



Growth and Yield Response of Sweet Potato (*Ipomoea batatas*) to Organic and Inorganic Fertilizer on Degraded Soil of Southern Guinea Savanna of Nigeria

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Abstract— The problem of soil fertility makes it difficult for some crops to attain higher yields; especially crops like sweet potato that our traditional peasant farmers believed that it does not require the application of fertilizer. Therefore, experiments were conducted during the rainy season of 2018 and 2019 titled “Growth and Yield Response of Sweet Potato (*Ipomoea batatas*) to Organic and Inorganic Fertilizer on Degraded Soil of Southern Guinea Savanna of Nigeria” to determine the optimal levels of both organic and inorganic fertilizer for sustainable sweet potato production. The treatments consisted of three levels of NPK fertilizer (0, 50 and 100 kg ha⁻¹); three rates of poultry manure (0, 5 and 10 t ha⁻¹). A factorial experiment laid in a Randomized Complete Block Design (RCBD) and replicated three times. The result showed NPK fertilizer applied at the rate of 100kg ha⁻¹ produced the highest number of leaves/plant (178, 233); number of branches/plant (10.45, 11.98); and vine length/plant (245.43cm, 258.79cm) in both 2018 and 2019 cropping season respectively. Also, poultry manure at 10t ha⁻¹ produced the highest number of leaves/pant (221, 242); number of branches/plant (11.24, 13.25); and vine length (252.45cm, 275.54cm) in both years of cropping respectively. Application of 100kg ha⁻¹ of NPK fertilizer produced the highest tuber weight of 21.12 and 22.72t ha⁻¹, in both 2018 and 2019 cropping seasons respectively compared with the other rates of fertilizer application and the control. Also, Poultry manure at the rate of 10 t ha⁻¹ produced the highest total weight of 21.32 and 24.19t ha⁻¹ of sweet potato in both 2018 and 2019 cropping seasons respectively compared with the other rate of fertilizer application. Interaction between NPK fertilizer and poultry manure show a significant ($p < 0.05$) increased on the total tuber weight in both years (2018 and 2019). For integrated nutrient management in sweet potato production 50kg ha⁻¹ of NPK fertilizer and 10t ha⁻¹ of poultry manure produced the best total tuber weight.

Keywords— Growth, Yield, NPK fertilizer, poultry manure, Sweet potato.

I. INTRODUCTION

Sweet potato (*Ipomoeae batatas* (L Lam) is a perennial crop belonging to the family of Convolvulaceae with its origin from tropical America (Hahn, 1983). However, it is usually cultivated as an annual crop. Globally, it is among the important food crops in the world. It ranks second following Irish potato in the world's root and tuber crop production; also within the sub-Saharan Africa, it is the third most important root and tuber crop after cassava and yam (Hahn and Hozyo, 1998). China accounts for the

highest world production of sweet potato, followed by Uganda and Nigeria in that order (FAO, 2004). Presently, 381,000 – 510,000 ha of land are subjected to sweet potato cultivation in Nigeria with an annual production figure of 3.46 million metric tons (NRCRI, 2009). Estimated yields of sweet potatoes in the research fields varied from 40 to 70 t/ha for improved varieties, while in multilocational trials yields averaged 23.5t/ha across seasons and locations (Tewe *et al.*, 2003).

Sweet potato is adaptable to tropical and subtropical climates, tolerant to drought and grows under marginal condition of low fertility and pH. The increasing potential of the crop in poverty alleviation and food security due to its high productivity per unit area and timely maturity makes sweet potato an important crop for the survival of the resource poor farmers in Nigeria (NRCRI, 2003). Sweet potato is valued for its tubers which are boiled, fried, baked or roasted for humans or boiled and fed to livestock as a source of energy. The potential of sweet potato to guarantee food security is under-estimated as its uses is often limited to a substitute food in African countries (Muktar *et al.*; 2010). The tubers can also be processed into flour for bread making, starch for noodles as well as used as raw material for industrial starch and alcohol. The flour is utilized also in sweetening local beverages like *Kunu-zaki*, *burukutu*, and for fortifying baby foods and foo-foo/pounded yam in Nigeria (Tewe *et al.*, 2003). The leaves are used as vegetables in yam and cocoyam porridge and are rich in proteins, vitamins and various minerals. Sweet potato tubers are rich in vitamins A, B, and C; and minerals such as K, Na, Cl, P and Ca (Onwueme & Sinha, 1991). It can therefore be a high value-added food particularly for children and pregnant women who are more often exposed to vitamin A deficiency in sub-Saharan Africa (Degras, 2003).

The problem of soil fertility and variability in climatic condition makes it difficult for some crops to attain higher yields especially crops like sweet potato that our traditional peasant farmers believe that it does not require the application of fertilizer. However, sweet potato like any other root and tuber crops is a heavy feeder, exploiting greater volume of soil nutrients and water (Osundare, 2004). Low soil fertility is one of the constraints in production of sweet potato in Nigeria (Okpara 2000). Rapid depletion of soil nutrients and poor physical condition of the savanna soils constitute a strong limitation to crop production (Sanchez 1996). As such, these soils must be supplemented with adequate macronutrients in order to keep them productive (Aisha *et al.*, 2007). Therefore, external nutrient inputs are essential to improve and sustain the growth and yield of sweet potato; these nutrient inputs may either be from organic sources or inorganic fertilizers (Njoku *et al.*, 2001). Though inorganic fertilizers have been the conventional method of soil nutrients input in sweet potato production. These fertilizers may pose a great danger to the environment, especially if it is inappropriately applied. Also, the shortage and high cost of inorganic fertilizers have limited their uses for crop production among the peasant farmers in Nigeria. Hence, organic manures can serve as alternative to mineral fertilizers for improving soil

fertility (Dauda *et al.*, 2008). Therefore, there is the need for increased dependence on the use of organic waste such as farmyard manure, crop residues and poultry manure for crop production (Ndors *et al.*, 2013). The production, marketing and utilization of sweet potato have expanded in the last decade to almost all ecological zones in Nigeria (NRCRI, 2009). In the north central Nigeria, this crop has also gained acceptability and currently there is increased in cultivation by small farm holders as a source of income. However, there is a dearth of documented information regarding the soil nutritional requirement of the crop and other agronomic practices that may be of help to these farmers for increasing the yield of the crop in this zone. This research therefore, is aimed at determining the optimal levels of both organic and inorganic fertilizer for sustainable sweet potato production in southern guinea savanna of Nigeria.

II. MATERIALS AND METHOD

Field trials were conducted at the College of Agriculture Lafia, Nasarawa State, Nigeria; Teaching and Research Farm in 2018 and 2019 cropping seasons. The study area falls within southern guinea savanna agroecological zone of Nigeria, and is located between Latitude 08.33 N and Longitude 08.32 E. Rainfall usually starts from April – October and the average monthly rainfall figures ranges from 40 mm-350 mm. The months of July and August usually records heavy rainfall. The daily maximum temperature ranges from 20.0°C – 38.5°C and daily minimum ranges from 18.7°C – 28.2°C. The months of February to early April are the months that have the highest maximum temperature while the lowest maximum temperature months are recorded in December and January because of the prevailing cold harmattan wind from the northern part of the country at this period. The relative humidity rises as from April to a maximum of about 75-90 percent in July (NIMET 2019).

2.1 Treatment and Experimental Design

The treatments consisted of three levels of NPK fertilizer (0, 50 and 100 kg ha⁻¹); three rates of poultry manure (0, 5 and 10 t ha⁻¹). A factorial experiment laid in a Randomized Complete Block Design (RCBD) and replicated three times.

2.2 Field preparation and Agronomic practices

The plot size was 3 m by 4 m; 0.5 m between plots and 1 m between replicates. The land was cleared, harrowed and made into 0.75m row ridges. The local sweet potato vines were obtained locally from farmers in Lafia town. Four node cuttings of the sweet potato vines were planted on the ridge at a spacing of 35 cm; the brand of the chemical

fertilizer used was NPK 20:10:10. The plots were kept weed free by regular hoe-weeding.

2.3 Soil Analysis

Soil samples were collected from the experimental site before planting for determination of both physical and chemical properties. Also, the poultry manure was subjected to chemical analysis.

2.4 Data Collection

Two plants were tag in the middle roll of each plot and the following data were collected: vine length, number of branches and number of leaves were taken at 8 and 12 weeks after planting. While, biomass weight, number of marketable tubers, weight of marketable tubers, number of unmarketable tubers, weight of unmarketable tubers, total marketable tubers and total unmarketable tubers were recorded at harvest.

2.5 Data Analysis: The data collected were subjected to analysis of variance for using GENSTAT (2008 Ed), and where there was a significant difference; the means were separated using F-LSD at 5% probability level.

III. RESULTS AND DISCUSSION

The result of soil analysis of the experimental site before cropping in the first year showed that, the soil was very sandy (87.0%) and slightly acidic in nature (pH 6.08 in H₂O and 6.00 in 0.01MKCL); but low in nitrogen, phosphorus, potassium, organic carbon and cation exchange capacity (Table 1). The result in second year did not show much difference, however, there were little reduction in the quantity of sand (80.0%), but there were increases in soil pH (6.34), nitrogen, phosphorus, potassium, organic carbon and cation exchange capacity.

Table 1: Laboratory analysis of soils at 0-20cm before cropping

Properties	2018	2019
Mech. Composition		
Clay (%)	10.6	14.6
Silt “	2.4	5.4
Sand “	87.0	80.0
TCL (USD)	SL	SL
Chemical composition		
pH(H ₂ O)	6.08	6.34
pH(0.01MKCl)	6.00	6.09
Ashes(gkg ⁻¹)	Nd	Nd
T N(gkg ⁻¹)	0.90	1.02

OC(gkg ⁻¹)	4.40	6.80
Avail. P (mgkg ⁻¹)	4.17	5.52
K(mgkg ⁻¹)	0.31	1.21
Mg(mol/kg)	1.12	1.78
Ca(mol/kg)	2.41	3.48
Na(mol/kg)	0.67	0.67
Al + H(acidity)	0.83	0.61
CEC(mol/kg)	5.17	6.24
%Base Saturation	81	87

The poultry manure used had N, P and K (3.14, 3.48 and 4.95%) respectively and a pH of 7.9 (slightly alkaline); the exchangeable cations were of moderate levels (Table 2). The nutrient contents of the manures were moderate to high; therefore, the quantities applied must have supplied the important nutrients such as N, P and K, which are critical for sweet potato growth and yield

Table 2. Chemical composition of the poultry manure used during the study

% Chemical properties	2015
Ph	7.9
N	3.14
P	3.48
K	4.95
Ca	5.52
Mg	0.45
Na	0.32

3.1 Effect of NPK fertilizer and poultry manure on vegetative growth of sweet potato

Application of NPK fertilizer and poultry manure had a significant ($p < 0.05$) increased in all the growth parameters assessed in both years of cropping (Table 3). NPK fertilizer applied at the rate of 100kg ha⁻¹ produced the highest number of leaves/plant (178, 233); number of branches/plant (10.45, 11.98); and vine length/plant (245.43cm, 258.79cm) in both 2018 and 2019 cropping season respectively. Also, poultry manure at 10t ha⁻¹ produced the highest number of leaves/pant (221, 242); number of branches/plant (11.24, 13.25); and vine length (252.45cm, 275.54cm) in both years cropping respectively. The interaction between NPK fertilizer and poultry manure did not produced any significant effects on growth parameters of sweet potato throughout the duration of this experiment.

Table 3: Effect of NPK fertilizer and poultry manure on vegetative growth of sweet potato

Treatments	No of leaves/plant		No of branches/plant		Vine length/plant(cm)	
NPK fertilizer (kg/ha)	2018	2019	2018	2019	2018	2019
0	129	145	5.12	7.23	130.25	181.34
50	147	186	7.32	9.89	158.56	206.53
100	178	233	10.45	11.98	245.43	258.79
LSD(0.05)	21	35	2.16	2.21	25.34	27.67
Poultry manure(t/ha)						
0	118	128	5.71	8.75	170.48	213.76
5	172	185	9.42	11.13	214.67	225.32
10	221	242	11.24	13.25	252.45	275.54
LSD(0.05)	20	31	1.45	1.87	31.65	26.73
Interaction						
NPK X PM	NS	NS	NS	NS	NS	NS

PM= Poultry manure NS= Not significant

3.2 Effect of NPK fertilizer and poultry manure on biomass weight and yield parameters of sweet potato at harvest

NPK fertilizer and poultry manure rates significantly ($p < 0.05$) increased the biomass weight and the tuber yield of sweet potato (Table 4). Application of 100kg ha⁻¹ of NPK fertilizer produced the biggest (15.00 and 16.13 t ha⁻¹) sweet potato biomass weight in both 2018 and 2019 cropping seasons respectively compared with the other rate of fertilizer application. The control produced the smallest biomass of 12.12 and 12.24 t ha⁻¹ in both 2018 and 2019 cropping seasons. Also, application of 10 t ha⁻¹ of poultry manure produced the biggest (16.24 and 17.65 t ha⁻¹) sweet potato biomass weight in both 2018 and 2019 cropping seasons respectively compared with the other rate of poultry manure application. The interaction between NPK and poultry manure showed a significant effect.

Application of NPK fertilizer and poultry manure rates had a significant ($p < 0.05$) increased on the weight of marketable tuber (Table 4). 100kg ha⁻¹ of NPK fertilizer produced the highest tuber weight of 20.58 and 20.01t ha⁻¹, in both 2018 and 2019 cropping seasons respectively compared with the other rate of fertilizer application. Poultry manure at the rate of 10 t ha⁻¹ produced the highest weight of 20.76 and 23.24t ha⁻¹ of sweet potato in both 2018 and 2019 cropping seasons respectively compared with the other rate of fertilizer application.

Application of NPK fertilizer and poultry manure rates did not have any significant ($p < 0.05$) increased on the weight of unmarketable tuber (Table 4). However, there was gradual decrease in the weight of unmarketable tubers

when NPK and poultry manure were increased in both 2018 and 2019 cropping seasons respectively compared with the other rate of fertilizer application.

Application of NPK fertilizer and poultry manure rates had a significant ($p < 0.05$) increased on the total weight of tubers (Table 4). 100kg ha⁻¹ of NPK fertilizer produced the highest tuber weight of 21.12 and 22.72t ha⁻¹, in both 2018 and 2019 cropping seasons respectively compared with the other rates of fertilizer application and the control. Also, Poultry manure at the rate of 10 t ha⁻¹ produced the highest total weight of 21.32 and 24.19t ha⁻¹ of sweet potato in both 2018 and 2019 cropping seasons respectively compared with the other rate of fertilizer application. The interaction between NPK and poultry manure showed a significant effect.

The result on (Table 5) showed that the interaction between NPK fertilizer and poultry manure show a significant ($p < 0.05$) increased on the biomass yield in both years. Application of 100kg ha⁻¹ of NPK fertilizer and 10 t ha⁻¹ of poultry manure produced the highest fresh biomass yield of 19.23 t ha⁻¹ and 19.80 t ha⁻¹ in 2018 and 2019 cropping seasons respectively. Another interaction result is on (Table 6), which showed that the interaction between NPK fertilizer and poultry manure show a significant ($p < 0.05$) increased on the total tuber weight in both years (2018 and 2019). Application of 50kg ha⁻¹ of NPK fertilizer and 10 t ha⁻¹ of poultry manure produced the highest tuber weight of 23.08 t ha⁻¹ and 24.02 t ha⁻¹ in 2018 and 2019 cropping seasons respectively. This result is statistically a par with application of 100kg ha⁻¹ of NPK

and 10 t ha⁻¹ of poultry manure in both 2018 and 2019 cropping seasons.

Table 4: Effect of NPK fertilizer and poultry manure on biomass weight and yield parameters of sweet potato at harvest

Treatments	Fresh biomass weight (t ha ⁻¹)		Wt of marketable tubers (t ha ⁻¹)		Wt of unmarketable tubers (t ha ⁻¹)		Total weight of tubers (t ha ⁻¹)	
NPK(Kg/ha)	2018	2019	2018	2019	2018	2019	2018	2019
0	12.12	12.24	15.08	15.79	0.79	0.98	15.87	16.77
50	13.22	13.82	18.14	19.12	0.62	0.74	18.76	19.74
100	15.00	16.13	20.58	22.01	0.54	0.71	21.12	22.72
LSD(0.05)	1.04	1.11	2.02	2.54	2.14	2.42	2.04	2.25
PM(t/ha)								
0	12.05	12.25	14.03	15.09	0.74	0.97	14.77	16.05
5	14.12	15.49	16.29	19.57	0.59	0.96	16.88	20.35
10	16.24	17.65	20.76	23.24	0.56	0.95	21.32	24.19
LSD(0.05)	1.20	1.06	2.14	2.25	2.60	2.28	2.09	2.41
Interaction								
NPK X PM	*	*	NS	NS	NS	NS	*	*

PM= Poultry manure, NS= Not significant

Table 5: Interaction between NPK and poultry manure on fresh biomass weight (t ha⁻¹) of Sweet potato at harvest

Treatment	2018 Cropping season			2019 Cropping season		
	Poultry manure (t ha ⁻¹)			Poultry manure (t ha ⁻¹)		
Urea(kg ⁻¹)	0	5	10	0	5	10
0	12.67	14.82	16.89	12.84	14.76	16.67
50	14.90	16.45	17.27	15.45	17.62	17.76
100	17.45	17.42	19.23	17.25	17.98	19.80
LSD(0.05)	1.04			1.12		

Table 6: Interaction between NPK and poultry manure on total weight of tubers (t ha⁻¹) of Sweet potato at harvest

Treatment	2018 Cropping season			2019 Cropping season		
	Poultry manure (t ha ⁻¹)			Poultry manure (t ha ⁻¹)		
Urea(kg ⁻¹)	0	5	10	0	5	10
0	16.52	19.65	19.54	16.97	20.43	18.45
50	18.05	20.98	23.08	18.78	19.98	24.02
100	19.68	21.67	22.24	19.85	21.34	23.56
LSD(0.05)	1.02			1.12		

IV. DISCUSSIONS

The result in table one, showed that the soil was slightly acidic, sandy and already exhausted; which may be due to intensive and continuous cultivation and without adequate application of replenishment measures to sustain its productivity. This result agrees with finding of (Jayeoba *et al.*, 2012; Ndor and Iorkua, 2013), who reported that soils

around Lafia are exhausted and slightly acidic. The significant increase recorded in growth parameters (number of leaves, number of branches and vine length) of sweet potato could be attributed to the ability of both fertilizers (NPK and poultry manure) to activate spontaneous vigorous growth which may be as a result of the high content of nitrogen in both NPK and poultry

manure which stimulated vegetative growth in both years of cropping. This corroborates the finding of Muktar *et al.*, (2010), who worked on agronomic characteristics of sweet potato grown under organic and inorganic fertilizers. Also, the significant increased recorded in the weight of sweet potato tubers in both 2018 and 2019 cropping season as a result of increased application of poultry and NPK fertilizers. This may be attributed to the fact that, after incorporation poultry manure into the soil and addition of NPK (20:10:10) fertilizer, macronutrients were readily available within the soil for plant uptake. This resulted in the synthesis of more photo-assimilates, which is used in dry matter (DM) accumulation in sweet potato tubers. This result is in line with the discovery of Yeng *et al.*, (2012); who study the growth and yield of sweet potato (*Ipomoea batatas* L.) as influenced by integrated application of chicken manure and inorganic fertilizer in Ghana. The superior performance of poultry manure in both years (2018 and 2019) compared to NPK fertilizer may not be attributed to the high quality of poultry manure (Table 2) used only; but the poultry manure was also able to improve on water retention capacity and the reduction of soil acidity so that availability of macronutrient like phosphorus will be enhance (Adam, 2005). The significant interactions between NPK fertilizer and poultry manure on biomass weight and total tuber weight was an affirmation of the fact that combined applications of both organic and inorganic manure is essential for increased growth and yield (Yeng *et al.*, 2012).

V. CONCLUSION

From this study, it can be concluded that 100kg ha⁻¹ of NPK fertilizer and 10t ha⁻¹ produced the highest tuber weight of (21.12 and 22.72t ha⁻¹), and (21.32 and 24.19t ha⁻¹) in both 2018 and 2019 cropping seasons. Therefore, the above rates could be the optimal fertilizer level for a good growth and yield of sweet potato. For integrated nutrient management in sweet potato production 50kg ha⁻¹ of NPK fertilizer and 10t ha⁻¹ of poultry manure can be used. However, further locational trials should be conducted within the zone to confirm this result.

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