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Comparative Evaluation of Poultry Manure and NPK Fertilizer on Soil Physical and Chemical Properties, Leaf Nutrient Concentrations, Growth and Yield of Yam (*Dioscorea rotundata* Poir) in Southwestern Nigeria

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Abstract: Field experiments were conducted in 2006, 2007 and 2008 cropping seasons at the Teaching and Research Farm of Rufus Giwa Polytechnic, Owo (7° 12'N, 5°35'E) in the forest-savanna transition zone of southwest Nigeria to evaluate the effects of poultry manure and NPK fertilizer on soil physical and chemical properties, leaf nutrient concentrations, growth and yield of yam. The treatments were no fertilizer/manure (control), 400 kg ha^{-1} NPK fertilizer, 20 t ha^{-1} poultry manure and 200 kg ha^{-1} NPK fertilizer + 10 t ha^{-1} poultry manure, laid out in a randomized complete block design with three replications. Application of poultry manure, poultry manure + NPK fertilizer significantly reduced soil bulk density, temperature and increased soil water content and porosity, whereas application of NPK fertilizer alone did not improve soil physical properties. Compared with the control, application of poultry manure, NPK fertilizer and poultry manure + NPK fertilizer significantly increased Soil Organic Carbon, N, P, K, Ca and Mg as well as leaf N, P, K, Ca and Mg concentrations. Poultry manure tended to improve soil pH, Soil Organic Carbon, N, K, Ca and Mg concentrations compared with NPK fertilizer and gave higher leaf nutrient concentrations, growth and tuber weight than NPK fertilizer. The highest leaf area, tuber length, tuber girth and tuber weight were obtained with combined application of sub-optimal rates of poultry manure + NPK fertilizer in 2006, 2007 and 2008. Compared with the control, the use of NPK fertilizer, poultry manure and poultry manure + NPK fertilizer increased tuber weight by 53, 86 and 131%, respectively. Therefore, the use of poultry manure + NPK fertilizer is recommended for soil conservation and yam production simultaneously.

Key words: Soil bulk density · Soil temperature · Soil water content · Leaf nutrient concentrations · Yam · Nigeria

INTRODUCTION

Yam (*Dioscorea rotundata* Poir) is a major tuber crop grown in tropical countries for its edible tubers and like any other root and tuber crops, is a heavy feeder, exploiting greater volume of soil for nutrients and water. Therefore continuous cultivation of yam in a given piece of land lead to depletion of soil nutrients and hence reduced nutrient uptake and drastic fall in yield [1]. The judicious management and conservation of the soil to guide against soil fertility problems that lead to decreased crop yield under intensive cropping have become major areas of agronomic research [2].

Most of the small-holding yam farmers have no access to inorganic fertilizers. Although, the use of chemical fertilizers alone to sustain high crop yield has not been successful, due to enhancement of soil acidity, nutrient leaching, nutrient imbalance and degradation of soil physical properties and organic matter status [3, 4]. Agboola and Omueti [5], observed that crop response to applied fertilizer depends on soil organic matter.

The need to use renewable forms of energy and reduced costs of fertilizing crops has revived the use of organic fertilizers worldwide [3, 6]. According to Lombin *et al.* [7], complimentary use of organic and

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inorganic fertilizers hold the key to sustainable agricultural productivity and has proved a sound fertility management strategy in many countries of the world and apart from enhancing crop yield, the practice has a greater beneficial residual effect than can be derived from the use of either inorganic fertilizer or organic manure when applied alone.

According to Sobulo [8] cited by Orkwor *et al.* [9], for a target yield of 29 Mg ha^{-1}, yam removes 133, 10 and 85 kg ha^{-1} of N, P and K, respectively from soil. Although, studies have been conducted on response of yam to inorganic fertilizers [10-12] cited by Orkwor *et al.* [9], the response of yam to organic manure and integrated use of organic and inorganic fertilizers is yet to receive research attention. The superior effect of integrated nutrient supply as opposed to application of inorganic fertilizer has been found to be essential for good growth and yield of maize [13, 14] and cocoyam [15]. Therefore, this work was conducted to evaluate the effects of integrated poultry manure and NPK 15-15-15 fertilizer on some soil physical and chemical properties, leaf nutrient status and performance of yam in southwest Nigeria.

MATERIALS AND METHODS

The experiment was conducted at the Teaching and Research Farm of Rufus Giwa Polytechnic, Owo (7°12'N, 5°35'E) during the 2006, 2007 and 2008 cropping seasons in the forest-savanna transition zone of southwest Nigeria. The soil of the experimental site belongs to an Alfisol classified as Oxic Tropuldalf [16] or Luvisol [17]. The mean annual rainfalls were 1241, 1335 and 1436 mm for 2006, 2007 and 2008, respectively. The rainy-season starts in March, lasting till October, while the dry season is between November and February with temperature ranging from 24°C to 32°C. The site has been an arable crop field, cultivated to a variety of crops, such as cassava (*Manihot esculenta* Crantz), maize (*Zea mays* L.), cocoyam (*Xanthosoma sagittifolium* L.), melon (*Colosynthis citrullus* L.) and groundnut (*Arachis hypogaea* L.), but left fallow for 2 years before the initiation of this study.

The experimental site was manually slashed, ploughed, harrowed and ridged. Treatments applied include (a) control (no fertilizer/manure), (b) NPK 15-15-15 fertilizer at 400 kg ha^{-1}, (c) poultry manure applied at 20 t ha^{-1} and (d) NPK 15-15-15 fertilizer at 200 kg ha^{-1} + poultry manure at 10 t ha^{-1}. These were laid out in randomized complete block design with three replications.

Crop Establishment: The experimental plot size in each trial was 10 m x 10 m. Blocks were 4 m apart and the plots were 3 m apart. One seedyam (*Dioscorea rotundata* cv, Gambari) (0.4 kg) was planted per hole at a spacing of 1 m x 1 m on 5 March 2006, 10 March 2007 and 16 March 2008, respectively. Poultry manure was applied at planting and thoroughly worked into the soil with a hoe. At sprouting, stakes (3 m) were installed. The NPK fertilizer was applied in two equal doses. The first dose was applied 1 month after vine emergence and the second dose 8 weeks, during tuber expansion, rapid stem and leaf development. Weeding was manually done with hoe at 3, 8, 12 and 16 weeks after planting in each experiment.

Determination of Soil Properties: Two months after planting, five samples (4 cm diameter, 10 cm high) were collected at 0-10 cm depth from each plot using a steel core sampler. The samples were oven-dried at 100°C for 24 h and used for the evaluation of bulk density, gravimetric water content and total porosity. Total porosity was calculated from the values of bulk density and particle density of 2.65 Mg m^{-3}. Soil temperature was determined at 15:00 h with a soil thermometer inserted to 10 cm depth. Five readings were recorded per plot at each sampling time at 2 months intervals and mean data computed.

Prior to planting, 10 core soil samples were randomly collected 0-15 cm depth with soil auger and thoroughly mixed in a plastic bucket to form a composite used for physical and chemical soil analysis. At harvest in 2008 (third crop), another set of composite samples were collected per plot and similarly analysed for routine chemical analysis as described by Carter [18]. The soil samples were air-dried and sieved with 2-mm sieve. Soil organic carbon was determined by the procedure of Walkley and Black using the dichromate wet oxidation method [19], total N was determined by micro-Kjeldahl digestion method [20], available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry [21]. Exchangeable K, Ca and Mg were extracted using 1.0 N ammonium acetate [22]. K was determined using a flame photometer and Ca and Mg were determined by the EDTA titration method. Soil pH was determined in soil-water (1:2) medium using the digital electronic pH meter. Particle size analysis was done using hydrometer method [23]. Ten core samplers (4 cm diameter, 10 cm high) were collected randomly before the start of the experiment for the determination of soil bulk density using the core method [24].

Preparation and Chemical Analysis of Poultry Manure: The poultry manure was stacked for 1 week under shed for quick mineralization process. Two grams sub-samples of the poultry manure were air-dried and crushed to pass through a 2-mm sieve and analysed for organic C, total N, P, K, Ca and Mg as described by Okalebo *et al.* [25].

Leaf Analysis: In 2007 and 2008, two to three weeks leaves were collected 5 months after planting from five plants per plot for chemical analysis. The leaf samples were oven-dried at 80°C for 48 h and ground in Willey-mill. Leaf N was determined by micro-Kjeldahl digestion method [20]. Samples were dry ashed at 500°C for 6 h in a furnace and extracted with nitric-perchloric-sulphuric acid for determination of P, K, Ca and Mg. Phosphorus was determined colorimetrically by the vanadomolybdate method [26]. Potassium was determined using a flame photometer and Ca and Mg were determined by the EDTA titration method [22].

Crop Growth and Yield Parameters: Ten plants were randomly selected per plot for determination of the leaf area at 5 months after planting. Leaf area was measured by graphical method [27]. Tuber length, tuber girth and tuber weight measurements were made at harvest (8 months after planting).

Statistical Analysis: The data collected were subjected to analysis of variance and treatment means were compared using Duncan's multiple range test (DMRT) at 5% probability level [28].

RESULTS

Soil and Poultry Manure Analysis: Soil properties of the experimental site before cropping and the poultry manure used are presented in Table 1. The soil was sandy loam and strongly acidic in reaction, with high bulk density. The soil organic C, total N, available P and exchangeable K were low while the exchangeable Ca and Mg were adequate. The poultry manure had higher values of N, P, K, Ca and Mg required for the growth of a tuber crop such as yam.

Effect of Treatments on Soil Physical Properties: The soil physical properties as affected by poultry manure, NPK fertilizer and NPK fertilizer + poultry manure are shown in Table 2. Compared with the (control), application of poultry manure and combined effect of poultry manure and NPK fertilizer significantly ($p < 0.05$) improved soil physical conditions as indicated by reduced bulk density and temperature, increased porosity and water content.

Effects of Treatments on Soil Chemical Properties: The effects of applied NPK fertilizer, poultry manure and NPK fertilizer + poultry manure on soil chemical properties are presented in Table 3. Applied fertilizer treatments significantly ($p < 0.05$) increased soil organic carbon, total N, available P and exchangeable K, Ca and Mg in 2008. The application of poultry manure, reduced NPK fertilizer level + poultry manure was observed to significantly ($p < 0.05$) increase soil nutrient concentrations than NPK fertilizer alone. Applied poultry manure improves soil reaction, organic C, N, K, Ca and Mg compared to NPK fertilizer.

Effects of Treatments on Leaf Nutrient Concentrations: The leaf nutrient concentrations of yam as affected by the application of poultry manure, NPK fertilizer and combined effect of poultry manure + NPK fertilizer in 2007 and 2008 is shown in Table 4. Irrespective of fertilizer source, fertilized plants performed better than control plants. Significant ($p < 0.05$) increased was noticed in leaf N, P, K, Ca and Mg over the control. While leaf N, P, Ca and Mg recorded for combined effect of poultry manure + NPK fertilizer were not significantly different ($p > 0.05$) from that of poultry manure alone, but these were significantly ($p < 0.05$) higher than NPK fertilizer.

Effects of Treatments on Growth and Yield Components: The effect of applied poultry manure, NPK fertilizer and poultry manure + NPK fertilizer on yam growth and yield components during 2006, 2007 and 2008 cropping seasons are presented in Table 5. Compared with the (control), poultry manure, NPK fertilizer and poultry manure plus NPK fertilizer significantly ($p < 0.05$) increased leaf area, tuber length, tuber girth and tuber weight. Relative to control, 400 kg ha^{-1} NPK fertilizer, 20 t ha^{-1} poultry manure and 200 kg ha^{-1} NPK fertilizer + 10 t ha^{-1} poultry manure increased mean leaf area per plant by 77, 102 and 141%, respectively. The mean increases in tuber length were 16, 35 and 44%, respectively. The mean increases in tuber girth were 33, 56 and 83%, respectively while the mean increases in tuber weight were 53, 86 and 131%, respectively.

Table 1: Soil physical and chemical properties (0-15 cm depth) of the experimental site before planting in 2006 and chemical composition of poultry manure

Soil sample		Poultry manure	
Property	Value	Property	Value
Sand (g kg^{-1})	669	pH (H_2O)	6.90
Silt (g kg^{-1})	156	Organic C (%)	14.90
Clay (g kg^{-1})	175	Nitrogen (%)	2.23
Textural class	Sandy loam	C:N	6.70
pH (H_2O)	5.5	Phosphorus (%)	0.85
Bulk density (Mg m^{-3})	1.52	Potassium (%)	2.20
Total porosity (%, v/v)	42.6	Calcium (%)	1.30
Organic carbon (%)	2.45	Magnesium (%)	0.58
Total N (%)	0.14		
Available P (mg kg^{-1})	6.9		
Exchangeable K (cmol kg^{-1})	0.15		
Exchangeable Ca (cmol kg^{-1})	2.3		
Exchangeable Mg (cmol kg^{-1})	0.92		

Table 2: Effect of applied poultry manure (PM) and NPK fertilizer on soil physical properties (0-10 cm depth) across four sampling periods (2, 4, 6 and 8 months after planting) in 2006, 2007 and 2008

	Bulk density (Mg m^{-3})			Total porosity (%, v/v)			Water content (g kg^{-1})			Temperature (°C)		
Treatment NPK/PM	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
(Control)	1.23a	1.25a	1.27a	53.6b	52.8b	52.1b	59b	66b	73b	33.7a	32.6a	33.4a
400 kg ha^{-1} NPK	1.24a	1.26a	1.28a	53.2b	52.5b	51.7b	61b	68b	75b	33.5a	32.8a	33.7a
20 t ha^{-1} PM	1.11b	1.08b	1.05b	58.1a	59.2a	60.4a	72a	79a	94a	29.6b	28.6b	29.3b
200 kg ha^{-1} NPK + 10 t ha^{-1} PM	1.13b	1.11b	1.09b	57.4a	58.1a	58.9a	69a	76a	88a	30.3b	29.9b	30.1b

Means followed by the same letters in the same column are not significantly different at $p \leq = 0.05$ Duncan's multiple range test (DMRT)

Table 3: Effect of applied poultry manure (PM) and NPK fertilizer on soil chemical properties (0-15 cm depth) in 2008

					K	Ca	Mg
Treatment NPK/PM	pH (water)	SOC(%)	N (%)	P (mg kg^{-1})	(cmol kg^{-1})		
(Control)	5.4a	1.88d	0.11d	5.7c	0.12d	1.3d	0.75d
400 kg ha^{-1} NPK	4.9b	2.15c	0.17c	8.5b	0.29c	1.9c	0.91c
20 t ha^{-1} PM	5.8a	2.89a	0.22a	8.8b	0.37b	2.6ab	1.74a
200 kg ha^{-1} NPK + 10 t ha^{-1} PM	5.6a	2.61b	0.20b	10.6a	0.45a	2.8a	1.52b

Means followed by the same letters in the same column are not significantly different at $p \leq = 0.05$ Duncan's multiple range test (DMRT)

Table 4: Effect of applied poultry manure (PM) and NPK fertilizer on leaf nutrient concentrations of yam in 2007 and 2008

	N (g $100g^{-1}$)		P (g $100g^{-1}$)		K (g $100g^{-1}$)		Ca (g $100g^{-1}$)		Mg (g $100g^{-1}$)	
Treatment NPK/PM	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
(Control)	2.79c	2.76c	0.32c	0.29c	1.43d	1.39d	1.45c	1.47c	0.46c	0.33c
400 kg ha^{-1} NPK	3.21b	3.12b	0.48b	0.44b	1.69c	1.59c	1.98b	2.09b	0.80c	0.75c
20 t ha^{-1} PM	3.48a	3.46a	0.61a	0.63a	1.87b	1.88b	2.36a	2.41a	1.08a	1.11a
200 kg ha^{-1} NPK + 10 t ha^{-1} PM	3.55a	3.51a	0.57a	0.60a	2.09a	2.11a	2.29a	2.33a	0.98b	1.01b

Means followed by the same letters in the same column are not significantly different at $p \leq = 0.05$ Duncan's multiple range test (DMRT)

Table 5: Effect of applied poultry manure (PM) and NPK fertilizer on leaf area, tuber length, tuber girth and tuber weight in 2006, 2007 and 2008 cropping seasons

	Leaf area per plant (m^2)			Tuber length (cm)			Tuber girth (cm)			Tuber weight (Mg ha^{-1})		
Treatment NPK/PM	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
(Control)	1.26d	1.22d	1.16d	44d	43d	42c	10.1c	10.0d	9.8d	22.4c	21.9d	21.3d
400 kg ha^{-1} NPK	2.18c	2.15c	2.09c	52c	50c	49b	13.9b	13.2c	12.9c	34.2b	33.8c	32.9c
20 t ha^{-1} PM	2.39b	2.45b	2.48b	56b	58b	59b	15.4b	15.6b	15.9b	39.8b	41.1b	41.5b
200 kg ha^{-1} NPK + 10 t ha^{-1} PM	2.88a	2.92a	2.96a	61a	62a	63a	17.8a	18.3a	18.7a	49.6a	50.8a	51.3a

Means followed by the same letters in the same column are not significantly different at $p \leq = 0.05$ Duncan's multiple range test (DMRT)

DISCUSSION

There was a general increase in soil organic carbon and other nutrients with the application of poultry manure than NPK fertilizer and control. Soil organic carbon content tended to be higher because of the poultry manure applied in the 3 years. The high contents of N, P, K, Ca and Mg in the soil were the products of high organic carbon contents observed. This agreed with the report of Grichs [29], that organic manure is a store house for plant nutrients and major contributor of cation exchange capacity and remained as buffering agent against pH fluctuation which plays a key role in sustaining desirable soil physical conditions for satisfactory growth and development of crops. Organic matter shows a greater capacity to retain nutrients in form that can easily be taken up by plants over a longer period of time. This result is consistent with the findings of Agbede *et al.* [30], Kingery *et al.* [31] and Adeniyan and Ojeniyi [13] that amendment of soil using poultry manure improves soil organic C, N, P, K, Ca and Mg concentrations.

Apart from the direct release of mineral nutrients, poultry manure has been shown to increase soil pH and microbial activity [32]. The increase in soil pH observed in this study could be attributed to increase in organic matter and calcium ions released into the soil solution during microbial decarboxylation of manure which is known to buffer change in soil pH. Natschner and Schetmann [33] and Agbede [34] have also reported similar findings. However, the application of NPK fertilizer alone did not improve soil pH and organic C concentrations; this can be due to the fact that nutrients released from NPK fertilizer were for short time because of leaching which easily removes nutrients from the reach of the plant roots. Lower soil nutrients were observed in treatment with NPK compared to poultry manure and complementary application of poultry manure + NPK fertilizer. A similar observation was also made by Agboola [35] who reported that repeated application of inorganic fertilizers resulted in signs of toxicities, poor growth responses and serious deterioration of soil properties.

The increased in growth parameters (leaf area, tuber length, tuber girth) and tuber yield of yam in poultry manure treatment compared with NPK fertilizer and control treatments could be attributed to increased availability of soil and leaf N, P, K, Ca and Mg and soil organic C due to the manure. In addition, lower soil bulk density and increased water content which might have enhanced tuberization. Higher tuber yield resulting from the application of manurial treatment has been reported by Ayuba *et al.* [36] and Ali *et al.* [37].

The best growth and yield performance of yam observed under complementary use of poultry manure and NPK fertilizer could be attributed to increased nutrient use efficiency, with the inclusion of the NPK fertilizer as reported by Murwira and Kirchman [38]. Also, Obigbesan [39] and Akanbi and Ojeniyi [40] in their studies confirm that yam performance is known to be strongly influenced by N and K. The soil bulk density observed in this study due to the application of poultry manure was consistent with the value obtained by Agbede and Ojeniyi [41] which is quite suitable for yam tuber formation. This is also in line with the observation of Kang and Balasubramanian [42] that high and sustained crop yield could be achieved with a judicious and balanced NPK fertilizer combined with organic matter amendments. Osundare [15, 43] also reported that incorporation of organic manure (5 t ha^{-1} composited and sorted town refuse + 5 t ha^{-1} poultry droppings) every year along with recommended dose of NPK fertilizer produced higher cocoyam and sweet potato yields than did the NPK treatment alone in trials conducted in southwest Nigeria.

CONCLUSION

Combined application of NPK fertilizer and poultry manure at sub-optimal rates ensured more availability of major nutrients in soil and increased yam leaf nutrient concentrations, growth and tuber yield compared with full rates of NPK fertilizer or poultry manure alone. Poultry manure or NPK fertilizer increased soil fertility and leaf nutrient concentrations, growth and tuber yield compared with control, but soil conditions and leaf nutrient concentrations and yam performance were better in poultry manure than NPK fertilizer. Application of poultry manure and NPK fertilizer gave the highest tuber yield of yam and therefore recommended for yam in the forest-savanna transition zone of southwest Nigeria.

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