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Comparative Effect of Poultry and Swine Manures on the Performance of White Guinea Yam (*Dioscorea rotundata* Poir) in an Ultisols Environment

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Abstract

White Guinea yam (*Dioscorea rotundata* Poir) is an important staple food in a number of African countries, including Nigeria and Ghana. However, the tuber yield in these areas is below its potential yield. The most probably constraint to low tuber yield is the low soil nutrient status. A field trial was conducted at the Experimental Farm of the Department of Crop Science, Faculty of Agriculture, University of Benin, Benin City, Nigeria, between April and November 2016 and 2017, to evaluate the effect of poultry and swine manures on the growth and tuber yield of white Guinea yam (*D. rotundata*) in an ultisols environment. The trial was laid out in a 2 × 3 split plot arrangement fitted into randomized complete block design with three replicates. The main plots were organic fertilizers (poultry and swine manures) and the sub-plots were represented by three rates (0, 300 and 450 kg N ha^{-1}) of application. Data collection on growth characters were on vine length (cm), vine girth (cm), number of nodes, number of leaves and leaf area index. At harvest, tuber length (cm), tuber girth (cm), number of tubers per plant, tuber weight and tuber yield (t ha^{-1}) were also evaluated. The results showed that growth and yield variables varied significantly ($p < 0.05$) with organic fertilizer types and application rates. Poultry manure treated plants produced higher ($p < 0.05$) number of nodes and leaves than swine manure treated plants. Application rates of 300 and 450 kg N ha^{-1} of poultry manure significantly increased vine length, vine girth, number of nodes and leaves as well as leaf area index. Tuber weight and yield were higher in plants treated with poultry manure with the application rates of 300 and 450 kg N ha^{-1} performed better than control in 2016, while the application rate of 300 kg N ha^{-1} had the highest tuber weight and yield in 2017. Application rates of 300 and 450 kg N ha^{-1} performed better than the control (0 kg N ha^{-1}) in 2016. However, in 2017, application rate of 300 kg Nha^{-1} had the highest tuber weight and yield. The present study suggests that poultry manure at application rate of 300 kg N ha^{-1} could be adopted by white Guinea yam farmers for high productivity of the crop under intense and continuous cropping in humid ultisols environment.

Keywords: growth variables; organic fertilizers; soil nutrient status; tuber yield

Introduction

White Guinea yam (*Dioscorea rotundata* Poir) is one of the important and widely consumed tubers in Nigeria, a leading producer country in the world (FAOSTAT, 2013). Resource-poor farmers in Nigeria depend upon tuber crops especially cassava and yam as a dietary supplement and a major source of energy and nutritional requirement.

Yam tuber yield of 12.66 t ha^{-1} per hectare (FAOSTAT, 2013)) is below its yield potential due to constraints such as low soil fertility status and poor cultural practices among other factors. The low soil fertility status is due to depletion of soil nutrients by leaching, erosion and loss of organic matter from most tropical soils (Law-Ogbomo and Remison, 2008). This was further aggravated with increasing demographic pressure, land use intensity, reduced forest cover and thus suitable land for yam cultivation becomes gradually limiting (Carsky *et al.*, 2010). In Edo State, Nigeria, farmers do practice slash and burn agriculture for yam production, which places great pressure on limiting fallow land resources.

Yam is a long period growing crop and needs a balanced supply of nutrients for higher tuber yield. This necessitates the need for soil fertility maintenance through external sources of nutrients for crop production. And this can be effectively achieved through the application of organic fertilizers. Ohiri and Chukwu (1991) reported that the application of organic nutrient sources ensures a more balanced nutrition and less probability of negative effect on quality. Organic fertilizers (poultry and swine manures) are

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reservoir of nutrients like N, P, K and other macro and micro-nutrients for healthy growth of plants (Okoli and Nweke, 2015). Organic fertilizers can sustain cropping system through better nutrients recycling and improvement of soil physical attributes (El-Shakweer *et al*., 1998).

Enormous quantities of organic wastes such as poultry and swine wastes are available in Nigeria, where they pose disposal problems and environmental hazards including the high cost of their disposal. These wastes are in the same time effective sources of nutrient for tuber crops like yam through composting. This process recycles organic wastes into organic fertilizers and prevents the environmental nuisance their improper disposal could cause.

The use of organic fertilizers as soil amendments to sustain adequate crop yields have been found effective for cereals (Law-Ogbomo and Osaigbovo, 2017) and vegetable crops (Law-Ogbomo *et al*., 2017). However, there is dearth of literature with regards to its requirement for optimum production of white Guinea yam for resource-challenged farmers. Hence, the present study was undertaken to evaluate the effect of organic fertilizers (poultry and swine manures) on growth and tuber yield of *D. rotundata* in a humid ultisols environment.

Materials and Methods

Experimental site

The study was carried out at the experimental farm of the Department of Crop Science, Faculty of Agriculture, University of Benin, Benin City, Nigeria, lying between Longitude 06° 44' E and Latitude 5° 39' N (FAAN, 2015). The experimental site had been under maize cultivation in previous years with no record of fertilizer application. The study environment had a humid tropical climate. It had a mean rainfall of 1,762 mm and daily temperature of 26.4 °C. It lays within the rainforest of agro-ecological zone of Edo State, Nigeria, and now degraded to secondary forest due to shifting cultivation.

Laboratory analysis

A composite soil sample (0 - 30 cm depth) was taken from the site using auger prior to land preparation for the routine physical and chemical properties, using standard laboratory procedures as outlined by Mylaravapus and Kennelley (2002). The organic fertilizers (cured poultry and swine manures) were also analyzed for their chemical composition.

Experimental design

The experimental design was 2 × 3 split-plot arrangement fitted into randomized complete block design with three replicates. The main plots were organic fertilizers (poultry and swine manures) and the sub-plots were three rates (0, 300 and 450 kg N ha^{-1}) of application. Prior to the incorporation of poultry and swine manures into soil, they were cured under shade for six weeks. The manures were applied four weeks before planting. The plot size was 4 × 3 m separated from the next one by 1 m, while two blocks were separated by 1 m apart.

Cultural practices

The white Guinea yam variety used for the study was 'Iyawo-Omorotiowan'. Yam sets of 200 g were protected against soil pest and pathogenic attacks by dusting with wood ash and dried under shade for three days. This allowed the cut surface to dry and cure. Yam sets were planted at a spacing of 1 × 1 m on April 12 in each year of the experiment, on mounds. At planting, each stand was mulched with dry grasses to conserve soil moisture, suppress weeds and prevent excessive heat and desiccation until there was adequate rain for sprouting. Staking was done singly with a 2 m stake per stand, when sprouted vines were about 1 m long. The plots were weeded manually first at 5 weeks after planting (WAP) and subsequently as at when due. Yam tubers were harvested at 33 WAP, when all the leaves dried out, vines had withered and vegetative growth had ceased.

Data collection

During the growing stage, four randomly selected plants from the inner row of each plot were tagged for data collection.

Data were collected on vine length (cm), vine girth (cm), number of nodes, number of leaves and leaf area index (LAI) at 10 and 20 WAP. Vine length was measured in centimeters from the ground level to the tip of vines of randomly selected plants. Vine girth was measured at 5 cm above ground level on each sampled plant with the use of vernier caliper. Number of nodes and leaves referred to total count of nodes and leaves per plant. Leaf area was determined using leaf area meter, while LAI was computed as by Remison (1997)

$$\text{LAI} = \frac{Leat\ area}{Land\ area\ occupied\ by\ the\ plant}$$

At harvest, data were collected on tuber length (cm), tuber girth (cm), number of tuber per plant, tuber weight (kg) and tuber yield (t ha^{-1}). Tuber weight was determined by weighing all harvested sampled plants in kg summed together and divided by number of plants and thus:

Tuber weight (kg plant^{-1}) =

$$\frac{Weight\ of\ tuber\ of\ sampled\ plants}{Number\ of\ sampled\ plants}$$

Tuber yield (t ha^{-1}) was estimated as:

$$\text{t ha}^{-1} = \frac{kg\ plant^{-1}}{1000}\ x\ 10{,}000 = \text{kg plant}^{-1} \times 10\ \text{t ha}^{-1}$$

Data analysis

Analysis of data was done using GENSTAT version 8.0 statistical software. Significant different treatment means were separated and compared using Fisher's least significant difference (F-LSD) at 5% level of probability.

Results

Soil properties and chemical composition of organic fertilizers

The results of the soil properties of the experimental site prior to cropping with white Guinea yam and the chemical composition of organic fertilizers are presented in Table 1.

The soil was strongly acidic in 2016 and moderately acidic in 2017. Organic carbon and exchangeable potassium were adequate in 2016. For 2016 and 2017, total N, available P, exchangeable calcium and magnesium were low, while C: N ratios of both years were high. Ca:Mg ratios of both years were less than three and effective cation exchange capacity was very low. The soils were sandy loam textually.

The pH of poultry manure was neutral and slightly acidic in 2016 and 2017, respectively. The soil reaction for swine manure in both years was slightly acidic. Organic carbon and total N of poultry manure were higher than that of swine manure in both years. C:N ratio of poultry manure was low (8.73) and medium (11.73) in 2017, while swine manure's C:N ratios was medium for both years. The organic fertilizers used in the study also contained appreciable quantity of plant nutrients.

Growth

Growth of white Guinea yam as influenced by poultry and swine manures is presented in Table 2. At the periods of measurements in both years, vine length did not vary significantly ($p > 0.05$) between the organic fertilizer types. Organic fertilizer application rates of 300 and 450 kg N ha^{-1} resulted in significantly ($p < 0.05$) longer vine length than at 0 kg N ha^{-1} at the periods of measurements in both years. Vine lengths of 300 and 450 kg N ha^{-1} treatments were similar at 10 WAP in 2016 and at 20 WAP in both years, but significantly ($p < 0.05$) longer than 0 kg N ha^{-1}. In 2017 at 10 WAP, the longest vines were observed on plants treated with 450 kg N ha^{-1}. There was no significant ($p > 0.05$) effect due to the interaction of organic fertilizer type and application rates on vine length in the study.

Vine girth varied non-significantly ($p > 0.05$) with organic fertilizer types in 2016 and 2017 at 10 and 20 WAP as both organic fertilizers produced similar vine girths. Organic fertilizer application rates had similar vine girth but significantly ($p < 0.05$) thicker than those obtained from the (control) non-treated plants in 2016 at 10 and 20 WAP. However, in 2017 at 10 and 20 WAP, vine girths were similar among plants treated with organic fertilizer application rates including 0 kg N ha^{-1}. The interaction of organic fertilizer types and application rates was not significant ($p > 0.05$) throughout the sampling periods in both years.

The number of nodes per plant was only significantly ($p < 0.05$) higher in poultry manure than swine manure treated plants at 20 WAP in both years. At 10 WAP in 2016 and 20 WAP in 2017, organic fertilizer application rate of 300 kg N ha^{-1} had the highest number of nodes per plant. However, at 10 and 20 WAP in 2017, organic fertilizer application rates of 300 and 450 kg N ha^{-1} had comparable number of nodes per plant but significantly ($p < 0.05$) more than 0 kg N ha^{-1}. There was no interaction of organic fertilizer types and application rates on number of nodes at periods of measurements in both years.

The number of leaves per plant was only significantly ($p < 0.05$) affected by organic fertilizer types at 20 WAP in 2017, as higher number of leaves per plant (345.00) was observed on plants grown with poultry manure. Number of leaves per plant was significantly ($p < 0.05$) affected by different rates of organic fertilizer in the periods of measurements in both years. The 300 and 450 kg N ha^{-1} rates of organic fertilizer produced similar number of leaves per plant but significantly ($p < 0.05$) more number of leaves compared to control (0 kg N ha^{-1}) throughout the periods of measurements in both years. The interaction of organic fertilizer types and application rates on number of leaves was only significant ($p < 0.05$) at 10 WAP in 2017, in which the highest number of leaves were observed in plants treated with swine manure at 300 kg N ha^{-1} (328) and poultry manure at 450 kg N ha^{-1} (294) (Fig. 1).

Table 1. Physical and chemical properties of the soil of the experimental site prior to cropping with white Guinea yam and chemical composition of organic fertilizers

Parameter	Soil		Organic fertilizer			
	2016	2017	Poultry manure		Swine manure	
			2016	2017	2016	2017
pH	5.42	5.68	7.70	6.76	6.50	6.82
Organic carbon (g kg^{-1})	20.11	17.00	26.20	28.70	21.00	26.40
Total nitrogen (g kg^{-1})	0.88	0.85	3.00	2.45	1.85	1.53
C:N ratio	22.85	20.00	8.73	11.71	11.35	17.25
Available phosphorus (mg kg^{-1})	7.45	7.73	14.80	13.20	13.00	12.50
Exchangeable cation (cmol kg^{-1})						
Calcium	0.72	0.62	5.03	3.29	4.20	3.00
Magnesium	0.12	0.21	1.06	0.48	0.48	0.52
Potassium	0.35	0.20	0.68	0.44	0.30	0.25
Sodium	0.75	0.13	0.23	0.16	0.20	0.16
Exchangeable acidity (cmol kg^{-1})	0.50	0.68	nd	nd	nd	nd
Effective cation exchange capacity (cmol kg^{-1})	1.94	1.84	nd	nd	nd	nd
Particle size (g kg^{-1})						
Sand	890.00	896.00	nd	nd	nd	nd
Silt	18.65	50.00	nd	nd	nd	nd
Clay	105.75	54.00	nd	nd	nd	nd
Textural class	Sandy loam	Sandy loam	nd	nd	nd	nd

Table2. Growth of white Guinea yam (*D. rotundata*) as influenced by poultry and swine manure

Treatment	Vine length (cm)				Vine girth (cm)				Number of nodes/plant				Number of leaves/plant				Leaf area index			
	Weeks after planting				Weeks after planting				Weeks after planting				Weeks after planting				Weeks after planting			
	10		20		10		20		10		20		10		20		10		20	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Org, fertilizer																				
Poultry manure	180.00	212.30	284.00	248.00	3.39	1.03	3.79	1.09	13.70	17.42	32.60	38.70	94.60	178.00	345.00	278.00	0.75	3.45	1.71	4.97
Swine manure	136.00	153.40	350.00	211.00	3.52	1.06	3.49	1.01	10.10	12.22	20.60	24.30	70.30	184.00	143.00	268.00	0.57	3.09	1.01	3.72
LSD $_{(0.05)}$	ns	Ns	ns	ns	ns	ns	ns	ns	ns	ns	7.490	11.100	ns	ns	74.60	ns	ns	ns	ns	ns
Rate (kg N ha $^{-1}$)																				
0	98.00	114.0	198.00	171.00	2.88	1.00	3.15	1.00	5.50	12.12	14.00	18.80	39.00	84.00	112.00	164.00	0.36	1.45	0.72	2.53
300	221.00	191.70	412.00	235.00	4.00	1.10	4.08	1.03	14.50	16.95	30.50	47.70	83.70	230.00	209.00	322.00	0.84	3.75	1.51	5.26
450	166.00	243.30	342.00	285.00	3.48	1.04	3.68	1.13	13.70	17.39	35.20	27.90	88.30	229.00	261.00	332.00	0.78	4.91	1.86	5.25
LSD $_{(0.05)}$	66.300	37.250	70.100	59.000	0.854	ns	0.7	ns	6.34	4.197	9.180	11.890	38.680	29.700	91.400	76.600	ns	1.860	0.060	2.309
interaction	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	40.400	ns	ns	ns	ns	ns	ns

ns - not significant at 0.05 probability level

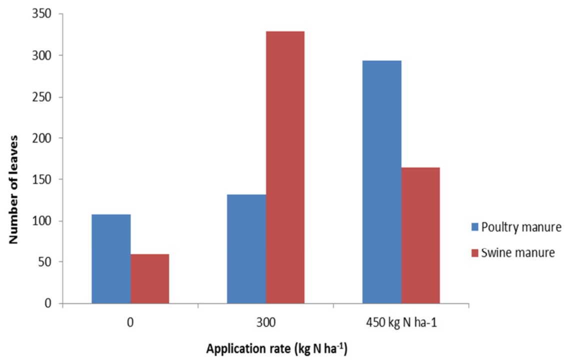

Fig. 1. Interaction of organic fertilizer types and application rates on the number of leaves at 10 WAP

Leaf area index (LAI) was not significantly ($p > 0.05$) influenced by organic fertilizers at the periods of sampling in both years. LAI increased significantly ($p < 0.05$) with increased rates of organic fertilizer application in 2016 at 20 WAP and in 2017 at both 10 and 20 WAP. The organic fertilizer application rates of 300 and 450 kg N ha^{-1} resulted in the same LAI, but significantly ($p < 0.05$) higher compared to the control except at 20 WAP in 2016, in which 450 kg N ha^{-1} had the highest LAI. Organic fertilizer types and application rates interaction effects were not significant ($p > 0.05$) in the periods of measurement in both years.

Tuber yield and its components

White Guinea yam tuber yield and its components as influenced by poultry and swine manures are presented in Table 3. Tuber length was not significantly ($p > 0.05$) influenced by organic fertilizer in both years and at the periods of sampling. Increase in the rates of organic fertilizer application also increased tuber length in 2017. However, the organic fertilizer applied rates of 300 and 450 kg N ha^{-1} resulted in similar tuber lengths but significantly ($p < 0.05$) longer compared to 0 kg N ha^{-1} in 2017. This performance pattern was also similar for the tuber girth. However, tuber girth was not significantly ($p > 0.05$) influenced by organic fertilizer types except in 2017 in which thicker tubers were observed in plants treated with poultry manure.

Organic fertilizer types and applied rates had no significant ($p > 0.05$) effect on number of tubers per plants in 2016 and 2017. Tuber weight of poultry manure treated plants were heavier ($p < 0.05$) than the swine manure treated plants. The performance pattern was also reflected in tuber yield in both years. The 300 and 450 kg N ha^{-1} organic fertilizer application rates had comparable tuber weight but significantly ($p < 0.05$) higher than control in 2016. This was also observed for tuber yield in 2016. In 2017, 300 kg N ha^{-1} had the highest tuber weight and yield.

Discussion

The soil of the experimental site was sufficient in organic carbon and exchangeable K. It was of low fertility status with respect to low level of total N, available P, exchangeable Ca and Mg. The soil was also low in cation exchange capacity and low Ca:Mg ratio. The soil was strongly acidic and moderately acidic in 2016 and 2017, respectively. This characteristic feature implied that ultisols are known to be in low nutrient status (Asadu and Ugwu, 1997). The nature of the soil cannot enhance full yield potential capacity. Law-Ogbomo and Nwachokor (2010) reported that nutrient status of soil plays a unique and significant role in the quality and crop performance. This necessitates the need for nutrient supplementation for the optimal performance of yam.

Poultry and swine manures used in the present study were found to contain essential nutrients in appreciable amounts needed by the plants. These nutrients could be utilized by plants and make them more productive than non-fertilizer treated plants. This observation also corroborated with the finding of Duncan (2005) who reported that organic fertilizer increased N, P and K contents of the soil. The manures also contained high amount of organic carbon. According to Crow (2009), organic carbon is a store room of nutrients and releases them slowly to replace those taken up by the plant. It improves the structure of the soil, allowing better penetration of air, water and plant roots. O'Sullivan (2010) reported that organic carbon creates favourable environment for the activities of microorganisms and this contributes to crop health in a variety of ways. Poultry manure contained higher organic C, total N, available P and exchangeable cations as compared to swine manure. This finding is in agreement with the observation of Egharevba and Ogbe (2002) who reported that poultry manure contain higher nutrients than other manures and enhanced the soil nutrient status through gradual release of nutrients to the soil. The C: N ratios of both manures are indication of high decomposition rate. However, the decomposition rate of poultry manure is higher than swine manure. The variation in C:N ratio was because of differences in the total N content of poultry and swine manures. Waste material derived from swine animals contains a fairly amount of fibrous materials due to the nature of diet fed to them.

The application of poultry and swine manure enhanced significantly the growth attributes of yam through higher nutrient availability from manures. The increase in vine length because of organic fertilizer application could be due to increased uptake of nutrients especially nitrogen. Nitrogen is a constituent of protein and protoplasm; it vigorously induces the vegetative development of the plant (Singh, 2015). The vine length of plants without soil amendment was comparatively short, which could be attributed to poor nutrient uptake from soil. Increase in nitrogen level from poultry manure had profoundly influenced the mobility of nutrients from the unavailability forms of nutrients mainly due to improved physical, chemical and biological properties of the soil. This had enhanced the growth variables and reconfirmed the role of nitrogen in promoting vigorous vegetative growth in vegetables (Tisdale and Nelson, 1990). This finding indicated that nitrogen stimulates formation of new leaves and increases the size of plant vines.

Number of leaves increased with increased in N levels of the organic fertilizer due to the formation of more nodes and thicker vines. This corroborated with Zhang *et al.* (2010) who reported that nitrogen enhances cell division and elongation, which results in better vegetative growth. Increase in the number of leaves led to increase in LAI. The LAI characterized and directly quantified plant canopy structure and is used to predict primary productivity and crop growth (Everitt and Brenda, 2003). An increased LAI enhanced photosynthetic capacity due to better utilization of solar radiation and hence increased tuber yield per hectare (Law-Ogbomo and Remison, 2008).

The enhancement of growth characters was a precursor to higher tuber yield. Plant fertilized with organic fertilizers had longer and thicker vines, more leaves and higher LAI compared to non-fertilizer treated plants translated into higher tuber yield. This implied that fertilizer treated plants were superior in tuber yield and benefitted more from the nutrients applied. Vine length and girth, number of leaves and LAI were at peak using levels of 300 and 450 kg N ha^{-1}, compared to plants without fertilizer which were low due to marginal nutrient availability. This is an indication that tuber yield was directly influenced by nitrogen level in the organic fertilizers (poultry and swine manures). This is in agreement with Uzoh *et al.* (2015) who reported that maize yield was directly influenced by N level in the organic materials. The superiority of tuber yield of poultry manure over swine manure could probably be due to higher nutrient composition of the former over the later. The differences in the tuber yield between the first and second cropping was mostly likely be due to the more severe deficiency of nutrients in the experimental site of the second cropping than the first cropping. The exchangeable K of the first cropping was higher than that of the second cropping. N and K are more critical nutrient elements for maximizing tuber yield (Law-Ogbomo, 2007). It is also probably that the soil of the second cropping was in excess of crop removal, suffered leaching or erosion losses and highly weathered.

Table 3. Yield and its components of white Guinea yam as influenced by poultry and swine manures

Treatment	Tuber length (cm)		Tuber girth (cm)		Number of tubers plant^{-1}		Tuber weight (kg plant^{-1})		Tuber yield (t ha^{-1})	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Organic fertilizer										
Poultry manure	38.00	41.00	33.70	37.90	2.78	2.11	4.09	2.16	40.90	21.60
Swine manure	36.10	34.40	31.10	27.00	1.89	1.89	2.74	1.81	27.40	18.10
LSD$_{(0.05)}$	Ns	Ns	Ns	2.030	Ns	Ns	0.564	0.320	1.320	2.230
Rate (Kg N ha^{-1})										
0	35.80	24.30	28.30	22.70	2.17	1.58	2.35	3.40	28.70	12.20
300	38.0	44.10	35.80	37.20	1.83	2.00	4.00	9.20	49.30	27.70
450	37.30	44.70	33.00	37.40	3.00	2.42	3.90	6.40	44.70	19.80
LSD$_{(0.05)}$	Ns	10.130	Ns	2.970	Ns	Ns	0.297	2.300	29.40	6.660
Interaction	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

ns - not significant at 0.05 level of probability

Conclusions

The present study showed that tuber yield was increased through organic fertilizer application. Tuber yield also increased with increase in application rate. Poultry manure produced higher number of nodes, leaves and tuber yield compared to swine manure. Organic fertilizer rate of 300 kg N ha^{-1} had the highest tuber weight and yield. Based on these findings, soil amendment in the form of poultry manure could be applied to white Guinea yam at the rate of 300 kg N ha^{-1}.

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