mn**	**Fe**
	soil pH		**yield (gm)**		**%**	**mg.kg^{-1}**
Fertilizer	3.8f	6.35d	0.21b	0.18d	1175a	2700a
Lime	6.1c	6.40d	0.10c	0.38a	550d	1560c
Manure	5.5d	17.44b	0.28ab	0.26c	425ef	700e
Lime+ Fertilizer	6.2bc	16.20b	0.32a	0.39a	425ef	1600c
Lime+ Manure	6.3b	14.20c	0.11c	0.36ab	450e	1200d
Fertilizer+ Manure	5.3e	26.13a	0.22b	0.21d	650c	2120b
Fertilizer+ Lime+ Manure	6.5a	13.40c	0.23b	0.33b	350f	1250d
Control	3.9f	3.60e	0.03c	0.22cd	1025b	2630a
SE	0.06	0.26	0.044	0.023	29.6	93.9

4. Discussion

The soil characteristics, especially nutrient fertility levels, varied in relation to the nature of land use in each site. Ugbogiobo site was a plot cleared from a previous fallow long enough for the soil to accumulate highest amounts of organic matter and respective nutrients whereas at Oko, the plot had been under continuous tillage and cultivation to annual crops in succession for over 30 years and contained the least values. Based on the soil test interpretation and soil fertility classes for Nigeria (FDALR, 2004; Anon, 2006), the soils contained medium organic matter and low amounts of available P and exchangeable cations. The unusually high available P in the soil from Ugbogiobo can be attributed to the high organic matter on account of the previous long fallow needed for nutrient fertility build-up and low exchangeable Al (Lal, 1999).

There was no significant response to liming in the soils from Oleh and Ugbogiobo probably because of the failure to adequately neutralize the factors responsible for low P availability (notably P fixation). Thus, peculiar P deficiency symptoms (purple leaf colouration) observed are a reflection of the disturbance of P nutrition in these soils despite the fact that they contained more available P than the soils from Agbarho and Oko which gave 81 and 85% increase in dry matter yield respectively. Manure application produced better maize dry matter yield than fertilizer and lime probably because it adds more nutrients as part of the observed general improvement in soil productivity (Opara-Nadi *et al*., 2000). The response was higher in the soils from Oko and Agbarho (994 and 1,081.7%) with lower nutrient status compared to Ugbogiobo and Oleh (111.7 and 175.9%).

The lack of yield response to fertilizer in the second cropping may be expected given that nutrients in the fertilizer are in soluble forms which leave little residual effects (Tisdale *et al*., 1993). However, the mineral fertilizer left residues as indicated by higher available P but the soil had become more acid with higher Al, Mn and Fe which must have affected P nutrition. This is unlike lime whose residual effect, as obtained in all the soils, is recognized and responses can be obtained in soils even after two years of application (Brady and Weil, 2002). Kang (1989) noted that low lime rates (0.5-2.0 $MT.ha^{-1}$) which serve primarily to meet Ca and Mg requirements and neutralize exchangeable Al can have considerable residual effects and sustain maize yields for six years. The manure was thoroughly mixed with the soils at the commencement of the study while subsequent watering during the first cropping followed by air-drying before the second cropping would have increased the rate of organic matter decomposition which reduced the contribution to nutrient supply with time.

Ultisols require proper nutrient management programmes for meaningful arable crop production to take place. Fertilizer alone would not be the appropriate management recommendation given the little effect on crop growth. First, the concentrations of Fe, Mn and Al were high in the soils and which lime and manure reduced significantly. Reeve and Sumner (1970) had suggested 1 $mg.kg^{-1}$ (0.011 $cmol.kg^{-1}$) as the toxic level to maize such that exchangeable Al was already limiting maize growth in the soils from Agbarho and Oko. Second, P was limiting maize growth and treatments without manure showed typical deficiency symptoms. Unfortunately, farmers are rarely advised to apply lime and manure before or along with fertilizer, as components of the improved technologies being extended, such that resultant poor maize growth and low yields must have contributed to the poor fertilizer use adoption in the states.

Lime reduced exchangeable Al which is responsible for poor crop growth in soils with pH<5.0, but it did not increase yield suggesting that other factors affecting P availability were still active and not effectively neutralized in the soils. Thus, one of the benefits of manure application is reduction of this Al to non-toxic levels. The increase in soil pH causes reduction in the exchangeable acidity since Al, its main component, would precipitate to Al-hydroxide the form in which Al exists in soils with pH 6.0 and above (Ano and Agwu, 2005). Manure reduced Mn but was not as effective as lime. The role of manure was probably indirect because high Ca concentration, contained more in the lime, is the actual factor responsible for reducing the amounts of Mn in soils. Natschner and Schwetmann (1991) noted that manure increased soil pH and reduced exchangeable acidity due to Ca ions released into soil solution during microbial de-carboxylation of the manure. Fe decreased due to reduction in its solubility as pH increased and the ability of organic products of microbial decomposition to chelate exchangeable Fe (Hargrove and Thomas, 1981). Manure application had increased soil organic matter content and so would alter the metal status of soils by affecting their solubility through the high molecular weight ligands (humic substances) it contains (Nolan and McLaughlin, 2005). Humic substances consist of soluble organic matter (fulvic acid) which promotes dissolution of metals from the adsorption sites on clay minerals while the less soluble fraction (humic acid) enhances metal adsorption on soil minerals thereby reducing their bio-availability.

Thus, the approach for nutrient management would be to neutralize this Al, supply Ca and Mg followed by adequate fertilizer application. Igbokwe *et al*. (1981) suggested liming to 5.0-5.5 to deal with the acidity problems of Ultisols in southern Nigeria because above this range, water-soluble Zn and Mn were reduced to non-detectable levels while H^+ from hydroxyl-Fe, Al compounds and organic matter would ionize resulting in complications which would culminate in the reduction of yield. The treatments which contained manure did not show P deficiency symptoms probably because of adequate supply of available P from the chelating action of organic acids (products of microbial decomposition of organic matter) on Al, Fe and Mn, responsible for P fixation and the expected contribution from native organic matter mineralization. Also, the manure provides P in organic form that is not easily fixed in the soils by the constituents, especially the metal oxides. The soils contained 1.20-1.86% organic matter which would contribute little to the available P, assuming 4% mineralization rate (Ayodele, 1986). However, the organic matter levels after cropping did not suggest sufficient input from decomposition and mineralization, and it would appear that inactivation of P fixation components ensured release of more available P for crop uptake.

Manure enhanced maize response to lime and fertilizer application through the improvement in soil pH, available P and exchangeable Ca and Mg, and reduction in Al. Fe and Mn. Busari *et al*. (2004) had noted that individual amendments were not as effective as the combined application of manure, fertilizer and lime. The Manure + Fertilizer gave better performance than the treatment containing the three amendments and should be the recommended practice for the management of these extremely acidic Ultisols.

5. Conclusion

Ultisols are located in the humid region of southern Nigeria where unconsolidated sands and sandstones (Coastal Plain Sands) parent materials and high rainfall regimes promote formation of acid soils deficient in basic cations. The potentials of these soils for maize production would be realized with management options that emphasize application of manure and complementary manure-inorganic fertilizer which promoted growth through increased availability of P and cations and reduction in toxic elements.

References

[1] Agboola, A.A. 2002. Farming systems in Nigeria. In: Agboola, A.A. (ed). Essentials of Agricultural Production in Nigeria. Green Line Publishers, Ado-Ekiti, Nigeria: 29-71

[2] Ano, A.O. and Agwu, J.A. 2005. Effect of animal manures on selected soil properties. *Nig. J. Soil Sci.* 15: 14-19

[3] Anon (2006). Nigeria Fertilizer Strategy Report. Presented at Africa fertilizer Summit held at International Conference Centre, Abuja, 9-13th June, 2006. 47pp.

[4] Ayodele OJ (1986). Effect of continuous maize cropping on yield, organic carbon mineralization and phosphorus supply of savannah soils in western Nigeria. *Biology and Fertility of Soils* 2: 151-155.

[5] Banful, A.B., Nkonya, E. and Oboh, V. 2010. Constraints to Fertilizer Use in Nigeria: Insights from Agricultural Extension Service. IFPRI Discussion Paper No 01010. International Food Policy Research Institute, Washington. 36pp

[6] Brady NC, Weil RR (2002). The Nature and Properties of Soils. 13th Edition, Pearson Educ. Pub. New Delhi, India. 881pp.

[7] Brouwer J, Powel JM (1995). Soil aspect of nutrient cycling in a manure application experiment in Niger. In: Powel JM *et al*. (eds). Livestock and Sustainable Nutrient Cycling in Mixed Farming Systems of Sub-Saharan Africa. Volume II. Technical Papers. Proceedings of International Conference held 22-26 Nov. 1993. ILCA, Addis Ababa, Ethiopia. 211pp.

[8] Buol, S.W., Southard, R.J., Graham, R.C. and McDaniel, P.A. 2011. Soil Genesis and Classification.

[9] Busari MA, Salako FK, Sobulo RA, Adetunji MT, Bello NJ (2004). Variation in soil pH and maize yield as affected by application of poultry manure and lime. In: Salako FK *et al*. (eds). Managing Soil Resources for Food Security and Sustainable Environment. Proceedings of 29th Annual Conference of Soil Science Society of Nigeria held at University of Agriculture, Abeokuta, Nigeria, December 6-10, 2004: 139-142.

[10] Evelyn, S.K., Jan, O.S. and Jeffrey, A.B. 2004. Functions of Soil Organic Matter and the Effect on Soil Properties. CSIRO Land and Water Report. 129pp

[11] Fageria, N.K. and Baligar, V.C. 2008. Ameliorating Soil Acidity of Tropical Oxisols by Liming for Sustainable Crop Production. Advances in Agronomy 99: 345-399

[12] FDALR (1990). The Reconnaissance Soil Survey of Nigeria (1:650,000). Soils Report Volume Three (Bendel, Lagos, Ogun, Ondo and Oyo States). Federal Department of Agricultural Land Resources, Lagos. 149pp.

[13] FDALR (2004). Handbook on Soil Test-based Fertilizer Recommendations for Extension Workers. Federal Department of Agricultural Land Resources in collaboration with National Special Programme for Food Security, Abuja, Nigeria.39pp.

[14] Fore RE, Okigbo BN (1973). Yield response of maize to various fertilizers and lime on Nkpologu sandy loam soil. *Nigerian Agric. J.* 9: 124-127.

[15] Hargrove WL, Thomas GW (1981). Effects of organic matter on exchangeable aluminium and crop growth in acid soils. In: Chemistry in the Environment. ASA Special Publication No 40. Amer. Soc. Agron, and SSSA, Madison, Wisconsin.

[16] Haynes, R.J. and Mokolobate, M.S. 2001, Amelioration of Al toxicity and P deficiency in acid soil by addition of organic residues. *Nutrient Cycling. Agroecosyst.* 59: 47-63

[17] Haynes RJ, Naidu R (1998). Influence of lime, fertilizer and manure on soil organic matter content and soil physical conditions: A review. *Nutrient Cycling Agroecosyst*. 15: 123-127.

[18] Heathcote RG (1970). Soil fertility under continuous cultivation in Northern Nigeria I. The role of organic manure. *Exptl Agric* 6: 229-237.

[19] Igbokwe MC, Njoku BO, Odurukwe SO (1981). Liming effects on the response of maize to phosphate fertilizer on an Ultisol in Eastern Nigeria. *Nigerian J of Soil Science* 11: 120-130.

[20] IITA (1979). Selected Methods of Soil and Plant Analysis. Manual Series No 1. International Institute of Tropical Agriculture, Ibadan, Nigeria. 70pp.

[21] Juo ASR, Wilding LP (1996). Soils of the lowland forest of West and Central Africa. In: essays on the Ecology of the Guinea Congo Rainforest. Proceedings Royal Society of Edinburgh. Vol. 1043. Section B: Biological Science. Edinburgh, Scotland, U.K.: 15-26.

[22] Juo ASR, Franzluebbers K, Dabiri A, Ikhile B (1996). Soil properties and crop performance on a kaolinitic Alfisol after 15 years of fallow and continuous cultivation. *Plant and Soil* 180: 290-217.

[23] Kamprath EJ (1971). Potential detrimental effects from liming highly weathered soils to neutrality (A review). *Soil Crop Sci Soc Fla. Proc* 31: 7-9.

[24] Kang, B.T. 1989. Nutrient management for sustained crop production in the huid and subhumid tropics. In: van der Heide, J. (ed). Nutrient Management for Food Crop Production in Tropical Farming Systems. Institute for Soil Fertility, Haren, The Netherlands and Universitas Brwijaya, Indonesia: 3-28

[25] Lal R (1999). Land use and cropping system effects on restoring soil carbon pool of degraded Alfisols in Western Nigeria. In: Lal R *et al*. (eds) Global Climate Change and Tropical Ecosystems. Advances in Soil Science. CRC Press, Boca Raton: 157-165.

[26] Liverpool-Tasie, S., Olaniyan, B.,Salau, S. and Sackey, J. 2010. A Review of Fertilizer Policy Issues in Nigeria. Nigeria Strategy Support Program (NSSP) Report No 28, IFPRI-Abuja. 5pp

[27] Martini JA, Mutters RC (1989). Soyabean root growth and nutrient uptake as affected by lime rates and plant age. II. Ca, Mg, K, Fe, Cu and Zn. *Turrialba* 39: 254-259.

[28] Mokwunye U (1980). Interactions between farmyard manure and fertilizers in savannah soils. In: *FAO Soils Bulletin* No 43: 192-200

[29] Müller-Sämann KM, Kotschi J (1994). Sustaining Growth: Soil Fertility Management in Tropical Smallholdings. GTZ, Germany and CTA, Netherlands. Margraf Verlag, Germany. 486 pp

[30] Natshner I, Schwetmann U (1991). Proton buffering in organic horizons of acid forest soils. *Geoderma* 48: 93-106.

[31] Nolan AL, McLaughlin MJ (2005). Prediction of zinc, cadmium, lead and copper availability to wheat in contaminated soil using chemical speciation, diffuse gradients in thin films extraction and isotopic diffusion techniques. *J Environ Quality* 34: 496-507.

[32] Ofori, C.S., Higgins, G.M. and Purnell, M.F. 1986. Criteria for choice of land suitable for clearing for agricultural production. In: Lal, R., Sanchez, P.A. and Cummings, R.W. Jr (eds). Land Clearing and Development in the Tropics. A.A. Balkema, Rotterdam: 19-28

[33] Ojanuga AG, Lekwa G, Akamigbo FRO (1981). Survey, classification and genesis of acid soils. In: Udo, E.J. and Sobulo, R.A. (eds). Acid Soils of Southern Nigeria. Soil Science Society of Nigeria Special Publication Monograph No 1: 1-8.

[34] Opara-Nadi AO, Omenihu AA, Ifemedehe SN (2000). Effects of organic wastes, fertilizers and mulch on productivity of an Ultisol. In: Babalola O (ed). Proceeding of 26th Annual Conference of Soil Science Society of Nigeria held at Ibadan, 30th October-3rd November, 2000: 112-120.

[35] Reeve NG, Sumner ME (1970). Effects of Al toxicity and phosphorus fixation on crop growth in Oxisols in Natal. *Soil Sci Soc Amer. Proc.* 34: 262-267.

[36] Sanchez, P.A. and Buol, S.W. 1975. Soilsof the tropics and the world food crisis. In: Abelson, P.H. (ed). Food: Politics, Economics, Nutrition and Research. American Association for the Advancement of Science Misc. Publication 75-7: 115-120

[37] Steel RDG, Torrie JH, Dickey DA (1997). Principles and Procedures of Statistics: A Biometrical Approach. 3rd Edition. McGraw Hill, New York. 665pp.

[38] Tisdale SL, Nelson WL, Beaton JD, Havlin JL (1993). Soil Fertility and Fertilizers. 5th Edition, Macmillan, New York.

[39] Vine H (1970). Review of Work on Nigerian Soils. Report of the National Research Council Committee on Tropical Soils. London, England.

[40] Yang, S., Zhang, Z., Cong, L., Wang, X. and Shi, S. (2013). Effect of fulvic acid on the phosphorus availability in acid soils. *J. Sci. and Plant Nutri.* 13: 526-533