International Journal of Innovation Sciences and Research
Vol.7, No, 07, pp.1162-1166, July, 2018
Available online at *http://www.ijisr.com*

RESEARCH ARTICLE

Enhancing soil nutrient status and cassava (*Manihiot esculenta Crantz*) performance through integrated application of ammonium sulphate fertilizer and plant residues

***Osundare B. and Balogun, T. J.**

Department of Crop, Soil and Environmental Sciences, Ekiti State University, Ado – Ekiti, Nigeria

Accepted 28th June 2018; Published Online 30th July 2018

ABSTRACT

In view of the limitations or inadequacies of sole use of organic or inorganic fertilizers, hence, there is a dire need to critically appraise the potential of combined application of organic and inorganic fertilizers as a nutrient source to improve soil fertility, and hence, ensure balanced crop nutrition. Consequent upon this, this research was initiated to assess the effects of integrated application of ammonium sulphate fertilizer and residues of *Gliricidia sepium* and *Panicum maximum* on soil chemical properties and cassava (*Manihot esculenta* Crantz) performance. The experiment was carried out at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Nigeria, during 2016 and 2017 cropping seasons. The experiment was laid out in a randomized complete block design, with three replicates. The ammonium sulphate fertilizer and plant residues combination treatments included: sole ammonium sulphate fertilizer (SASF); ammonium sulphate (ASF)+Gliricidia sepium residues (GSR) (ASF+GSR); ammonium sulphate fertilizer+ Panicum maximum residues(PMR) (ASF+PMR) and no fertilizer application (NFA) (i.e.check). The results obtained indicated existence of significant ($P = 0.05$) differences among the different ammonium sulphate fertilizer and plant residues combination treatments as regards their effects on soil chemical properties and cassava root yield. Relative to initial nutrient status of the soil before cropping, at the end of 2016 cropping season, ASF+PMR and ASF+GSR increased soil organic carbon (SOC) by 5 and 15%, respectively, contrasting decreases of 60 and 45% for SAS and NFA, respectively. Similarly, at the end of 2017 cropping season, ASF+PMR and ASF+GSR increased SOC by 12 and 24%, respectively, contrasting decreases of 71 and 60% for SASF and NFA, respectively. At the end of 2016 cropping season, ASF+PMR and ASF+GSR increased total N by 15 and 33%, respectively, contrasting decreases of 30 and 63% for SASF and NFA , respectively. At the end of 2017 cropping season, ASF+PMR and ASF+GSR increased total N by30 and 53%, respectively, contrasting decreases of 43 and 75% for SASF and NFA, respectively. Mean values of cassava root yield data over the two years of experimentation indicated that, integrated application of ammonium sulphate fertilizer and plant residues significantly increased cassava root yield from 3.00 t ha^{-1} for NFA to 3.89, 8.39 and 8.22 t ha^{-1} for the respective SASF, ASF+GSR and ASF+PMR.

Key words: Ammonium, cassava, nutrients, residues, status, sulphate

INTRODUCTION

Agricultural productivity of tropical soils is adversely affected by the inherently low fertility status of the soils, characterized by low – activity - clay (LAC), organic matter, nitrogen, phosphorus, buffering capacities and exchangeable basic cations (Adenle, 2010; Pestov, 2012). Recognizing the constraints or limitations for the utilization of the low- activity-clay tropical soils for continuous crop production has necessitated growing search for professionally sound soil fertility management practices, which in recent time, has included the adoption of appropriate and adequate fertilizer packages, involving the use of organic and/ or inorganic fertilizers (Atete, 2012; Lege, 2012). The use of inorganic or mineral fertilizers in maintaining soil fertility has been reported to be ineffective, due to certain limitations. Some of these limitations include: low efficiency (as a result of losses through volatilization and leaching), declined soil organic matter content, nutrient imbalance, soil acidification, as well as soil physical degradation, with resultant increased incidence of soil erosion (Kader, 2012).

Corresponding author: **Osundare B.,**
Department of Crop, Soil and Environmental Sciences, Ekiti State University, Ado – Ekiti, Nigeria.

Asides, high cost and occasional scarcity of mineral fertilizers have posed a lot of problem to their use as nutrient sources (Guman, 2011). The limitations of the use of mineral fertilizers to improve soil fertility and crop yield has consequently informed shift of attention to the use of organic fertilizers for soil fertility improvement, especially, the highly weathered tropical soils (Ame, 2012; Kader, 2012). However, the use of organic fertilizers, too, has certain demerits of slow release and non – synchronization of nutrient release with period of growth for most short – season crops, as well as being required in large quantities to sustain crop production, which may not readily be available to the small – scale farmers (Kiani *et al*; 2005). Plant residues and other biomass constitute an important resource; as they have a great potential of improving the physical, chemical and biological properties of soil after decomposition (Aribe, 2003; Udeata, 2008; Nottidge *et al*. 2010). Singh (2005) noted that the amount of N, P and K and certain micronutrients contained in the plant residues is 60 times as high as the nutrients applied through mineral or synthetic fertilizers. In view of the limitations of sole application of organic or inorganic fertilizers in improving soil fertility and crop yield, there is a dire need to critically appraise the potential of combined or integrated application of organic and inorganic fertilizers as a nutrient source to improve soil fertility, and hence, ensure balanced crop nutrition. Consequent upon this, this research was initiated to assess the effects of integrated application of ammonium sulphate fertilizer and residues of *Gliricidia sepium* and *Panicum maximum* on soil chemical properties and cassava performance.

MATERIALS AND METHODS

Study site: A field experiment was carried out at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, during 2016 and 2017 cropping seasons. The soil of the study site belongs to the broad group Alfisol (SSS, 2003). The soil was strongly leached, with low to medium organic matter content. Prior to this investigation, the study site had earlier been under intensive and continuous cultivation of a variety of arable crops for many years.

Experimental design and treatments: The experiment was laid out in a randomized complete block design with three replications. The ammonium sulphate fertilizer and plant residues combination treatments included: sole ammonium sulphate fertilizer (SASF); ammonium sulphate (ASF)+ Gliricidia sepium residues (GSR) (ASF+GSR); ammonium sulphate+ Panicum maximum residues(PMR) (ASF+PMR) and no fertilizer application (NFA) (i.e.check). ASF,GSR and PMR were applied at the rates of 260 kg ha^{-1}, 5 and 7 t ha^{-1}, respectively (Awani, 2012; Balogun, 2012; Lege, 2012). Each plot size was 3 m x 3 m.

Collection and analysis of soil samples: Prior to cropping, 35 core soil samples, randomly collected from 0 – 15 cm soil depth, were mixed inside a plastic bucket to form a composite sample, which was analyzed for chemical properties. Similarly, at the end of cropping, another sets of soil samples were collected in each treatment plot and analyzed. The soil samples were air – dried, ground, and passed through a 2 mm sieve. The processed soil samples were analyzed in accordance with the soil analytical procedures, as outlined by the International Institute of Tropical Agriculture (IITA) (1989).

Planting: Planting of cassava was done on March 1 and March 3 in 2016 and 2017, respectively. Stem – cuttings (20 cm long each) of early maturing cassava variety tropical manihot series (TMS 30572), obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, were planted on the flat, at 1 m x 1 m (10,000 cassava plants ha^{-1}). Weeding was carried out at 3, 6 and 9 weeks after planting (WAP), using a hand hoe**.** At harvest, data were collected on cassava root yield and yield components.

Data analysis: All the data collected on soil chemical properties and cassava root yield and yield components were subjected to analysis of variance (ANOVA), and treatment means were compared, using the Duncan Multiple Range Test (DMRT) at 5% probability level.

RESULTS

Chemical composition of plant residues used in the experiment

Table 1 shows chemical composition of plant residues used in the experiment

Table 1. Chemical analysis of plant residues used in the experiment

Nutrient	Value	
	GSR	PMR
Organic carbon (g kg^{-1})	1.24	2.96
Nitrogen (g kg^{-1})	2.64	1.20
C/N ratio	0.47	2.47
Phosphorus (g kg^{-1})	0.60	0.66
Potassium (g kg^{-1})	0.53	0.71
Calcium (g kg^{-1})	0.46	0.82
Magnesium (g kg^{-1})	0.59	0.64
Sodium (g kg^{-1})	0.44	0.58

GSR, *Gliricidia sepium* residue; PMR *Panicum maximum* residue

Chemical properties of soil in the study site prior to investigation: Table 2 shows the chemical properties of soil in the study site before investigation

Table 2. Chemical properties of the soil before investigation

Soil properties	Values
pH	4.8
Organic carbon (g kg^{-1})	0.84
Total nitrogen (g kg^{-1})	0.40
Available phosphorus (mg kg^{-1})	0.66
Exchangeable bases (cmol kg^{-1})	
Potassium	
Calcium	0.44
Magnesium	0. 51
Sodium	0.38
Exchangeable Acidity	0.21
Effective Cation Exchangeable Capacity (ECEC) 1.81	0.27

Chemical properties of the soil as affected by integrated application of plant residues and ammonium sulphate fertilizer after 2016 cropping season: Table 3 shows the effects of integrated application of plant residues and ammonium sulphate fertilizer on soil chemical properties after 2016 cropping season. Relative to initial nutrient status of the soil before cropping, at the end of 2016 cropping season, ASF+GSR and ASF+PMR increased pH of the soil by 71 and 69%, respectively, contrasting decreases of 31 and 17% for SASF and NFA, respectively. ASF+PMR and ASF+GSR increased soil organic carbon (SOC) by 5 and 15%, respectively, contrasting decreases of 60 and 45% for SAS and NFA, respectively. Similarly, ASF+PMR and ASF+GSR increased total N by 15 and 33%, respectively, contrasting decreases of 30 and 63% for SASF and NFA, respectively. ASF+PMR and ASF+GSR increased available P by 6 and 11%, respectively, contrasting decreases of 5 and 8% for SASF and NFA, respectively. ASF+PMR and ASF+GSR increased exchangeable Ca by 6 and 65%, respectively, contrasting decreases of 45 and 41% for SASF and NFA, respectively. Similarly, ASF+PMR and ASF+GSR increased exchangeable Mg by 13 and 29%, respectively, contrasting decreases of 58 and 50% for SAS and NFA, respectively. ASF+PMR and ASF+GSR increased exchangeable Na by 29 and 57%, respectively, contrasting decreases of 76 and 62% for SAS and NFA, respectively. The percentage decreases in exchangeable K, were 80, 86, 46 and 59% for the respective NFA, SASF, ASF+GSR and ASF+PMR.

Chemical properties of the soil as affected by plant residues and ammonium sulphate fertilizer after 2017 cropping season: Table 4 shows the effects of integrated application of plant residues and ammonium sulphate fertilizer on soil chemical properties after 2017 cropping season. Relative to initial nutrient status of the soil before cropping, at the end of

Table 3. Chemical properties of the soil as affected by plant residues and ammonium sulphate fertilizer after 2016 cropping season

Treatments (FC)	pH	Org. C. (g kg^{-1})	Total N (g kg^{-1})	Avail. P (mg kg^{-1})	Exchangeable bases (cmol kg^{-1})			
					K	Ca	Mg	Na
NFA	4.00c	0.46c	0.15d	0.61b	0.09c	0.30c	0.19c	0.08c
SAS	3.30d	0.34d	0.28c	0.63b	0.06c	0.28c	0.16c	0.05c
AS+GSR	8.22a	0.97a	0.53a	0.73a	0.24a	0.60a	0.49a	0.33a
AS+PMR	8.10b	0.88b	0.46b	0.70a	0.18b	0.54b	0.43b	0.27b

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). FC, fertilizer combination NFA, no fertilizer application; SAS, sole ammonium sulphate, AS+GSR, ammonium sulphate+ *Gliricidia sepium* residue; AS+PMR, ammonium sulphate+*Panicum maximum* residue.

Table 4. Chemical properties of the soil as affected by plant residues and ammonium sulphate fertilizer after 2017 cropping season

Treatments (FC)	pH	Org. C. (g kg^{-1})	Total N (g kg^{-1})	Avail. P (mg kg^{-1})	Exchangeable bases (cmol kg^{-1})			
					K	Ca	Mg	Na
NFA	3.60c	0.34c	0.10d	0.59b	0.06c	0.25c	0.15c	0.05c
SAS	3.00d	0.24d	0.23c	0.57b	0.04c	0.23c	0.12c	0.03c
AS+GSR	8.30a	1.04a	0.61a	0.79a	0.28a	0.64a	0.53a	0.37a
AS+PMR	8.15b	0.94b	0.52b	0.76a	0.23b	0.58b	0.48b	0.32b

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). FC, fertilizer combination; NFA, no fertilizer application; SAS, sole ammonium sulphate, AS+GSR, ammonium sulphate+ *Gliricidia sepium* residue; AS+PMR, ammonium sulphate+*Panicum maximum* residue.

Table 5. Cassava root yield and yield components as affected by plant residues and ammonium sulphate fertilizer at harvest

Treatments (FC)	Cassava root yield (t ha^{-1})			Cassava root length (cm)			Cassava root diameter (cm)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
NFA	3.12d	2.89d	3.00	11.50d	11.36d	11.43	7.27d	7.00d	7.14
SAS	3.80c	3.68c	3.89	11.91c	11.73c	12.82	11.07c	10.80c	10.94
AS+GSR	8.26a	8.51a	8.39	23.11a	23.41a	23.16	20.52a	20.89a	20.76
AS+PMR	8.10b	8.34b	8.22	22.90b	23.18b	23.04	20.20b	20.46b	20.33

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). FC, fertilizer combination; NFA, no fertilizer application; SAS, sole ammonium sulphate, AS+GSR, ammonium sulphate+ *Gliricidia sepium* residue; AS+PMR, ammonium sulphate+*Panicum maximum* residue.

2017 cropping season, ASF+GSR and ASF+PMR increased pH of the soil by 73 and 70%, respectively, contrasting decreases of 38 and 25% for SASF and NFA, respectively. ASF+PMR and ASF+GSR increased SOC by 12 and 24%, respectively, contrasting decreases of 71 and 60% for SASF and NFA, respectively. Similarly, ASF+PMR and ASF+GSR increased total N by 30 and 50%, respectively, contrasting decreases of 43 and 75% for SASF and NFA, respectively. ASF+PMR and ASF+GSR increased available P by 15 and 20%, respectively, contrasting decreases of 14 and 11% for SAS and NFA, respectively. ASF+PMR and ASF+GSR increased exchangeable Ca by 14 and 25%, respectively, contrasting decreases of 55 and 51% for SASF and NFA, respectively. Similarly, ASF+PMR and ASF+GSR increased exchangeable Mg by 26 and 39%, respectively, contrasting decreases of 68 and 61% for SASF and NFA, respectively. ASF+PMR and ASF+GSR increased exchangeable Na by 52 and 76%, respectively, contrasting decreases of 86 and 76% for SASF and NFA, respectively. The percentage decreases in exchangeable K were 86, 91, 36 and 48% for the respective NFA, SASF, ASF+GSR and ASF+PMR.

Cassva root yield and yield components as affected by plant residues and ammonium sulphate fertilizer at harvest: Table 5 shows cassava root yield and yield components as affected by plant residues and ammonium sulphate fertilizer at harvest. Mean values of cassava root yield data over the two years of experimentation indicated that, integrated application of plant residues and ammonium sulphate fertilizer significantly increased cassava root yield from 3.00 t ha^{-1} for NFA to 3.89, 8.39 and 8.22 t ha^{-1} for the respective SASF, ASF+GSR and ASF+PMR. Mean values of cassava root length data over the two years of experimentation indicated that integrated application of plant residues and ammonium sulphate fertilizer significantly increased cassava root length from 11.43 cm for NFA to 12.82, 23.16 and 23.04 cm for the respective SASF, ASF+GSR and ASF+PMR. Similarly, mean values of cassava root diameter data over the two years of experimentation indicated that integrated application of plant residues and ammonium sulphate fertilizer significantly increased cassava root diameter from 7.14 cm for NFA to 10.94, 20.71 and 20.33 cm for the respective SASF, ASF+GSR and ASF+PMR.

DISCUSSION

The chemical properties of soil in the study site, prior to cropping indicated that the soil was slightly acidic, with a pH of 4.8. The soil organic carbon (SOC) value of 0.84 k kg^{-1} was below the critical level of 5.8 g kg^{-1} for soils in southwestern Nigeria (Geis, 2012; Awani, 2012). The total nitrogen of 0.40 g kg^{-1} was below the 1.5 g kg^{-1} critical level reported by Atete (2012). The K value of 0.44 cmol kg was below the 0.86 cmol kg critical level reported by Atete (2012). The Ca, Mg and Na values were all below the established critical levels for soils in southwestern Nigeria (Lege, 2012). Relative to the initial nutrient status of the soil, prior to 2016 cropping season, the decreases in the soil pH (i.e. increased acidity), observed in the plots of control and ammonium sulphate (AS) fertilizer treatments, after cropping, agree with the findings of Aina (2008); Dada (2011) and Lege (2012), who reported increased soil acidity (i.e. decreased pH) of soil in the control and AS fertilizer plots, after cropping. The decreases in the pH values of soil in the control and AS fertilizer plots can be ascribed to decreases in exchangeable bases, after cropping. The decreases in the exchangeable bases, associated with the control and AS fertilizer treatments can be attributed to uptake of the exchangeable bases by cassava during the growing period. Much as the decreases in the soil pH, after cropping, observed in the plots of AS fertilizer and the control can be adduced to uptake of the exchangeable bases by cassava, however, another factor that can be implicated for the increased soil acidity, associated with AS fertilizer and the control treatments, is the acidifying effects of ammonium sulphate fertilizer on soil, through release of hydrogen ions (H^+), following oxidation of the ammonium ion (NH_4^+)component of ammonium sulphate fertilizer [$(NH_4)_2SO_4$] (Nana, 2011; Pestov, 2012). Conversely, after cropping, soil pH values increased in the plots of AS+GSR and AS+PMR. These increases in soil pH can be adduced to the release of the exchangeable bases by *Panicum maximum* and *Gliricidia sepium* residues on decomposition. Similar findings had earlier been reported by Nottidge *et al*; (2010) and Balogun (2012), who reported significant increases in soil pH and base saturation due to increases in exchangeable bases, following addition of residues of certain tropical grasses and legumes. These observations suggest that, residues of *Panicum maximum* and *Gliricidia sepium* have liming effects on soil, in addition to enhancing soil fertility or increasing nutrient availability in the soil. The increases in soil organic carbon (SOC), observed in the plots of AS+GSR and AS+PMR can be attributed to increases in soil organic matter (SOM), following decomposition of *Panicum maximum* and *Gliricidia sepium* residues. These observations corroborated the findings of Nottidge *et al*; (2010); Balogun (2012). The higher percentage increase in SOC for AS+GSR than that for AS+PMR, can be ascribed to higher rate of decomposition of *Gliricidia sepium* residues than that of *Panicum maximum* residues, due to lower lignin content (i.e. lower C/ N ratio) (Table 1)of *Gliricidia sepium* residues than that of *Panicum maximum* residues. So, the higher rate of decomposition of *Gliricidia sepium* residues than that of *Panicum maximum* residues may have resulted in higher organic matter content of soil in the plots of AS+GSR, and hence, higher value of SOC.

On the contrary, SOC decreased in the plots of AS fertilizer and control. The decreases in SOC, adduced to AS fertilizer and control treatments can be explained in the light of increased soil acidification (decreased pH), associated with AS fertilizer and control treatments. This is because, previous studies (Nana, 2011; Awani, 2012) had established that, the rate of organic matter decomposition, and hence, SOC value, depends on pH of the soil medium, with the rate of organic matter decomposition by soil microbes decreasing with increasing soil acidity (i. e. decreasing pH). These authors also opined that the rate of organic matter decomposition becomes almost negligible at soil pH value below 5.1. So, the lower pH values (i.e. higher acidity) of soil in the plots of AS fertilizer and control treatments can be implicated for the observed lower SOC values for AS fertilizer and control treatments, since this condition of higher acidity in the plots of AS fertilizer and control treatments may have impaired microbial decomposition of the native organic matter of soil in the plots of AS fertilizer and control treatments, with resultant lower SOC values (Awani, 2012; Pestov, 2012). The decrease in total N for AS fertilizer, after cropping, suggests that, the amount of N supplied in the form of ammonium ion (NH_4^+) by ammonium sulphate fertilizer. Apart from exchangeable K that decreased after cropping, the increases in total N, available P and exchangeable Ca, Mg and Na for AS+GSR and AS+PMR are in conformity with the reports of Aina (2008) and Phi (2012), who reported increases in total N, available P, exchangeable Ca, Mg and Na for AS+GSR and AS+PMR of an Afisol amended with AS+GSR and AS+PMR, after cropping. These observation can be explained in the light of the observed increases in SOC/SOM in the plots of AS+GSR AS+PMR. This is because previous studies (Dada, 2011; Phi, 2012) had established that, the SOM is a reservoir of other nutrient elements, that is, other nutrients are integrally tied to it. Thus, the maintenance of SOM is paramount in sustaining other soil quality factors (Phi, 2012).

The very low percentage decrease in available P, after cropping, compared to other nutrients, recorded in the plots of AS fertilizer and the control, implies low uptake of P by cassava, compared to N and K. The low correlation between soil P and plant – content and yield testifies to the low uptake of P by cassava (Ryi, 2007). The low P uptake by cassava can be attributed to mycorrhizal association, which provides about 10 – 15 ppm P to the soil from fixed P by soil mycorrhizal (Ryi, 2007). The practical implication of the low P uptake by cassava is that, P perhaps, is not a limiting nutrient in the nutrition of cassava, thus, cassava can thrive well in a soil of inherently low native P. After cropping, the observed highest value of percentage decrease in K, compared ton other nutrients, point to indispensability of K in the nutrition of cassava. The huge amount of K removed in cassava tubers at harvest, as well as the significant root yield reduction, associated with K deficiency testify to the indispensability of K in cassava nutrition, especially as regards bulking process (Atete, 2012; Kader, 2012). The higher percentage increases in SOC, total N, available P and exchangeable bases for AS+GSR and AS+PMR at the end of the second year (2017) cropping season, compared to what obtained at the end of the first year (2016) cropping season, can be explained in the light of the residual effects of the first year (2016) *Gliricidia sepium* and *Panicum maximum* residues application, coupled with the additional *Gliricidia sepium and Panicum maximum* residues application in the second year. Similarly, the residual effects of ammonium sulphate fertilizer application in the first year (2016), coupled with the additional ammonium sulphate fertilizer application in the second year (2017) account for the increased acidity (i.e. decreased pH) of soil in the plots of ammonium sulphate fertilizer at the end of the second year cropping. In view of the problem of soil acidity, occasioned by ammonium sulphate fertilizer application, to avert this problem, and achieve sustainability of crop production, hence, application of limes to soil under application of ammonium sulphate fertilizer is strongly recommended.

The significantly higher cassava root yield and yield components for AS+GSR and AS+PMR than that for sole ammonium sulphate fertilizer, are in conformity with the findings of Ausser (2012) and Geis (2012). These observations can be explained in the light of complementary roles of integrated application of organic fertilizers (*Gliricidia sepium* and *Panicum maximum* residues) and inorganic fertilizers (ammonium sulphate fertilizer) in maintaining soil fertility, and hence, enhancing crop productivity. This is because, the complementary use of organic and inorganic fertilizers increases water and nutrient use efficiency, with the organic fertilizer component increasing the organic matter content of the soil, as well as providing certain essential micronutrients which are not present in inorganic fertilizers (Geis, 2012). Futhermore, the complementarity of organic and inorganic fertilizers satisfies immediate nutrient requirements of crops, as the inorganic fertilizer component releases its nutrients faster than the organic fertilizer component, thus, making nutrients more readily available to plants (Geis, 2012; Ausser, 2012). The higher cassava root yield and yield components for AS+GSR and AS+PMR, recorded at the end of the second year (2017), as against what obtained at the end of the first year (2016), can be ascribed to higher soil fertility level in the second year (2017), due to the residual effects of the previous year (2016) application of *Gliricidia sepium* and *Panicum maximum* residues, coupled with the additional application of *Gliricidia sepium* and *Panicum maximum* residues in the second year. On the contrary, cassava root yield in the first year (2016) cropping season under the control treatment was higher than what obtained in the second year (2017) under the control. This can be explained in the light of declined soil fertility in the second year as a result of nutrient removal by cassava in the preceding year (2016).

REFERENCES

Adenle, A.A. 2010. Influence of integrated application of *Gliricidia sepium* residues and poultry manure on nutrient status of an Alfisol and maize yield. *Soil Fertility Research*. 12: 80 – 86.

Aina, P.A. 2008. Tree legume residues effects on soil physical and chemical properties and yield of maize in an Alfisol. *Journal of Applied Science*. 15:33 -40.

Ame, A.D. 2012. Soil physical and chemical properties as affected by legume residues. Soil and *Environmental Research*. 6:22 – 28.

Aribe, M.N. 2003. Soil fertility and maize performance under tillage practices and plant residues management techniques. *Soil Fertility*. 27:200 – 206.

Atete, B.O. 2005. Enhancing fertility of an acid Alfisol and maize performance through integrated application of cattle manure and urea. *Soil Science*. 21(1. 251 -259.

Ausser, P. 2012. Evaluation of fertility status of an Alfisol and maize performance under different plant residue management techniques. *Journal of Agriculture and Forestry*. 11(2):6 – 11.

Awani, U.S. 2012. Organic matter dynamics and maize yield under plant residue management techniques and NPK fertilization. *Soil Resources*. 14:30- 37.

Balogun, J.R. 2012. Assessment of fertility status of an Alfisol under plant residues and NPK Fertilization. *Soil Science*. 13: 6 – 12.

Dada, EO. 2011. Soil organic matter dynamics and cassava performance under plant residue management techniques. *Soil Organic Matter Dynamics*.23: 100 – 106.

Geis, F.O. 2012. Responses of fertility status of an Alfisol and maize performance to plant residue management techniques. *Soil and Land Development*. 22(2):1 -7.

Guman, H.O. 2011. Comparative effects of plant residues on soil and leaf nutrient content and maize yield. *Fertilizer and Environmental Research*. 23:44 – 52.

International Institute of Tropical Agriculture (IITA) (1989). Automated and semi – automated methods soil and plant analysis. *Manual Series*. No 7, IITA, Ibadan, Nigeria.

Kader, B.R. 2012. Phosphorus requirements of groundnut and soybean as affected by N nutrition. Plant Nutrition. 23: 44 – 49.

Kiani, M.J., Abbas, K.M. and Rahim, N. 2005. Use of organic manure with mineral N – fertilizers to increase wheat yield at Rawakalot Azad. *Archives of Agronomy and Soil Science*.51:299 - 309

Lege, B.N. 2012. N, P, and K mineralization and maize grain yield following application of *Gliricidia* sepium residues to an acid Alfisol in southwestern Nigeria. *Soil Fertility and Plant Nutrition*. 21:6 -14

Nana, G.O. 2011. Assessment of the potential of tree prunings in ameliorating degreded Alfisol. *International Journal of Agriculture and Food Technology*. 15(1. 34 -41

Nottidge, D.O., Ojeniyi, S.O. and Asawalam, D.O. 2010. Effects of different woodash levels on nutrient content of maize and geain yield in an acid Alfisol. *Nigerian Journal of Soil Science*.17: 98 - 103

Pestov, J.C. 2012. Responses of fertility status of an Alfisol and maize performance to plant residue management techniques. *Soil and Land Development*. 22(2):1 -7.

Phi, S.U. 2012. Effects of incorporating legume hedgerows prunings on chemical properties of an Alfisol in Nigeria. *Food and Agricultural Research*. 11(1):1 – 7.

Ryi, A.O. 2007. Mineral nutrition of cassava. *Crop Physiology*. 12:6 -11

Singh, P. 2005. Improving soil fertility and maize yield performance through *Chromolaena odorata* residues. *International Journal of Food and Agricultural Research*. 10(2. 60- 70.

Soil Survey Staff (SSS. Keys to soil taxonomy, 9th edition. USDA Natural Resources Conservation Services, US Department of Agriculture, Washington D.C.306 pp.

Udeata, F. 2008. N mineralization and maize yield, following application of tree prunings to a sandy loam soil in Nigeria. *Agroforestry Systems*. 21(2. 212 – 219.

****