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Comparative Effect of Poultry Manure, Ash and NPK Fertilizer on Soil Chemical Properties and Trifoliate Yam (*Dioscorea dumetorum*) Performance in an Alfisol of Southwestern Nigeria

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ABSTRACT

The decline in soil fertility is a fundamental impediment to agricultural growth and food production. This has necessitated the growing search for efficient soil fertility improvement practices. The field experiment was conducted in Akure during the major cropping seasons of 2013 and 2014 to assess the effect of different amendments on the chemical properties of an Alfisol using trifoliate yam (Dioscorea dumetorum) as a test crop. The experiment was laid out in a randomized complete block design with three replications. The treatments were Poultry Manure (PM) at 20tha-1, Wood Ash (WA) at 20tha-1, NPK 15:15:15 at 400kgha-1 and a Control (CTRL) (no soil amendment). Data collected on soil chemical properties and crop growth and yield performance were subjected to analysis of variance (ANOVA) with the means separated using Duncan Multiple Range Test (DMRT). Results of this study indicated that WA increased the number of leaves, vine length, tuber length and tuber weight of yam and also improved soil pH, OC, N, P, K, Ca and Mg compared with the CTRL (control). NPK did not increase the yield of trifoliate yam but improved the soil nutrient concentrations compared with the CTRL (control). Relative to the control, WA increased the tuber weight by 14% in 2013 and 34% in 2014 respectively. Compared with NPK fertilizer, WA improved tuber yield of trifoliate by 17% in 2013 and 31% in 2014 respectively. Wood Ash amendment applied at 20 t/ha gave the highest yam tuber yield compared with other treatments and therefore recommended for yam production on an Alfisol for improving soil fertility conditions and sustained productivity.

Keywords: *Amendments, Alfisol, Trifoliate yam.*

1. INTRODUCTION

Continuous use of agricultural land for crop production as a result of increasing population has led to low fertility and soil degradation in Africa especially in alfisols. (Lal, 1987; Lume, 2013). As a result of these, cultivation of tropical soils requires application of amendments, either of synthetic or organic sources, to supplement soil nutrients as well as to increase crop production. Over the years, various researches have been centered on developing efficient soil fertility improvement practices (Atete, 2012) which involve the application of organic and inorganic nutrient sources in solving majority of associated problems limiting alfisols production in the tropics (Ojeniyi 2002; Nwite *et. al.*, 2016). The use of inorganic fertilizers has also been linked with some soil problems like soil acidification, soil degradation leading to soil erosion, nutrient imbalance as a result of high volatilization and leaching of nutrients (Awodun and Olafusi, 2007; Sekar, 2013) . Some other reasons hindering farmers from the use of inorganic fertilizers in improving soil fertility are scarcity and high cost (Lege, 2012; Exma, 2012). There is, therefore, a dire need to explore other nutrient source in improving fertility status in order to increase the present yield of crop. Consequent upon this, the sole use of organic or inorganic source of nutrients to improve soil fertility has been accorded enough research attention in Nigeria. However, in view of the high cost and non – availability of inorganic fertilizers in Nigeria, it is thus, imperative to critically assess the potential of readily available and cheap organic fertilizers, as nutrient sources to improve soil fertility and ensure balanced crop nutrition with attendant high crop yield. To this end, this study was designed to evaluate the effect of application of poultry manure, wood ash and inorganic fertilizers on fertility status of an Alfisol and performance of trifoliate yam.

2. Materials and methods

2.1 Site description

This trial took place at the Teaching and Research Farm of the Federal Universtiy of Technology, Akure (Lat. 5^o 18' E, Long. 7^o 17' N), Nigeria. The site is a well-drained deep red Alfisol in the tropical zone. There are two rainy seasons, one from March to July and the other from mid-August to November, with temperature ranging from 24 to 32^{o}C and annual rainfall in Akure is about 1500mm. The study site had been under continuous cultivation of a variety of arable crops, among which was cassava, maize, melon, cocoyam, sweet potato, prior to the commencement of this study.

2.2 Field layout and treatments

Based on field recommendation for high nutrient requiring tuber crop like yam as well as on a nutrient depleted soil (NRCRI 1982; FPDD 1989; Onweremadu et al. 2008), the treatments were poultry manure (PM), wood ash (WA) both at the rate of 20 t/ha; mineral NPK 15-15-15 fertilizer (NPK) at the rate of 400kg/ha and the control (CTRL, which required no soil amendment). The treatments were laid out in a randomized complete block design and replicated three times. Each plot size planted with white variety of trifoliate yam at a spacing of 1m x 1m. Mounds of about 0.75 m high and 0.75 m wide at the base were used in a plot. The size of each of the 12 plots was 2 x 2 m, giving a plant population of 4 plants per plot. Blocks were 1 m apart and the plots were 0.5m apart.

2.3 Treatments application and crop husbandry

One seed yam weighing 0.4 kg of white trifoliate yam (*Dioscorea dumetorum*) was planted per hole. The organic fertilizers were applied in a ring form at planting, and thoroughly worked into the soil with a hoe. Split application of NPK 15–15–15 fertilizer was applied in a ring form. The first dose was applied at 1 month after vine emergence, and the second 8 weeks later when tuber expansion, rapid stem and leaf development were in progress. Stakes were installed after sprouting. Weeding was done manually with a hoe once in a month at each experimental plot.

2.4 Collection and analyses of amendments

The wood ash (WA) used for the study was collected from a Garri processing unit of the Ekiti state university and was sieved with 2-mm sieve before application. The poultry manure (PM) used was stacked for 1 week under a shed to allow for mineralization. Small samples from the PM and WA used for the study were taken for laboratory analysis to determine their nutrient compositions. The samples were analysed for organic C, N, P, K, Ca and Mg as described by Okalebo et al. (1993).

2.5 Soil sampling and analysis

Before the start of the experiment (after land clearing), soil samples, randomly collected from 0-30 cm depth were thoroughly mixed inside a plastic bucket to form a composite which was later analysed for physical and chemical properties. The soil samples were bulked, air-dried and sieved using a 2-mm sieve for routine chemical analysis, as described by Carter (1993). Particle-size analysis was carried out for textural class using the hydrometer method (Sheldrick and Hand Wang 1993). Soil pH was determined in a soil/water (1: 2) suspension using a digital electronic pH meter. Soil organic carbon was determined by the Walkley and Black procedure by wet oxidation using chromic acid digestion (Nelson and Sommers 1996). Total N was determined using micro-Kjeldahl digestion and distillation techniques, available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry. Exchangeable K, Ca and Mg were extracted with a 1 M NH_4OAc, pH 7 solution. Thereafter, K was analysed with a flame photometer and Ca and Mg were determined with an atomic absorption spectrophotometer (Okalebo et al. 2002).

2.6 Data collection

Soil samples were collected randomly at 0–30 cm depth at three sites per plot for chemical analyses. Two plants were randomly selected per plot for determination of number of leaves and vine length at 5 months after planting when the yam plant formed a full canopy. Number of leaves was determined by counting the number of leaves on each yam plant and Vine length was determined by meter rule. Tuber yield was determined at harvest (8 months after planting) by recording the weight of fresh tuber from two plants selected randomly from each plot using a top loading balance to determine their weights and tuber length was determined by meter rule.

2.7 Data analysis

Data collected on soil chemical properties, growth and yield of trifoliate yam were subjected to analysis of variance (ANOVA) using SPSS 15.0 software package, and means separated using Duncan Multiple Range Test (DMRT).

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3. RESULTS

The data presented in Table 1 are the results of the physical and chemical analyses of the experimental site before the start of the experiment and the amendments used. The pre crop physical analysis of the site carried out showed the textural class was sandy loam according to the USDA textural triangle. The bulk density was 1.28 g / cm^3, total porosity was 52.38 % while the volumetric moisture content was 21.51% at 0-30 cm soil depth respectively. The chemical analysis showed low N (0.13 %), P (3.92 mg/kg), organic carbon (1.70 %) and K (0.11 cmol/kg) values against the critical levels of 1.77% OC, 0.2% N, 10.0 mg/kg available P, 0.16–0.20 cmol/kg exchangeable K, 2.0 cmolkg^{-1} exchangeable Ca, 0.40 cmol/kg exchangeable Mg recommended for yam production in ecological zones of Nigeria (Akinrinde and Obigbesan, 2000); thus justified the need for the application of other nutrient sources. The table also shows the chemical composition of organic amendments used for the experiment. The pH of WA was very strongly alkaline and that of PM was neutral. The values for organic P, K and Ca were higher in WA than PM. Poultry manure (PM) have low C:N ratio compared with WA. The amendments have higher values of organic C, N and cations than the soil used for the experiment. Hence, it is expected that the soil amendments used would improve the fertility of the soil and trifoliate yam yield.

Table 1: Pre-cropping Soil Physicohemical Properties and nutrient composition of amendments used

Property/Nutrient	Soil value in Akure	Poultry manure	Wood ash
Sand (%)	62.50	--	--
Silt (%)	19.00	--	--
Clay (%)	18.50	--	--
Textural class	Sandy loam	--	--
Bulk density (g/cm^3)	1.28	--	--
Total porosity (%)	52.38	--	--
pH (H_2O)	4.85	6.85	10.90
Carbon (C)	1.70(%)	27.2(%)	13.1(%)
Nitrogen (N)	0.13(%)	3.30(%)	1.37(%)
Phosphorus (P)	3.92 (mg kg^{-1})	1.10%	3.21%
Potassium (K)	0.10 (cmol kg^{-1})	3.82%	9.04%
Calcium (Ca)	2.29 (cmol kg^{-1})	3.06%	8.80%
Magnesium (Mg)	0.97 (cmol kg^{-1})	1.16%	0.87%
Sodium (Na)	0.14 (cmol kg^{-1})	0.46%	0.66%
C:N	13.85	8.36	9.77

The results of the study in table 2 and 3 showed significant ($p \leq 0.05$) effects of amendments on some of the chemical properties (pH, OC, N, P, K, Ca and Mg) in 2013 and 2014. pH was significantly reduced ($p \leq 0.05$) in NPK amended plots than all other treatments, while OC was significantly ($p \leq 0.05$) increased in amended plots with highest increase observed in PM amended plots in 2013 and 2014 respectively. Similarly, addition of amendments increased N, P, K and Mg contents in relative to the CTRL with the highest increase in N and Mg observed in PM amended plot for the two growing seasons. Application of WA had highest increase in Ca content. The observed value of Ca was higher by 84% in 2013 and 75% in 2014 than that of control. However, there was no significant ($p \leq 0.05$) effect of amendments on Na contents for both seasons.

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Table 2 Effect of Amendments on soil Chemical properties in Akure (2013)

Amendments	pH	OC	N_{Total}	Avail. P	Exchang. K	Exchang. Na	Exchang. Ca	Exchang. Mg
		(%)		mg/kg	(cmol/kg)			
PM	5.09b	1.54a	0.37a	5.99b	0.28b	0.51a	1.01b	2.61a
WA	5.30a	1.45b	0.35a	5.81b	0.29a	0.38a	1.27a	2.15b
NPK	4.60c	1.50b	0.37a	9.92a	0.28b	0.36a	0.88bc	1.90b
CTRL	5.14ab	1.33c	0.32b	5.21c	0.26c	0.47a	0.69c	1.34c

Values followed by similar letters under the same column are not significantly different at *p*≤0.05 according to Duncan's multiple range test (DRMT). PM = Poultry Manure; WA=Wood Ash; NPK = Inorganic fertilizer; CTRL = Control, OM=Organic Carbon, P=Phosphorus, N=Nitrogen, K= Potassium, Na=Sodium, Ca=Calcium, Mg=Magnesium.

Table 3 Effect of Amendments on soil Chemical properties in Akure (2014)

Amendments	pH	OC	N_{Total}	Avail. P	Exch. K	Exch. Na	Exch. Ca	Exch. Mg
		(%)		mg/kg	(cmol/kg)			
PM	5.64a	1.47a	0.31a	6.00b	0.25a	0.29a	1.30b	1.79a
WA	5.59a	1.39b	0.28b	5.61b	0.27a	0.28a	1.56a	1.32b
NPK	5.07b	1.33b	0.29b	8.43a	0.23a	0.28a	1.01bc	1.14b
CTRL	5.44a	1.27c	0.25c	5.19c	0.20b	0.28a	0.89c	0.95c

Values followed by similar letters under the same column are not significantly different at *p*≤0.05 according to Duncan's multiple range test (DRMT). PM = Poultry Manure; WA=Wood Ash; NPK = Inorganic fertilizer; CTRL = Control, OM=Organic Carbon, P=Phosphorus, N=Nitrogen, K= Potassium, Na=Sodium, Ca=Calcium, Mg=Magnesium.

The effects of amendments on growth and yield of trifoliate yam is shown in Table 4. Organic amendments significantly ($p \le 0.05$) increased the number of leaves (2014), tuber length (2014) and weight of tuber (2013 and 2014) in relative to control. The WA gave the highest values of growth and yield parameters. There were no significant differences in the number of leaves and tuber length in 2013. Application of NPK fertilizer significantly recorded better growth parameters but lower yield parameters. Relative to the control, WA increased the tuber weight by 14% in 2013 and 34% in 2014 respectively. Compared with NPK fertilizer, WA improved tuber yield of trifoliate by 17% in 2013 and 31% in 2014 respectively.

Table 4: Effect of Amendments on growth and yield performances of Trifoliate Yam in Akure (2013 and 2014).

Amendments	Number of Leaves		Vine length (m)		Tubers length (cm)		Weight of Tubers (t/ha)	
	2013	2014	2013	2014	2013	2014	2013	2014
PM	810.83a	862.58a	3.10ab	3.09b	18.03a	19.84a	8.39a	15.02b
WA	839.42a	909.08a	3.16ab	3.29a	18.24a	19.95a	8.91a	17.22a
NPK	733.42a	847.75ab	3.29a	3.25ab	17.31a	17.38b	7.64c	13.12bc
CTRL	785.75a	772.67b	2.94b	3.11b	16.42a	17.61b	7.83bc	12.84c

Values followed by similar letters under the same column are not significantly different at *p*≤0.05 according to Duncan's multiple range test (DRMT). PM = Poultry Manure; WA=Wood Ash; NPK = Inorganic fertilizer; CTRL = Control

4. DISCUSSION

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The Amended treatments increased the soil pH, organic carbon, N and P relative to the control and the initial soil status. This could be attributed to quick mineralization of both the organic and inorganic amendments to release nutrients to the soil. The result confirmed the findings of Kayode *et al*. (2013) and Šimon and Czakó (2014) that organic fertilizers improved post cropping soil pH, organic carbon, available P and N. however, the CTRL gave the lowest values for soil total N, available P, exchangeable K and Mg and soil organic C. This could be attributed to initial lower nutrient status of the soil and continuous cultivation without fertilization, thus indicating poor soil fertility. This observation agreed with the study carried out by Adekiya and Agbede (2009), which reported a decrease of 23.8% in organic C due to continuous cultivation of tomato crop on an Alfisol at Owo, southwest Nigeria without fertilization. The deleterious effect of continuous application of chemical fertilizer in enhancing soil and crop productivity was clearly shown on pH values because the NPK resulted in significantly lower pH and Ca values compared with either mixed or sole application of organic fertilizers. This may be due to loss of nitrogen through the leaching of nutrients. The CTRL treatment gave the lowest growth and yield parameters for yam, such as number of leaves and vine length, tuber length and tuber weight. However, application of organic amendments (Wood Ash and Poultry manure) to soils with low fertility status gave favourable growth and yield values for trifoliate yam, which could be due to their rich nutrient concentrations. This could be attributed to its higher nutrient concentrations (N, P, K, OC, Ca and Mg), which increased the availability of nutrients in the soil, leading to increased uptake by trifoliate yam plants. In addition, another reason could be due to increased microbial activities and mineralization of nutrients induced by the addition of organic amendments, which should have facilitated nutrient release and increased production of nutrients. This finding is in agreement with the work of Moyin-Jesu and Ojeniyi (2006), which reported a rapid response in the yield and growth of okra with the application of organic fertilizers. The superlative performance of the WA treatment in increasing number of leaves, vine length, tuber length and tuber weight of trifoliate yam compared with NPK and CTRL could be a result of the use of soil K and Ca by the trifoliate yam plant for tuber formation which is high in WA. This could also be due to the liming effects of WA on the soil since yam thrives well in soils with neutral pH (Azeez et al. 2007; Agbede 2010) unlike NPK, which could lead to soil acidity (decrease soil pH) with repeated use. This study agreed with the findings of Agboola and Omueti (1982) that continuous use of inorganic fertilizers resulted in the serious deterioration of soil properties and poor yield responses. The decrease in tuber weight of yam in the NPK treatment was related to the fact that nutrients are quickly released into soil, which may not benefit subsequent yam crops and its continuous application degrades soil properties (Agbede 2010), which is known to buffer change in soil pH.

5. CONCLUSION

The WA amendment increased number of leaves, vine length, tuber lenght and tuber weight of yam and increased soil pH, OC, N, P, K, Ca and Mg compared with the CTRL (control). NPK did not increase yield of trifoliate yam, but improved the soil nutrient concentrations compared with the CTRL (control). Wood Ash amendment applied at 20 t/ha gave the highest yam tuber yield due to its higher soil pH, K and Ca values compared with other treatments and therefore recommended for yam production on an Alfisol for improving soil fertility conditions and sustained productivity. This recommendation agreed with the fact that organic materials are cheap, available and sustainable, and also have beneficial secondary effects on soil properties and are more favorable to the environment.

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