European Journal of Agriculture and Forestry Research

Vol.1, No.1, pp. 17-25, September 2013

Published by European Centre for Research Training and Development UK (www.ea-journals.org)

MORINGA *(MORINGA OLEIFERA* LAM.) LEAVES EFFECT ON SOIL PH AND GARDEN EGG (SOLANUM AETHIOPICUM L.) YIELD IN TWO NIGERIA AGRO-ECOLOGIES

Utietiang L. Undie[1*], Michael A. Kekong[2] & Tom O. Ojikpong[3]

1, 2, 3 Faculty of Agriculture, Cross River University of Technology, Obubra, Nigeria

ABSTRCT: *Soil acidity is a major constraint in soil fertility maintenance, particularly, in the humid tropics. Sustainable production of crops on acidic soils depends on soil amendment to remediate acidity and fertility status. The objective of this research was to investigate the effects of incorporating Moringa leaves on soil acidity amelioration and garden egg yield. The field trials were conducted at the Research Farms of the University of Agriculture, Makurdi, and the Faculty of Agriculture, Cross River University of Technology, Obubra in 2009 and 2010. Treatments consisted of two varieties of garden egg (Gilo and Kumba) and four rates of Moringa leaves. Fresh Moringa leaves were applied at the rates of 0, 5, 10 and 20 t ha^{-1}. The experiment was laid out in a Randomized Complete Block Design with three replications. The results obtained showed that all rates of the manure reduced the soil pH within 30 days after incorporation in both years and locations. At 60 days after application, and up to 140 days after incorporation, all manure rates increased the pH in both locations and years. The control, however, showed a steady pH decrease up to 140 days after incorporation. All manural rates significantly ($P<0.05$) increased the yield of the garden egg varieties over the control. Moringa at 20 t ha^{-1} produced the highest fruit yield in both years and locations. The crop yields were significantly higher in Makurdi than Obubra in both years and the yield for 2010 was significantly higher than for 2009 in both locations. Moringa leaves, at the rate of 20 t ha^{-1}, are a promising soil amendment for the remediation of soil acidity and for sustainable production of garden egg*.

KEYWORDS; Garden Egg, *Moringa*, Soil Acidity Remediation, Soil Ph, Sustainable Production, Humid Tropics.

INTRODUCTION

Declining soil fertility has been identified as the fundamental cause of declining crop yields in many parts of Africa (Sanchez *et al*, 1997). Soil acidity is a major constraint in soil fertility maintenance particularly in the humid tropics. As the soil pH declines, the supply of most plant nutrients decreases while aluminum and a few micronutrients become more soluble and toxic to plants. These problems, according to Harter (2007), are particularly acute in humid tropical regions that have been highly weathered. Sanchez and Logan (1992) had earlier observed that one- third of the tropics or 1.7 billion hectares of tropical land is acidic enough for soluble aluminum to be too toxic for most crop plants.

One of the problems of soil acidity includes the fixation of phosphorus by the oxides of Al and Fe to form complexes that are insoluble in water, making it unavailable to the plants. Aluminum, hydrogen and manganese cause root injuries, which affect the uptake of some important mineral nutrients from the soil and this consequently affect crop growth and yield (Lee *et al.*, 2007). Onyekwere *et al,* (2005) also reported that soil acidity has negative effects on bacteria population and activities, which could lead to reduced nitrogen transformation in the soil.

The use of liming materials from agricultural and domestic wastes has been found to improve the availability of nutrients in the soil, increase crop yields and activities of soil micro organisms due to amelioration of soil pH (Ojeniyi *et al.,* 1999; Ano and Agwu, 2005; Kekong *et al.,* 2010). Leguminous plant residues have been investigated for soil fertility improvement (Booth and Wickens, 1998). *Moringa*.has been reported to possess wide adaptations and high nutrients composition in its biomass (Bosch, 2004). Our objective was to evaluate the efficacy of *Moringa* leaves for soil pH regulation, soil fertility maintenance and garden egg yield since these are more environmental friendly and affordable than chemical fertilizers.

MATERIALS AND METHODS

Location

The study was carried out at the Research Farms of the University of Agriculture, Makurdi (7^0 45' N, 8^0 35' E) and Faculty of Agriculture, Cross River University of Technology, Obubra (6^0 06' N, 8^0 18' E). Makurdi is located within the sub humid Guinea Savanna agro ecology of Nigeria while Obubra is in the Rainforest zone. Makurdi has an annual rainfall of 1000 mm – 1250 mm while its mean annual temperature is 25.4^0C. Obubra is characterized by mean annual rainfall of 2250 mm – 2500 mm, with an annual temperature range between 25^0C and 27^0C.

Experimental design and treatments

The experiment was a factorial combination of *Moringa* leaves (M) at the rates of 0, 5, 10 and 20 t ha^{-1} with two varieties of garden egg: Gilo (V_1) and Kumba (V_2), and this was laid out in a randomized complete block design. The treatments consisted of M_0V_1, M_0V_2, M_5V_1, M_5V_2, $M_{10}V_1$, $M_{10}V_2$, $M_{20}V_1$ and $M_{20}V_2$. These were replicated three times.

DATA COLLECTION

Soil sampling and processing: At the commencement of the experiment, a composite sample from ten random points was collected, using a soil auger, at 0-20 cm depth for both years and locations. Post manuring and planting soil samples were collected for each treatment and replication. Each was bulked for the three replications at 30, 60, 90 and 140 days after application. The samples were air-dried, sieved through a 2 mm mesh and packed in paper bags for laboratory analysis.

Plant sampling: A net plot of inner ridges in each treatment was used with four tagged plants for fruit count per plant per harvest and fruit weight. The mean cumulative number of fruits per plant for the number of harvests was taken. The cumulative yield per net plot from first harvest to the last harvest for each plot was calculated as yield in tonnes per hectare.

Soil analysis: The soil samples collected were subjected to routine analyses at the Soil Science Laboratory of the Federal University of Technology, Minna, Nigeria, and the Federal University of Agriculture, Makurdi, Nigeria. Particle size distribution (PSD) was determined by the Bouyoucos (hydrometer) method as described by Udo *et al.* (2009). Soil pH was determined in both water and KCl in a ratio of 1:1 soil: water and 1:2.5 soil: KCl, respectively (Udo *et al.*, 2009).The Walkley – Black wet method as outlined by Page et al.

(1982), was used to determine organic matter. Total nitrogen was determined by the Macro Kjeldahl method as described by Udo *et al.* (2009), while available phosphorus was determined by Bray-I method as outlined by Page *et al.* (1982). Exchangeable cations were determined by the ammonium acetate extraction method as described by Udo *et al*. (2009).

Statistical Analysis: Analysis of variance (ANOVA) for RCBD was performed on the garden egg yield and yield components using the computer software Genstat, (Genstat, 2005). F-LSD was calculated at the probability levels of $P \leq 0.05$ and $P \leq 0.01$ to separate the means. T-test was used to determine the location and year effects on crop yield (Gomez and Gomez, 1984).

RESULTS AND FINDINGS

Pre- treatment soil properties

Results of initial soil properties before treatment application in the two locations and manure analysis are presented in Tables 1 and 2. The soils at both locations were sandy-loam, low in organic matter (OM), N, P, exchangeable cation and CEC. The CEC and OM were, however, relatively higher in Makurdi than Obubra. The soils were slightly acidic in Makurdi and moderately acidic in Obubra with a higher exchangeable acidity in Obubra than Makurdi. The *Moringa* leaves showed high concentration of N, K, Ca and organic carbon in both locations.
Changes in soil pH (Tables 3 and 4) showed that application of *Moringa* leaves increased the pH of the soils at all the manure rates especially at the higher rates from 60 days after incorporation. At 30 days after application, there was a slight decrease in the soil pH in all treatments, including the control. The control, however, showed a steady decline in soil pH from 30 days and up to 140 days in the two locations and in the two years. From 60 days after incorporation of the *Moringa* leaves, there was an increase in the soil pH up to 90 days. There was no further increase between 90 and 140 days after the manure application. Soil units that received 20 t ha^{-1} *Moringa* leaves had the highest increase in soil pH. The least increase was observed in the manure rates of 5 t ha^{-1}, in both locations and years.

Results of plant dry matter and number of fruits per plant are presented in Tables 5. Results showed that application of *Moringa* leaves significantly ($P < 0.05$) increase dry matter yields of both varieties in Makurdi and Obubra and in each year of the trial.

In 2009, application of *Moringa* leaves at 20 t ha^{-1} produced highest amount of plant dry matter in locations, varieties and years. The least yield was obtained from the control. There was no significant difference in dry matter yield between Gilo and Kumba varieties of the crop in Makurdi but in Obubra, Kumba produced significantly higher dry matter yield than Gilo. *Moringa* leaves applied at the rate of 20 t ha^{-1} produced the highest number of fruits per plant in both locations. The least number of fruits per plant was obtained from the control. In 2010, the number of fruits per plant followed the same trend as that of 2009. In both years and locations Gilo variety of garden egg significantly produced higher number of fruits per plant than Kumba.

Gilo garden egg produced significantly ($P < 0.05$) higher fruit yield per unit area in 2009 in both Makurdi and Obubra (Table 6). In 2010, however, there was no significant yield difference between Gilo and Kumba in Makurdi . In Obubra, Gilo produced significantly higher fruit yield than Kumba.

Results of location and year effect of *Moringa* leaves on the yield of garden egg (Table 7) showed that cross the years, application of *Moringa* leaves significantly produced higher fruit yield ($t < 0.05$) in Makurdi than Obubra. Between the years, total fruit yield of the garden egg was significantly higher ($t < 0.05$) in 2009 than 2010 in both locations.

DISCUSSION

Similar results on the increase in soil pH due to incorporation of plant sources of manure were reported by Akanbi and Ojeniyi (2007) for *Chromolaena* leaves, and Ogeh (2010) for almond leaves. The mechanism responsible for this increase in soil pH was probably due to ion exchange reactions which occur when terminal OH^- of Al^{3+} and Fe^{2+} hydroxyl oxides are replaced by organic anions which are products of decomposition of organic manures (Bell and Besho, 1993). The ability of organic manure to increase soil pH can be attributed to the enrichment of the soil through mineralization of cations particularly Ca. Natschner and Schwartzman (1991) reported that such basic cations are released upon microbial decarboxylation. Narambuye and Haynes (2006) reported that the short-term effects of manure in reducing potentially toxic Al^{3+} solution are attributed to both increase in pH and a complexing effect by soluble organic matter. The decrease in soil pH within the first 30 days was similar to the observations of Haynes and Mokolobate (2001). They opined that this initial decrease in soil pH with organic manure application was due to the buffering reserves of acidity in soils and nitrification of accumulated N. Similarly, Naramibuye and Haynes (2006) noted that in the early stages of degradation, microbial processes of decarboxylation of organic acid anions during manure decomposition are unlikely to contribute to elevated pH.

The significant increase in yield and yield components of garden egg varieties is a manifestation of the positive effect of organic manures on soil properties that transformed into soil fertility and a confirmation of the high mineralizable nutrient composition of *Moringa*. This high mineralizable composition of organic manures has been reported by Warman (1986) and Duncan (2005). The yield response of the crop varieties due to these organic manure sources agreed with the assertions by Isitekhale and Osemota (2010) that organic manures are important short-term suppliers of nutrients as well as for long-term maintenance of soil organic matter. This yield response showed that the higher the pH above 5 in the soil, the higher the yield of garden egg. Ojeniyi *et al.* (1999) have earlier identified soil pH as one of the most important indicators of soil fertility in the tropics. Sanchez and Logan (1992) stated that the level of pH especially in tropical soils is an essential determinant of its fertility and, therefore, corroborated the garden egg yield response to increased pH levels above 5 and up to 6.7. The yield increase of garden egg varieties due to *Moringa oleifera* leaves manure agrees with the findings of Booth and Wickens (1988) who noted that the high protein biomass of *Moringa oleifera* is suited for use and acts as a natural fertilizer while Davis (2006) reported that the use of Moringa as a green manure significantly improved soil fertility.

The higher yield of Gilo variety over Kumba is attributed to the genotypic characteristics of the crop varieties. Sanginga *et al.* (2000) reported that some crop genotypes tend to have greater need for nutrients and are often more responsive to nutrient input, thus their yield differences.

The higher yield of garden egg varieties in Makurdi than Obubra could be attributed to soil properties and climatic variations (Table 1). Chude (1998) reported that Cross River State soils in the Rainforest zone have low P and exchangeable cations which are higher in the Nigerian Savanna.

CONCLUSION

The manurial and organic matter enrichment potentials of *Moringa oleifera* leaves and their positive effects on soil pH were found to be efficient in increasing soil pH and maintaining soil fertility for sustainable garden egg production. Application of these manure rates, especially, the higher rates increased soil pH level and significantly increased garden egg yield over the control. Moringa leaves can serve as alternative source of soil organic matter and Ca, or a replacement for inorganic fertilizers, with facilitating effect on soil pH and plant nutrients release for optimum production of garden egg.

Table 1: Pre-cropping soil physical and chemical properties in Makurdi and Obubra in 2009 and 2010.

	Makurdi		Obubra	
Soil parameters	2009	2010	2009	2010
Sand (g/kg)	874	888	853	839
Silt (g/kg)	84	79	79	72
Clay (g/kg)	42	43	68	89
Texture class	S/L	S/L	S/L	S/L
pH (water)	6.16	6.20	5.50	5.48
pH (KCL)	5.00	4.80	4.30	4.20
Organic matter (%)	2.80	2.76	1.82	1.94
Total nitrogen (g/kg)	1.0	0.9	0.8	0.8
Available P (M/kg)	5.5	4.6	3.6	3.4
Exch. Ca (cmol kg^{-1})	3.40	3.10	2.50	2.61
Exchange. M (cmol kg^{-1})	0.30	0.28	0.22	0.24
Exchange. M (cmol kg^{-1})	0.92	0.98	1.01	1.08
Exchange Na (cmol kg^{-1})	0.16	0.15	0.17	0.18
Exchange. Acidity	2.30	2.25	2.75	2.85
CEC (cmol kg^{-1})	2.3	2.2	1.7	1.8

S/L = sandy loam

Table 2: Nutrient composition of *Moringa* leaves in Makurdi and Obubra in 2009 and 2010

Location	N (%)	P (%)	K (%)	Ca (%)	M (%)	Na (%)	Org. C (%)	C:N
Makurdi	4.10	1.21	1.71	13.6	0.12	2.19	10.8	2.6
Obubra	4.02	1.18	1.80	12.4	0.11	1.16	11.1	2.8

European Journal of Agriculture and Forestry Research
Vol.1, No.1, pp. 17-25, September 2013
Published by European Centre for Research Training and Development UK (www.ea-journals.org)

Table 3: Effects of different rates of *Moringa* leaves, varieties and days after application on soil pH at Makurdi and Obubra in 2009

	Makurdi				Obubra			
	Days after application of manure							
Treatment	30	60	90	140	30	60	90	140
M_oV_1	5.95	5.90	6.01	6.00	5.41	5.42	5.31	5.31
M_oV_2	6.00	6.01	6.00	6.01	5.42	5.32	5.31	5.30
M_5V_1	6.05	6.21	6.20	6.20	5.40	5.95	5.98	5.99
M_5V_2	6.08	6.20	6.21	6.20	5.39	5.98	5.97	5.98
$M_{10}V_1$	6.00	6.20	6.21	6.21	5.38	5.98	6.03	6.03
$M_{10}V_2$	5.98	6.22	6.23	6.23	5.39	6.00	6.04	6.04
$M_{20}V_1$	5.90	6.23	6.24	6.24	5.18	6.10	6.12	6.12
$M_{20}V_2$	5.99	6.23	6.24	6.23	5.18	5.95	6.10	6.10

$M_0 - M_{20}$ = *Moringa* Leaves rates at 0, 5, 10 and 20 t ha^{-1}; V_1 = Gilo, V_2 = Kumba

Table 4: Effects of different rates of *Moringa* leaves, variety and days after application on soil pH at Makurdi and Obubra in 2010

	Makurdi				Obubra			
	Days after application of manure							
	30	60	90	140	30	60	90	140
M_oV_1	6.01	5.95	5.94	5.95	5.11	5.10	5.10	5.09
M_oV_2	6.08	5.95	5.94	5.94	5.15	5.11	5.11	5.10
M_5V_1	6.01	6.25	6.50	6.51	5.14	5.60	5.61	5.61
M_5V_2	6.00	6.25	6.53	6.53	5.13	5.61	5.60	5.61
$M_{10}V_1$	6.01	6.22	6.60	6.61	5.11	5.64	5.95	5.64
$M_{10}V_2$	5.96	6.25	6.59	6.60	5.11	5.64	5.95	5.64
$M_{20}V_1$	5.91	6.23	6.64	6.65	5.11	5.9	6.00	6.01
$M_{20}V_2$	5.90	6.24	6.63	6.63	5.10	5.9	6.00	6.01

$M_0 - M_{20}$ = *Moringa* Leaves rates at 0, 5, 10 and 20 t ha^{-1}; V_1 = Gilo, V_2 = Kumba

Table 5: Plant dry matter and number of fruits per plant of garden egg as affected by variety and application of *Moringa* leaves at Makurdi and Obubra in 2009 and 2010

	Plant dry matter (kg/ha $^{-1}$)				Number of fruits per plant			
	2009		2010		2009		2010	
Treatment	Makurdi	Obubra	Makurdi	Obubra	Makurdi	Obubra	Makurdi	Obubra
M_0	58.5	58.3	58.0	55.5	11.2	8.50	26.5	25.0
M_1	122.8	118.5	146.5	141.3	31.6	26.50	50.5	49.5
M_2	190.0	183.8	208.7	203.0	37.3	30.17	70.2	59.5
M_3	205.8	197.5	233.5	229.0	51.0	40.67	76.3	68.2
LSD (P<0.05)	9.16	18.23	18.44	14.10	5.0	3.18	10.90	5.25
V_1	148.9	145.5	175.5	162.1	52.4	44.67	81.8	74.3
V_2	146.7	139.1	179.6	173.6	28.0	24.00	31.9	29.2
LSD(P<0.05)	NS	NS	NS	NS	2.26	1.42	4.88	2.35

NS = not significant; $M_0 - M_{20}$ = *Moringa* Leaves rates at 0, 5, 10 and 20 t ha^{-1}; V_1 = Gilo, V_2 = Kumba

Table 6: Fruit yield of garden egg as influenced by rates of application of *Moringa* and variety at Makurdi and Obubra in 2009 and 2010

	Fruit yield (t ha^{-1})			
	2009		2010	
Treatment	Makurdi	Obubra	Makurdi	Obubra
M_0	1.18	0.92	3.32	2.97
M_5	2.42	2.78	7.88	6.73
M_{10}	5.47	5.77	10.42	8.30
M_{20}	7.22	6.68	10.37	9.17
LSD ($p<0.05$)	0.47	0.67	1.31	0.77
V_1	5.89	5.39	8.53	7.66
V_2	4.67	4.65	8.30	6.79
LSD($P<0.05$)	0.21	0.31	NS	0.34

NS = not significant; M_0 – M_{20} = *Moringa* Leaves rates at 0, 5, 10 and 20 t ha^{-1}; V_1=Gilo, V_2=Kumba

Table 7: Location and year effects on fruit yield of garden egg as affected by *Moringa* leaves application and variety at Makurdi and Obubra in 2009 and 2010

	Fruit yield (t ha^{-1})							
	2009		2010		Makurdi		Obubra	
Treatment	Makurdi	Obubra	Makurdi	Obubra	2009	2010	2009	2010
M_oV_1	1.17	1.00	3.10	2.93	3.10	1.47	2.93	1.00
M_oV_2	0.90	0.03	3.53	3.00	3.53	0.90	3.00	0.83
M_5V_1	2.81	3.30	7.33	6.87	7.33	2.80	6.87	3.30
M_5V_2	2.03	2.27	8.43	6.89	8.43	2.03	6.60	2.27
$M_{10}V_1$	6.40	6.67	10.17	8.47	10.17	6.40	8.47	6.67
$M_{10}V_2$	4.53	4.87	10.67	8,13	10.67	4.53	8.13	4.87
$M_{20}V_1$	7.97	4.20	11.00	9.63	11.00	7.97	9.63	7.20
$M_{20}V_2$	6.47	6.17	9.73	8.70	9.73	6.47	8.70	6.17
$\dot{X}$	5.28	5.05	8.42	7.23	8.42	5.28	7.23	5.04
SE±	0.069		0.177		0.35		0.14	

M_0 – M_{20} = *Moringa* Leaves rates at 0, 5, 10 and 20 t ha^{-1}; V_1=Gilo, V_2=Kumba

REFERENCES

Akanbi, O.S. & S.O. Ojeniyi (2007). Effect of Siam weed mulch on soil properties and performance of yam in Southwest Nigeria. *Nigerian Journal of Soil Science* 17: 120-125.

Ano, A.O & J.A. Agwu (2005). Effect of animal manures on selected soil properties (1). *Nigerian Journal of Soil Science* 15:14-19.

Bell, L.C & T. Besho (1993). Assessment of aluminum detoxification by organic matter in a litisol using soil solution characteristic and plant response. In: *Dynamics of Organic*

Matter in Relation to Sustainability of Agricultural Systems. John Wiley and Sons, London. pp 317-330.

Booth, F.E.M. & G.E. Wickens (1988). Non timber uses of selected arid zone trees and shrubs in Africa. FAO Conservation Guide. FAO, Rome. pp 92-101.

Bosch, C.H. (2004). *Moringa oleirefera* Lam. In: Grubben, G.J.H. & O.A. Denton. (Editors). *Plant Resources of Tropical Africa 2. Vegetables.* PROTA Foundation, Wageningen, Netherlands/Backhuys Publishers, Leiden, Netherlands/CTA, Wageningen, Netherlands. pp 392-395.

Chude, V.O. (1998) Understanding Nigeria Soils and their Fertility Management for Sustainable Agriculture. Inaugural lecture delivered at ABU, Zaria on Thursday Nov. 26. 1998. Inaugural lecture series 13.

Davis, A.S., D.F. Jacobs, K.E. Wightman. (2006). Organic matter amendment of fallow forest tree seedlings nursery soils influences soil properties and biomass of sorghums cover crop. Purdue University, West Lafayette, IN 112 – 118.

Duncan, J. (2005). *Composting Chicken Manure*. WUS cooperative Extension, King County Master Gardener and Cooperative Extension Livestock Advisor.

Genstat (2005). Genstat Release 4.24DE (PC/Windows XP), Laves Agricultural Trust (Rothamstal) Experimental Station) Discuring edt. 2.

Gomez, K.A. & A.A. Gomez (1984*). Statistical Procedures for Agricultural Research.* John Wiley and Sons, New York.

Harter, R.D. (2007). *Acid Soils of the Tropics* . ECHO Technical Note. North Fort Myers, USA.

Haynes, R.J. & M.S. Mokolobate (2001). Amelioration of AI toxicity and P deficiency in acid soils by additions of organic residues: A critical review of the phenomenon and the mechanisms involved. *Nutrients Cycling in Agroecosystems* 59: 47-63.

Isitehale, H.H.E. & I.O. Osemota (2010). Residual effect of poultry manure and NPK fertilizer on soil physical properties in the forest and derived savanna soils of Edo State, Nigeria. *Nigerian Journal of Soil Science* 20 (2) 26-34.

Kekong, M.A., S.A. Ayuba & A. Ali (2010). Effect of cow dung and poultry droppings on soil chemical properties and yield of garden egg (*Solanum spp*) in the sub humid guinea savanna and rainforest belts of Nigeria. *Nigerian Journal of Soil Science* 20(1) 97-104.

Lee, C.H., H. Lee, Y.B. Lee, H.H. Chang, M.A. Ali, W. Min, S. Kin & P.J. Kin (2007). Increase of available Phosphorus by Fly-ash application in paddy soils. *Communication in Soil Science and Plant Analysis* 38: 1551-1562.

Naramabuye, F.X. & R.J. Haynes (2006). Short-term effects of three animal manures on soil pH and Al solubility. *Australian Journal of Soil Research* 15:18-24.

Natschner, L. & U. Schwartzmann (1991). Proton buffering in organic horizons of acid forest soils. *Geoderma* 48:93-106.

Ogeh, E.S. (2010). The performance of maize in acid infertile soil amended with municipal tree leaves residue and phosphorus. *Nigerian Journal of Soil Science* 20 (2): 76- 81.

Ojeniyi, S.O., A.O. Adetoro & S.A. Ojedina (1999). Effect of ash on soil fertility nutrients content and yield of Okra. Paper presented at the Horticultural Society of Nigeria conference, Port Harcourt.

Onyekwere, I. N., C.C. Chinaka & U.N. Onyekwere (2005). Exchangeable acidity status in relationship to some physico-chemical properties of some wetland soils of the Niger – Delta. *Proceedings of the 39th Annual eeting of the Agriculture Society of Nigeria* held in Calabar, Nigeria. pp 280 -283.

Page, A.L., R.H. Miller & D.R. Keeney (1982). *Methods of Soil Analysis: Chemical and Microbiological Properties*. American Society of Agronomy, Madison, Wisconsin.

Sanchez P.A. & T.L. Logan (1992). Myths and science about the chemistry and fertility of soils in the Tropics. In: R. Lal and P.A. Sanchez. *Myths and Science of Soils of the Tropics*. Soils Science Society of America Special Publication Number 29, Madison, Wisconsin.

Sanchez, P.A., K..D. Shepherd, M.J. Sonle, F.M. Place, R.J. Buresh, A.M. Izac, A.U. Mokwunye, F.R. Kwesiga, C.G. Nderitu & P.L Woome (1997). Soil fertility replenishment in Africa: an investment in natural resource capital. In: Buresh, R.J., P.A. Sanchez & F. Calhoun (Editors) *Replenishing Soil Fertility in Africa.* Soil Science Society of America, Special publication Number 51, Madison, Wisconsin. pp 1-46.

Sanginga, N., O. Lyasse & B.B. Singh (2000). Phosphorus use efficiency and nitrogen balance of cowpea breeding lines in a low P soil of the derived savanna zone in West Africa. *Plant and Soil Journal* 220: 119 – 128.

Udo, E J., T.O. Ibia, J.O. Ogunwale, A.O. Ano & I. Esu (2009). *Manual of Soil, Plant and Water Analysis*. Sibon Books Ltd. Lagos.

Warman, P.R. (1986). The effect of fertilizer, chicken manure and dairy manure on Timothy yield, tissue composition and soil fertility. *Agricultural Wastes* 18: 289-298.