International Journal of Forestry and Crop Improvement
Volume **4** | Issue 1 | June, 2013 | 6-12

Research Article

Assessment of organic and inorganic soil amendments on fertility status of an acid alfisol and performance of cocoyam (*Zanthosoma sagittifolium*)

B. OSUNDARE

ABSTRACT : The non – sustainability of the practice of soil fertility maintenance through bush fallow, due to increasing population pressure and demand for land for agricultural and other human activities, as well as the problem of soil fertility depletion, occasioned by continuous cultivation, have necessitated growing search for alternative soil fertility maintenance options, with a view to solving the current problem of acute shortage of food supply that grips Nigeria. To this end, a two – year field experiment was conducted in 2010 and 2011 cropping seasons, at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, to evaluate the influence of *Gliricidia sepium* residues, NPK (15 – 15 – 15) fertilizer, and their combination on the chemical properties of an acid Alfisol, growth and yield of cocoyam (*Zanthosoma sagittifolium*).The experiment was laid out in a randomized complete block design with three replicates. The soil amendments included: *Gliricidia sepium* residues (GSR); NPK fertilizer; GSR + NPK; and no fertilizer (NF), which served as the control treatment. The results obtained indicated existence of significant (P = 0.05) differences among the soil amendments as regards their effects on soil chemical properties, growth, yield and yield components of cocoyam. At the end of 2010 cropping season, application of the fertilizer treatments resulted in significant (P = 0.05) increases in soil organic carbon (SOC) from 0.63 g kg^{-1} for NF to 1.04, 1.40, and 1.32 g kg^{-1} for sole NPK, sole GSR and GSR + NPK, respectively. Similarly, at the end of 2011 cropping season, fertilizer treatments significantly increased SOC from 0.43 g kg^{-1} for NF to 0.88, 1.51 and 1.40 g kg^{-1} for the respective sole NPK, sole GSR and GSR + NPK. At the end of 2010 cropping season, soil amendments significantly increased total N from 0.20 g kg^{-1} for NF to 0.44, 0.57 and 0.66 g kg^{-1} for the respective sole NPK, sole GSR and GSR + NPK. Similarly, at the end of 2011 cropping season, addition of the soil amendments resulted in significant increases in total N from 0.08 g kg^{-1} for NF to 0.36, 0.64 and 0.71 g kg^{-1} for sole NPK, sole GSR and GSR + NPK, respectively. Combining the mean values of cocoyam cormel yield data over the two years of experimentation, soil amendments significantly increased cocoyam cormel yield from 4.26 t ha^{-1} for NF to 8.05, 7.23 and 8.85 t ha^{-1} for sole GSR, sole NPK and GSR + NPK, respectively.

KEY WORDS : Acid, Alfisol, Amendments, Cocoyam, Fertility, Inorganic, Organic

How to cite this Article : Osundare, B. (2013).Assessment of organic and inorganic soil amendments on fertility status of an acid alfisol and performance of cocoyam (*Zanthosoma sagittifolium*). *Internat. J. Forestry & Crop Improv.*, **4** (1) : 6-12.

Article Chronical : Received : *03.05.2013;* Revised : *12.05.2013;* Accepted : *21.05.2013*

INTRODUCTION

One of the major constraints to crop production in the tropics is the inherently low soil fertility status, characterized by low activity clay, organic matter, nitrogen, phosphorus and exchangeable bases (Vanlauwe *et al.*, 2000; Bååth and Arnebrant, 1995). The limitations of the utilization of the low activity clay (LAC) tropical soils for continuous crop production have necessitated growing search for professionally efficient soil fertility improvement practices, which in recent time, have included adoption of appropriate

AUTHOR FOR CORRESPONDENCE
B. OSUNDARE, Department of Crop, Soil and Environmental Sciences, Ekiti State University, Ado-Ekiti, NIGERIA
Email : biodunosundare@yahoo.com

and adequate fertilizer packages, involving the use of organic and / or inorganic fertilizers (Eghball, 2002). The use of inorganic or mineral fertilizers in improving and maintaining soil fertility has been reported to be ineffective, due to certain limitations. Some of these limitations include: low efficiency (due to loss of nutrients through volatilization and leaching), declined soil organic matter content, nutrient imbalance, soil acidification, as well as soil physical degradation and attendant increased incidence of soil erosion. Besides, high cost and occasional scarcity of mineral fertilizers have posed a lot of problem to their use as nutrient sources.

The limitations of the use of mineral fertilizers to improve soil fertility has consequently resulted in shift of attention to the use of organic fertilizers for soil fertility improvement, especially the highly weathered tropical soils. 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 – term 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).

The return of plant residues to the soil is the main component of fallowing, which results in accumulation of nutrients, increases in organic matter with resultant improvement of soil physical, chemical and biological properties. Plant residues and other biomass constitute an important resource; as they have a potential of improving and maintaining soil fertility after decomposition. Plant residue management, with respect to the quantity and quality of biomass applied to the soil, has a significant impact on soil quality, resilience, as well as agronomic productivity.

Traditionally, soil fertility maintenance in Nigeria, and most West African countries, has been through shifting cultivation and bush fallow. The fallow period, however, has been drastically reduced as a result of increasing population pressure and demand for land for agricultural and other human activities. Consequent upon this, there has been increasing problem of soil nutrient depletion due to continuous cultivation, which has been identified as a major cause of decreased crop yield and per capita food production in Nigeria. There is, therefore, a dire need to critically evaluate the potentials of certain external soil amendments in forms of inorganic and organic fertilizers (green manure, compost manure, farmyard manure etc) to improve or ameliorate the severely degraded Nigerian soils, hence, raising the present level of productivity of these soils. With these ideas in view, a two – year field trial was carried out to evaluate the influence of *Gliricidia sepium* residues, NPK fertilizer, and *Gliricidia sepium* residues + NPK fertilizer on fertility status of an acid Alfisol, growth and yield of cocoyam.

EXPERIMENTAL METHODS

Study site:

A two – year field experiment was conducted at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, during 2010 and 2011 cropping seasons. The soil of the study site belongs to the broad group Alfisol (SSS, 2003). The site had earlier been cultivated to arable crops, among which were maize, cassava, sweet potato, cocoyam, melon etc before it was allowed to fallow for four years. During the fallow period, cattle, sheep, and goat used to graze on the fallow land. At the commencement of this study, the fallow vegetation was manually cleared, after which the land was ploughed and harrowed.

Collection and analysis of soil samples:

Prior to 2010 cropping season, ten core soil samples, randomly collected from 0 – 15 cm soil depth, were bulked inside a plastic bucket to form a composite sample, which was analyzed for chemical properties. At the end of 2010 and 2011 cropping seasons, 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). The chemical analysis of the *Gliricidia sepium* residues used in the experiment was also carried out (Table1).

Experimental design and treatments:

The experiment was laid out in a Randomized Complete Block Design with three replications. The soil amendments included: *Gliricidia sepium* residues (GSR); NPK fertilizer; GSR + NPK; and no fertilizer (NF), which served as the control treatment.

The *Gliricidia sepium* residues, applied at the rate of 6.60 t ha^{-1} were worked into the soil, two weeks before planting (WBP). The NPK 15 – 15 – 15 fertilizer was applied in two split doses, at two and four months after planting (MAP) at the rate of 400 kg ha^{-1}. Each plot size was 4 m x 4 m.

Planting, weeding, collection and analysis of data:

Planting was done on March 1 and March 3 in 2010 and 2011, respectively. Whole cocoyam corms of 150 g each, obtained from the Institute of Agricultural Research and Training (IAR&T), Ibadan, Oyo State, Nigeria, were used as planting setts, planted at 1 m x 1 m (10,000 cocoyam plants ha^{-1}). Weeding was done manually at 1, 2, 3 and 4 MAP, using a hoe. Leaf area was determined in accordance with the procedures outlined by Faw (2013) and Rafa (2013). At harvest (8 MAP), data were collected on cormel yield and yield components. All the data collected were subjected to analysis of variance (ANOVA), and treatment means were compared, using the Duncan Multiple Range Test (DMRT) at 5% level of probability.

EXPERIMENTAL RESULTS AND ANALYSIS

Table 1 shows the chemical properties of soil in the study site prior to 2010 cropping season and chemical composition of the *Gliricidia sepium* residues used in the experiment.

Changes in soil chemical properties after 2010 and 2011 cropping seasons:

Soil chemical properties as affected by the soil amendments at the end of 2010 and 2011 cropping seasons are presented in Tables 2 and 3. At the end of 2010 cropping season, soil amendments significantly increased soil pH from 4.10 for NF to 8.00, 10.00 and 8.76 for sole NPK, sole GSR and GSR + NPK, respectively. Similarly, at the end of 2011cropping season, soil amendments significantly increased soil pH from 3.51 for NF to 6.61, 10.66 and 8.89 for the respective sole NPK, sole GSR and GSR + NPK. At the end of 2010 cropping season, soil amendments significantly increased soil organic carbon (SOC) from 0.61 g kg^{-1} for NF to 1.04, 1.40 and1.32 g kg^{-1} for sole NPK, sole GSR and GSR + NPK, respectively. At the end of 2011 cropping season, soil amendments significantly increased SOC from 0.43 g kg^{-1} for NF to 0.88, 1.51 and 1.40 g kg^{-1} for sole NPK, sole GSR and GSR + NPK, respectively. At the end of 2010 cropping season, soil amendments significantly increased total N from 0.20 g kg^{-1} for NF to 0.44, 0.57 and 0.66 g kg^{-1} for the respective sole NPK, sole GSR and GSR + NPK. At the end of 2011 cropping season, soil amendments significantly increased total N from 0.08 g kg^{-1} for NF to 0.36, 0.64 and 0.71 g kg^{-1} for sole NPK, sole GSR and GSR + NPK, respectively. At the end of 2010 cropping season, soil amendments significantly increased available P from 0.65 mg kg^{-1} for NF to 0.73, 0.89 and 0.81 mg kg^{-1} for sole NPK, sole GSR and GSR + NPK, respectively. Similarly, at the end of 2011 cropping season, soil amendments significantly increased available from 0.61 mg kg^{-1} for NF to 0.70, 0.90 and 0.83 mg kg^{-1} for the respective sole NPK, sole GSR and NPK + GSR. At the end of 2010 cropping season, soil amendments significantly decreased exchangeable Al from 0.80 cmol kg^{-1} for NF to 0.68, 0.40 and 0.53 cmol kg^{-1} for sole NPK, sole GSR and GSR + NPK, respectively. Similarly, at the end of 2011 cropping season, soil amendments significantly decreased exchangeable Al from 0.84 cmol kg^{-1} for NF to 0.73, 0.35 and 0.47 cmol kg^{-1} for sole NPK, sole GSR and NPK + GSR, respectively. At the end of 2010 cropping season, soil amendments significantly increased exchangeable K from 0.21 cmol kg^{-1} for NF to 0.47, 0.60 and 0.51cmol kg^{-1} for the respective sole NPK, sole GSR and NPK + GSR. Similarly, at the end of 2011 cropping season, soil amendments significantly increased exchangeable K from 0.09 cmol kg^{-1} for NF to 0.30, 0.71 and0.63 cmol kg^{-1} for sole NPK, sole GSR and NPK + GSR, respectively. At the end of 2010 cropping season, soil amendments significantly increased exchangeable Ca from 0.20 cmol kg^{-1} for NF to

Table 1 : The chemical properties of soil in the study site before 2010 cropping season and chemical composition of the *Gliricidia sepium* residues used in the experiment

Soil		*Gliricidia sepium* residues	
pH	5.20	Organic carbon (g kg^{-1})	0.81
Organic carbon (g kg^{-1})	1.89	Total nitrogen (g kg^{-1})	1.56
Total nitrogen (g kg^{-1})	0.69	C/N ratio	0.52
Available phosphorous (mg kg^{-1})	0.69	Phosphorus (g kg^{-1})	0.46
Exchangeable Aluminium (cmol kg^{-1})	0.72	Potassium (g kg^{-1})	0.50
Exchangeable bases (cmol kg^{-1})		Calcium (g kg^{-1})	0.41
Potassium	0.70	Magnesium (g kg^{-1})	0.59
Calcium	0.65	Sodium (g kg^{-1})	0.37
Magnesium	0.59		
Sodium	0.41		
Exchangeable acidity	0.29		
Effective Cation Exchangeable Capacity (ECEC)	2.64		
Micro – nutrients (mg kg^{-1})			
Copper	2.76		
Zinc	2.61		
Manganese	2.58		
Iron	2.56		

0.29, 0.49 and 0.40 cmol kg^{-1} for sole NPK, sole GSR and NPK + GSR, respectively. At the end of 2011 cropping season, soil amendments significantly increased exchangeable Ca from 0.11 cmol kg^{-1} for NF to 0.18, 0.61and 0.52 cmol kg^{-1} for the respective sole NPK, sole GSR and NPK + GSR. At the end of 2010 cropping season, soil amendments significantly increased exchangeable Mg from 0.18 cmol kg^{-1} for NF to 0.27, 0.45, 0.40 cmol kg^{-1} for sole NPK, sole GSR and NPK + GSR, respectively. Similarly, at the end of 2011 cropping season, soil amendments significantly increased exchangeable Mg from 0.06 cmol kg^{-1} for NF to 0.19, 0.48 and 0.43 cmol kg^{-1} for sole NPK, sole GSR and NPK + GSR, respectively. At the end of 2010 cropping season, soil amendments significantly increased exchangeable Na from 0.13 cmol kg^{-1} for NF to 0.24, 0.38 and 0.31 cmol kg^{-1} for the respective sole NPK, sole GSR and NPK + GSR. Similarly, at the end of 2011 cropping season, soil amendments significantly increased exchangeable Na from 0.04 cmol kg^{-1} for NF to 0.10, 0.52 and 0.43 cmol kg^{-1} for sole NPK, sole GSR and NPK + GSR, respectively. At the end of 2010 cropping season, soil amendments significantly decreased Cu from 2.65 mg kg^{-1} for NF to 2.54, 2.37 and 2.48 mg kg^{-1} for the respective sole NPK, sole GSR and NPK + GSR. Similarly, at the end of 2011 cropping season, soil amendments significantly decreased Cu from 2.70 mg kg^{-1} for NF to 2.60, 2.31 and 2.42 mg kg^{-1} for sole NPK, sole GSR and NPK + GSR. At the end of 2010 cropping season, soil amendments significantly decreased Zn from 2.49 mg kg^{-1} for NF to 2.41, 2.24 and 2.33 mg kg^{-1} for sole NPK, sole GSR and NPK + GSR, respectively. At the end of 2011 cropping season, soil amendments significantly decreased Zn from 2.54 mg kg^{-1} for NF to 2.48, 2.18 2.25 mg kg^{-1} for sole NPK, sole GSR and NPK + GSR, respectively. At the end of 2010 cropping season, soil amendments significantly decreased Fe from 2.42 mg kg^{-1} for NF to 2.19, 1.97 and 2.10 mg kg^{-1} for the respective sole NPK, sole GSR and NPK + GSR. At the end of 2011 cropping season, soil amendments significantly decreased Fe from 2.47 mg kg^{-1} for NF to 2.24, 1.86 and 2.03 mg kg^{-1} for sole NPK, sole GSR and NPK + GSR, respectively. At the end of 2010 cropping season, soil amendments significantly decreased Mn from 2.36 mg kg^{-1} for NF to 2.00, 1.70 and 1.87 mg kg^{-1} for the respective sole NPK, sole GSR and NPK + GSR. At the end of 2011 cropping season, soil amendments significantly decreased Mn from 2.41 mg kg^{-1} for NF to 2.09, 1.61 and 1.76 mg kg^{-1} for sole NPK, sole GSR and NPK + GSR, respectively.

Cocoyam leaf area:

Cocoyam leaf area as affected by soil amendment treatments is presented in Table 4. On the two – year average, soil amendments significantly increased cocoyam leaf area from 3.02 m^2 plant^{-1} for NF to 3.70, 3.59 and 3.91 m^2 plant^{-1} for sole GSR, sole NPK and GSR + NPK, respectively.

Cocoyam cormel and corm yield:

Table 5 shows the effects of soil amendments on cocoyam cormel and corm yield at harvest. The mean cocoyam yield data indicated that, soil amendments significantly increased cocoyam cormel yield from 4.26 t ha^{-1} for NF to 8.05, 7.23 and 8.85 t ha^{-1} for sole GSR, sole NPK and GSR + NPK, respectively. Similarly, soil amendment treatments significantly increased cocoyam corm yield from 6.56 t ha^{-1} for NF to 9.29, 8.76 and 9.62 t ha^{-1} for the respective sole GSR, sole NPK and GSR + NPK.

Length and diameter of cocoyam cormel:

Table 6 shows the effects of soil amendment treatments on length and diameter of cocoyam cormels at harvest. The

Table 2: Chemical properties of the soil as affected by soil amendment treatments after 2010 cropping season

Treatments	pH	Org. C (g kg^{-1})	Total N (g kg^{-1})	Avail. P (mg kg^{-1})	Exch. Al (cmol kg^{-1})	Exchangeable bases (cmol kg^{-1})				Micro – nutrients (mg kg^{-1})			
						K	Ca	Mg	Na	Cu	Zn	Fe	Mn
No fertilizer (NF)	4.10d	0.63d	0.20d	0.65d	0.80a	0.21d	0.20d	0.18d	0.13d	2.65a	2.49a	2.42a	2.36a
Sole NPK	8.00c	1.04c	0.44c	0.73c	0.68b	0.42c	0.29c	0.27c	0.24c	2.54b	2.41b	2.19b	2.00b
Sole GSR	10.00a	1.40a	0.57b	0.89a	0.40d	0.60a	0.49a	0.45a	0.38a	2.37d	2.24d	1.97d	1.70d
NPK +GSR	8.76b	1.32b	0.66a	0.81b	0.53c	0.51b	0.40b	0.40b	0.31b	2.48c	2.33c	2.10c	1.87c

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). GSR = *Gliricidia sepium* residues

Table 3 : Chemical properties of the soil as affected by soil amendment treatments after 2011 cropping season

Treatments	pH	Org. C (g kg^{-1})	Total N (g kg^{-1})	Avail. P (mg kg^{-1})	Exch. Al (cmol kg^{-1})	Exchangeable bases (cmol kg^{-1})				Micro – nutrients (mg kg^{-1})			
						K	Ca	Mg	Na	Cu	Zn	Fe	Mn
No fertilizer (NF)	3.51d	0.43d	0.08d	0.61d	0.84a	0.09d	0.11d	0.06d	0.04d	2.70a	2.54a	2.47a	2.41a
Sole NPK	6.61c	0.88c	0.36c	0.70c	0.73b	0.30c	0.18c	0.19c	0.10c	2.60b	2.48b	2.24b	2.09b
Sole GSR	10.66a	1.51a	0.64b	0.90a	0.35d	0.71a	0.61a	0.48a	0.52a	2.31d	2.18d	1.86d	1.61d
NPK +GSR	8.87b	1.40b	0.71a	0.83b	0.47c	0.63b	0.52b	0.43b	0.43b	2.42c	2.25c	2.03c	1.76c

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). GSR = *Gliricidia sepium* residues

two – year average value of cocoyam cormel length indicated that, soil amendments significantly increased cocoyam cormel length from 14.25 cm for NF to 17.84, 16.04 and 18.88 cm for sole GSR, sole NPK and GSR + NPK, respectively. Similarly, soil amendments significantly increased cocoyam cormel diameter from 7.56 cm for NF to 9.85, 8.85 and 10.52 cm for the respective sole GSR, sole NPK and GSR + NPK.

With reference to the control treatments, the significant increases in soil pH (*i .e.* decreasing acidity), after 2010 and 2011 cropping seasons, observed in the plots of *Gliricidia sepium* residues, NPK fertilizer, and NPK fertilizer + *Gliricidia sepium* residues, agree with the findings of Silora and Enkiri (2000), who reported that application of the afore – mentioned soil amendments resulted in significant increases in pH of an acid alfisol after cropping. The lowest pH value of soil in the check plots, can be ascribed to the lowest values of the exchangeable bases in the check plots. The lowest values of the exchangeable bases in the control plots can be attributed to exhaustive uptake of the exchangeable bases by cocoyam during the growing period. Sole application of *Gliricidia sepium* residues resulted in the highest soil pH value after cropping, suggesting greatest liming effects of *Gliricidia sepium* residues, compared to those of other soil amendments. This observation implies that, application of *Gliricidia sepium* residues, apart from enhancing soil fertility through nutrient release, it can also help in correcting soil acidification. The significantly lower pH values of soil in the NPK fertilizer plots than that of the soil in the *Gliricidia sepium* residues plots can be attributed to acidifying effects of NPK fertilizer. The acidifying effects of NP K fertilizer can be ascribed to its acid – forming nature, due to its N and P content.

The significant increases in soil organic carbon (SOC), related to the control treatment, adduced to *Gliricidia sepium* residues, corroborate the results of Sikora and Enkiri (2000), who reported significant increases in SOC after cropping, following application of *Gliricidia sepium* residues. These observations can be ascribed to increase in soil organic matter (SOM), resulting from decomposition of the *Gliricidia sepium* residues.The significantly lower SOC value for NPK fertilizer, compared to what obtained for sole *Gliricidia sepium* residues, can be explained in the light of the lower pH value or higher acidity of soil in the NPK fertilizer plot. This is because, previous studies had established correlation between the rate of soil organic matter decomposition and pH of the soil medium, with the rate of organic matter decomposition decreasing with decreasing pH (*i.e.* increasing acidity) of the soil medium. These authors also added that, the rate of organic matter decomposition becomes negligible at soil pH value below 5.1. So, the lower pH value (higher acidity) of soil in the NPK fertilizer plots can be implicated for the observed lower SOC value for NPK fertilizer treatment, since this condition of lower pH value may have inhibited microbial decomposition of organic matter of soil in the NPK fertilizer plots, with resultant lower SOC value. This implies that, liming (reduction of soil acidity) can indirectly influence nutrient availability in the soil system through its effects on soil pH, which in turn, determines the rate of decomposition and subsequent mineralization regimes of organic matter in the soil system.

The highest total N value, adduced to GSR + NPK can be ascribed to the release of more N by both *Gliricidia sepium* residues and NPK fertilizer. The lowest available P value, associated with the control treatment can be attributed to the lowest pH value of soil in the check plots. This is because, the availability of P in the soil, depends on the pH of the soil

Table 4: Cocoyam leaf area as influenced by soil amendments

	Cocoyam leaf area (m^2 $plant^{-1}$)						
	2 MAP		4 MAP		6 MAP		
Treatments	2010	2011	2010	2011	2010	2011	Mean
No fertilizer (NF)	2.41c	2.51c	3.01d	3.11d	3.51d	3.58d	3.02
Sole NPK	2.95a	2.99a	3.71c	3.88c	4.00c	4.08c	3.59
Sole GSR	2.81b	2.89b	3.93b	3.97b	4.27b	4.34b	3.70
NPK +GSR	2.97a	3.04a	4.20a	4.28a	4.47a	4.51a	3.91

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). GSR = *Gliricidia sepium* residues; MAP = Months after planting

Table 5: Cocoyam cormel and corm yield as influenced by soil amendments at harvest

Treatments	Cocoyam cormel yield (t ha^{-1})			Cocoyam corm yield (t ha^{-1})		
	2010	2011	Mean	2010	2011	Mean
No fertilizer (NF)	4.21d	4.31d	4.26	6.51d	6.61d	6.56
Sole GSR	8.00b	8.10b	8.05	9.24b	9.33b	9.29
Sole NPK	7.21c	7.25c	7.23	8.71c	8.80c	8.76
NPK +GSR	8.81a	8.88a	8.85	9.58a	9.65a	9.62

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). GSR = *Gliricidia sepium* residues

medium, with available P decreasing with decreasing pH. The decreasing available P phenomenon, associated with increasing acidity or decreasing pH, is due to the conversion of P into unavailable forms under acid soil conditions as a result of fixation by Fe and Al, which abound in acid soils. The highest value of exchangeable Al, adduced to the control treatment, can be ascribed to the least pH value of soil in the control plots. This is because, the availability of exchangeable Al depends on the pH of the soil medium, with exchangeable Al value decreasing with increasing pH (*i.e.* decreasing acidity). The decrease in exchangeable Al, associated with increasing pH can be adduced to precipitation of aluminium hydroxide [$Al(OH)_3$], which occurs at increased soil pH. Aluminium exists in the soil as insoluble aluminium hydroxide [$Al(OH)_3$] at soil pH above 6.00. The highest concentration of the micro – nutrients (Cu, Zn, Mn and Fe), recorded in the check plots can be attributed to the lowest pH value of soil in the check plots. Availability of the micro – nutrients in the soil and the pH of the soil medium, with their (micro – nutrients) availability increasing with decreasing soil pH (*i.e.* increasing acidity). Thus, the lowest pH value of soil in the check plots accounts for the observed highest concentrations of micro – nutrients of soil in the control plots.

The higher values of pH, SOC, total N, exchangeable bases and available P, recorded in the plots of sole GSR and GSR + NPK at the end of the second year (2011) cropping season, compared to what obtained at the end of the first year (2010) cropping season, can be ascribed to the residual effects of application of *Gliricidia sepium* residues during the first year, coupled with additional application of the residues of *Gliricidia sepium* in the second year.

The very slight decrease in available P value after cropping, compared to other nutrient elements, observed under all the soil amendments, suggests that, cocoyam did not remove much P, unlike N and K, from the soil during the growing period. The low correlation between soil P and plant – content and yield testifies to the low P uptake in cocoyam. The practical implication of the low P uptake in cocoyam is that, P perhaps, is not a limiting nutrient element in mineral nutrition of cocoyam, thus, cocoyam can thrive well in a P - deficient soil or soil of inherently low P.

The highest cocoyam cormel yield and yield components, adduced to integrated application of *Gliricidia sepium* residues and NPK fertilizer, highest cocoyam cormel yield and yield components under integrated application of *Gliricidia sepium* residues and NPK fertilizer. These observations point to the superiority of integrated application of *Gliricidia sepium* residues and NPK fertilizer to sole application of *Gliricidia sepium* residues and sole application of NPKfertilizer. The superiority can be explained in the light of the complementary roles of combined application of organic fertilizer (*Gliricidia sepium* residues) and inorganic fertilizer (NPK fertilizer) in improving soil fertility, and hence, enhancing crop yield. 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, providing certain essential micro – nutrients, which are not present in inorganic fertilizers, as well as preventing Aluminium toxicity due to increased soil pH and base saturation. Asides, the complementarity of integrated application of organic and inorganic fertilizers satisfies immediate nutrient requirements of crops, as the inorganic fertilizer component releases its nutrients faster than the organic fertilizer counterpart, thus, making nutrients more readily available to crops. In view of the best growth and yield performance of cocoyam that attended integrated application of *Gliricidia sepium* residues and NPK fertilizer, the recommendation of an adequate fertilizer package, involving a judicious and balanced combination of organic and inorganic fertilizers for cocoyam cultivation is imperative. The higher values of growth, yield and yield components of cocoyam, adduced to all the soil amendment treatments at the end of second year (2011) cropping season, compared to what obtained at the end of first year (2010) cropping season, can be attributed to the release of more plant nutrients in the second year, due to the residual effects of the previous year (2010) application of the soil amendments, coupled with the additional soil amendments application in the second year (2011).

Conclusions:

At the end of both cropping seasons, values of the growth, yield and yield components of cocoyam under the soil amendment treatments can be ranked as: NF < sole NPK < sole GSR < NPK + GSR. At the end of both cropping seasons,

Table 6 : Length and diameter of cocoyam cormels as influenced by soil amendments at harvest

	Cocoyam cormel length (cm)			Cocoyam cormel diameter (cm)		
Treatments	2010	2011	Mean	2010	2011	Mean
No fertilizer (NF)	14.20d	14.29d	14.25	7.51d	7.60d	7.56
Sole GSR	17.80b	17.87b	17.84	9.81b	9.88b	9.85
Sole NPK	16.00c	16.08c	16.04	8.80c	8.89c	8.85
NPK +GSR	18.84a	18.91a	18.88	10.49a	10.54a	10.52

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). GSR = *Gliricidia sepium* residues

values of the exchangeable bases, pH, soil organic carbon and available P under the soil amendments can be ranked as: NF < sole NPK < NPK + GSR < sole GSR. At the end of both cropping seasons, values of the micro – nutrients, adduced to the soil amendments can be ranked as: sole GSR < NPK + GSR < sole NPK < NF.

REFERENCES

Bååth, E. and Arnebrant, K. (1995). Growth rate and response of bacterial communities to pH in limed and ash-treated forest soils. *Soil Biol. Biochem.,* **26** : 995-1001.

Eghball, B. (2002). Soil properties as influenced by phosphorus- and nitrogen-based manure and compost applications, *Agron. J.,* **94** : 128-135.

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

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 (3) : 299 – 309.

Sikora, L.J. and Enkiri, N.K. (2009). Efficiency of compost – fertilizer blends compared with fertilizer alone. *Soil Sci.,* **165** (5) : 444 – 451.

Soil Survey Staff (SSS)(2003). Keys to soil taxonomy, 9th edition. United States Department of Agriculture. Natural Resources Conservation Services, US Department of Agriculture, Washington D. C. 306 pp.

Vanlauwe, B., Aihou, K., Aman, S., Tossah, B.K., Diels, J., Lyasse, O., Hauser, S., Sanginga, N., Merckx, R. (2000). Nitrogen and phosphorus uptake by maize as affected by particulate organic matter quality, soil characteristics, and land use history for soils from the West African moist savanna zone. *Biol. & Fertility Soils,* **30** : 440-449.