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THE PERFORMANCE AND PROFITABILITY OF SWEET POTATO (*Ipomoea batatas* L.) AS INFLUENCED BY PROPAGULE LENGTH AND APPLICATION RATES OF CATTLE DUNG IN HUMID ULTISOLS

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ABSTRACT
This study was conducted in 2013 and 2014 at the Teaching and Research Farm of the Faculty of Agriculture, University of Benin, Benin City, Nigeria. The aim of the study was to evaluate the effect of propagule length and cattle dung application rates on the growth, yield and profitability of sweet potato (Ipomea batatas* L.*) in a humid Ultisols. Treatments consisted of three different propagule lengths of vine cuttings (30, 40 and 50 cm) and three rates (0, 225 and 450 kg N ha^{-1}) of cattle dung in a 3 × 3 factorial arrangement fitted into randomized complete block design and replicated three times. The productivity of sweet potato was enhanced by the application of cattle dung and increasing propagule length positively. Growth and yield variables varied significantly with propagule length and cattle dung application. Number of vines, vine girth and number of leaves increased significantly with increase in propagule length. Cattle dung application rates of 225 and 450 kg N ha^{-1} had statistically at par number of vines, vine girth, vine length, number of nodes and leaves and leaf area index but significantly higher than unfertilized plants. The highest tuber yield of 26.10 and 22.00 t ha^{-1} was obtained from vine cutting of 40 cm and 20 t ha^{-1} cattle manure, respectively. The interaction of propagule length and cattle dung application rate on all growth and yield parameters were not significant. Tuber size significantly ($P \leq 0.05$) correlated positively with number of leaves ($r = 0.351$), number of nodes ($r = 0.288$), number of tubers ($r = 0.377$), tuber length ($r = 0.475$). Tuber yield significantly correlated positively with the number of leaves ($r = 0.335$), number of tubers ($r = 0.281$), tuber length ($r = 0.365$) and tuber size ($r = 0.652$). The appropriate propagule length and cattle dung application rates were 40 cm and 225 kg N ha^{-1}, respectively as they had the highest return per naira invested.

Key words: economic analysis, growth variables, organic fertilizer, tuber yield

INTRODUCTION
Sweet potato (*Ipomoea batatas* (L.) Lam Poir) is a member of the morning glory (Convolvulaceae) family, an important stable food in many countries of Sub-Saharan Africa with both domestic and industrial usages. It possesses medicinal properties with great nutritional values which exceeded other tuber crops such as yam, cassava and cocoyam (Loebenstein, 2009). The crop has a short growing period of 3-5 months depending on the variety, and this permits the growing of two or three crop cycles in a year. This crop is usually produced by resource-challenged farmers.

The yield per hectare of this crop in Nigeria is 6 t ha^{-1} (BNARDA, 2008). This is low and below African average yield of 7 t ha^{-1} (FAOSTAT, 2012). This implies low economic returns from farming activity and a discouragement to the farmers as this will further confirmed them to poverty and deprivation (Hahn *et al.*, 1993). The causes of low productivity of this crop among other factors can be attributed to unproductive cultural practices and low nutrient status of the soil (CRI, 2002). The low nutrient status of most Nigerian soils resulted from dominance of low-activity clays (Uzoh *et al.*, 2015), the practice of intensive cropping, slash and burn farming system associated with bush fallow and with excessive leaching of the soil (Zingore *et al.*, 2003). The system is presently unsustainable due to high population pressure and other human activities which have resulted in reduced fallow period (Steiner, 1991). Sweet potato is among the feeder crops which removes high amount of nutrients from the soil and inadequate nutrient availability to the plant had resulted in low productivity.

The problem of low productivity associated with intensive cropping practices has resulted to use inorganic fertilizers to enhance soil and crop productivity. The continuous use of these with inorganic fertilizers has led to pollution of ground water, inimical to the activity of soil microbes

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(Akinrinde, 2006), increased soil acidity and bulk density and does not improved soil structure (Gordon *et al*., 1993). Other problems associated with inorganic fertilizers are high cost, inaccessibility and unavailability of the products to farmers (Akanni et *al*., 2011).

These have necessitated the needs for alternative strategies that are environmental friendly, affordable and accessible to the poor-resource farmers. Hence, the research into the utilization of agricultural wastes for improved soil and crop productivity. Organic residue addition to soil is particularly important for maintenance of tropical soils (Uzoh *et al*., 2015). Many crop species respond well to the application of organic fertilizer in the form of cattle dungas it can sustain yield under continuous cropping on most soils unlike chemical fertilizer (Maynard, 1991). Organic fertilizer aimed at protecting the ecosystem, ensure environmental cleanliness and make the soil to be more productive and sustainable. Salawu and Mukhar (2008) reported that the application of organic fertilizers have significantly imparted on growth and yield of sweet potato. Cattle dung is an organic material high in nutrient (Guptal *et al*., 2004). As composted cattle dung contain beneficial bacteria which converts nutrients into easily accessible form that can be moderately released for the plant uptake.

Increase in the propagule length has been reported to increase sweet potato yield positively (Brobbey, 2015). Brobbey (2015) reported that tuber yield tend to increase with increase in propagule length used and a length of about 30 cm is recommended. Propagule length longer than this tends to be wasteful of plant material.

Several hypotheses have been formulated on the use of organic fertilizers and methods of propagation of sweet potato. However, there is paucity of information on the optimum combination of propagule length and cattle dung for sweet potato production especially in humid ultisols. Therefore, there is need to develop a sustainable cropping system through appropriate propagule length and supply of nutrient through fertilizer application for optimum production of sweet potato. This study was conducted to evaluate the effects of cattle manure and vine cutting size on the growth and yield of sweet potato in humid Ultisols.

MATERIALS AND METHODS

Site Description

The study was carried out at the Teaching and Research Farm of the Faculty of Agriculture, University of Benin, Benin City, Nigeria lying between longitude 5^0 E and 6^0 42′ E and latitude 5^0 45′ and 7^0 34′ N of the equator (FAAN, 2015). The experimental site had been cultivated in previous years, with no record of fertilizer application. One composite soil sample (0–30 cm depth) was taken from the site prior to planting and analyzed for routine soil physical and chemical properties using standard laboratory procedures (Mylavarapus and Kennelley, 2002). The cattle dung was analyzed for their chemical composition. The proximate nutrient composition of the cattle manure was pH 6.5, organic carbon 30.20g kg^{-1}, N 22.50 g kg^{-1} available P 8.90 g kg^{-1}, 3.40% Ca, 0.56% Mg and 0.45% K.

Field Experiment, Treatments and Data Collection

The experimental design was 3 × 4 factorial arrangement fitted into randomized complete block design with three replications. The factors are three (30, 40 and 50 cm) lengths of vine cutting and three rates (0, 225 and 450 kg N ha^{-1}) of cattle dung. The cattle dung before incorporation into the soil was cured for six weeks under shade and applied at the aforementioned rates at four weeks before planting. The sweet potato variety used for this study was "SPK004". Propagule length of sweet potato of various sizes (30, 40 and 50 cm) taken from apical sections of the plant were planted at the designated plots at a spacing of 1m between ridges and 0.30 m within rows on 12^{th} of April each year. The vines were planted at angle of $45^0$with about four nodes buried inside the ground. The planting depth was 5 cm. Weeding was done manually first at two weeks after planting and subsequently as of when due.

During the growing stage, data were collected on number of vines per plant, vine girth (cm), vine length (cm), number of nodes, internode length (cm), number of leaves and leaf area index at 4, 8 and 12 weeks after planting (WAP). Sweet potato leaf area was estimated using Ramaniyam and Indira (1978) formula and thus:

$$(LW.0.42).N$$

where *L* is leaf length, *W* is leaf width, and *N* is number of leaves. From the leaf area, leaf area index (LAI) was computed as thus (Remison, 1997):

$$\text{LAI} = \frac{Leaf\ area}{Land\ area}$$

At harvest, data were collected on tuber length (cm), number of tuber per plant, tuber size (g), tuber weight (g) and tuber yield (t ha^{-1}). Tuber weight was determined by weighing all harvested tubers within each net plot (1 m × 1 m) in grammes and dividing by the number of plants within the net plot. Tuber yield was estimated thus:

$$\text{Tuber yield (t ha}^{-1}) = \frac{g\ plant^{-1} x\ 10{,}000}{1{,}000{,}000}$$

Data Analysis

Analysis of data was done using Genstat Version 8.0 Statistical Software. Significantly different treatment means were separated and compared using Fisher's least significant difference (F-LSD) at 5% level of probability. Pearson's correlation coefficient was used to test a correlation between yield parameters and growth assessment at 12 WAP using Genstat Statistical Software. Economic analysis was determined for the most profitable combination of tested factors for sweet potato production (Erhabor, 2005). All expenses (variable cost which include total cost of labour (land preparation, planting, weeding, fertilization and harvesting), fertilizer (cattle dung), planting material (propagules) and transportation and revenue were calculated per hectare thus:

(i) GM = TR-TVC

where GM is gross margin, TR is total revenue, and TVC is total variable cost (all expressed in ₦ ha^{-1}).

Returned per naira invested = $\frac{TR}{TVC}$.

RESULTS

Initial Soil Physical and Chemical Properties of the Experimental Site

The results of the pre-planting soil analysis of the experimental site are presented in Table 1. The soil was sandy loam with slightly acidic condition in 2013 and highly acidic in 2014. Organic carbon, total nitrogen, exchangeable calcium and magnesium were adequate in 2013 while in 2014, only exchangeable calcium was adequate. For both 2013 and 2014, exchangeable K was inadequate, Ca: Mg ratio was less than 3 and effective cation exchange capacity was less than 10 cmol kg^{-1}.

Table 1: Physical and chemical properties of the soils of the experimental site prior to cropping with sweet potato

Parameter	2013	2014	Critical level
Particle size (g kg^{-1})			
Sand	710	690	
Silt	80	80	
Clay	210	230	
Textural class	Sandy loam		
Conductivity	578	95.90	
pH (H_2O) 1:1	6.10	5.20	
Organic carbon (g kg^{-1})	28.50	11.97	20-30[a]
Total N (g kg^{-1})	1.68	0.94	1.5-2.00[b]
Avalable P (mg kg^{-1})	7.28	5.33	10-16[c]
Exchangeable cations (cmol kg^{-1})			
Caclcium	4.35	2.40	2.50[d]
Magnesium	0.70	0.15	0.20-0.40[c]
Potassium	0.21	0.04	0.16-0.25[e]
Sodium	0.08	0.03	0.20[f]
Exchangeable acidity (cmol kg^{-1})	0.03	0.16	
ECEC	5.37	2.78	

[a]Adeoye and Agboola (1985), [b]Sobulu and Osiname (1995), [c]Adeoye and Agboola (1985), [d]Akinrinde and Obigbesan (2000), [e]Ibedu *et al*. (1988), [f]Amalu (1997)

Effect of Propagule Length and Cattle Dung on Plant Growth Parameters

Number of vines per plant

Number of vines per plant varied significantly with the propagule length in 2013 at 4 WAP (Table 2). In 2014, propagule lengths of 40 and 50 cm had similar number of vines per plant but significantly ($P < 0.05$) higher than propagule length of 30 cm. This was repeated in 2013 at 8 WAP. At 8 WAP in 2014 and 12 WAP in both years, only propagule length of 50 cm was significantly ($P < 0.05$) higher than that of 30 cm. However, propagule lengths of 40 cm and 50 cm were statistically the same. Cattle dung application rates of 225 and 450 kg N ha^{-1} had similar number of vines but significantly higher than those obtained from unfertilized plants at all assessment periods in both years of measurement. The interaction of propagule length and cattle dung application rates was not significant throughout the sampling periods in both years.

Sweet potato vine girth and length

At all periods of measurement in both years, vine girth did not significantly ($P > 0.05$) vary among propagule length (Table 3). Cattle dung application rates of 225 and 450 kg N ha^{-1} resulted in significantly ($P < 0.05$) larger vine girth than at 0 kg ha^{-1} at all periods of measurement in both years. There was no significant ($P > 0.05$) effect by the interaction of propagule length and cattle dung rate on the vine girth within the period of study.

The influence of propagule length and cattle dung application rate on vine length of sweet potato is presented in Table 4. The results revealed that propagule length of 30 cm significantly ($P < 0.05$) produced the longest vines at 4 WAP and 8 WAP in 2013 and 2014. In 2014, both propagule lengths of 30 and 50 cm produced statistically the same length but significantly ($P < 0.05$) longer than propagule length of 40 cm. Cattle dung application rates of 225 and 450 kg N ha^{-1} produced longer vines than those produced at 0 kg N ha^{-1}. The interaction of propagule length and cattle dung rate on vine length was not significant ($P > 0.05$).

Number of nodes and internode length

The number of nodes on the propagule length of 30 cm plants were significantly ($P < 0.05$) higher than on the propagule lengths of 40 and 50 cm plants in 2013 at 4 WAP (Table 5). There were significant ($P < 0.05$) differences in the number of nodes among cattle dung application rates at 4 WAP in 2013. At 4 WAT in 2013, cattle dung application rates of 225 and 450 kg N ha^{-1}gave statistically the same number of nodes but significantly ($P < 0.05$) higher than at 0 kg N ha^{-1}. There was no significant interaction of propagule length and cattle dung application rates on number of nodes at all the periods of measurement in both years.

Table 2: Number of vines of sweet potato as influenced by propagule length and cattle dung application rate

Treatment	4 weeks after planting		8 weeks after planting		12 weeks after planting	
	2013	2014	2013	2014	2013	2014
Propagule length (cm)						
30	2.26	2.10	3.89	4.40	4.37	4.72
40	2.28	2.98	4.56	4.76	4.83	5.20
50	2.59	2.79	4.92	5.10	5.11	5.51
LSD	ns	0.68	0.581	6.580	0.587	0.564
Cattle dung (kg N ha^{-1})						
0	1.92	1.99	4.08	4.13	4.16	4.57
225	3.04	3.11	4.48	4.81	4.88	5.13
450	2.67	2.77	4.82	5.33	5.26	5.73
LSD	0.645	0.68	0.581	0.580	0.587	0.564
Interaction	ns	ns	ns	ns	ns	ns

ns - not significant at 5% level of probability

Table 3: Vine girth (cm) of sweet potato as influenced by propagule length and cattle dung application rate

Treatment	4 weeks after planting		8 weeks after planting		12 weeks after planting	
	2013	2014	2013	2014	2013	2014
Propagule length (cm)						
30	1.20	1.56	1.57	1.59	1.74	1.76
40	1,17	1.64	1.59	1.67	1.76	1.84
50	1,15	1.68	1.66	1.71	1.85	1.92
LSD	ns	ns	ns	ns	ns	ns
Cattle dung (kg N ha^{-1})						
0	0.98	1.42	1.51	1.52	1.67	1.72
225	1.33	1.71	1.64	1.76	1.82	1.92
450	1.21	1.76	1.67	1.69	1.86	1.88
LSD	0.150	0.171	0.100	0.118	0.107	0.138
Interaction	ns	ns	ns	ns	ns	ns

ns - not significant at 5 % level of probability

Table 4: Vine length (cm) of sweet potato as influenced by propagule length and cattle dung application rate

Treatment	4 weeks after planting		8 weeks after planting		12 weeks after planting	
	2013	2014	2013	2014	2013	2014
Propagule length (cm)						
30	60.00	77.40	78.70	83.90	81.80	89.0
40	41.20	65.40	66.50	70.10	69.80	72.4
50	38.20	78.90	71.50	71.70	74.70	71.1
LSD	14.090	ns	ns	13.510	ns	12.980
Cattle dung (kg N ha^{-1})						
0	29.70	58.70	61.90	66.10	64.50	71.0
225	58.60	80.50	77.60	77.20	81.10	83.4
450	51.20	82.40	77.20	82.30	80.70	84.0
LSD	14.090	16.460	13.370	13.510	13.211	12.980
Interaction	ns	ns	ns	ns	ns	ns

ns - not significant at 5% level of probability

Table 5: Number of nodes of sweet potato as influenced by propagule length and cattle dung application rate

Treatment	4 weeks after planting		8 weeks after planting		12 weeks after planting	
	2013	2014	2013	2014	2013	2014
Propagule length (cm)						
30	19.39	28.00	26.00	27.70	28.20	30.10
40	13.89	29.40	26.80	27.00	29.50	29.10
50	12.71	26.60	23.20	24.20	25.70	25.70
LSD	3.681	ns	ns	ns	ns	ns
Cattle dung (kg N ha^{-1})						
0	12.51	23.40	22.00	23.60	24.40	25.10
225	16.70	30.60	27.50	28.20	30.50	29.90
450	16.79	26.60	26.50	27.70	28.40	29.90
LSD	3.081	ns	ns	ns	ns	ns
Interaction	ns	ns	ns	ns	ns	ns

ns - not significant at 5% level of probability

Table 6: Internode length (cm) of sweet potato as influenced by propagule length and cattle dung application rate

Treatment	4 weeks after planting		8 weeks after planting		12 weeks after planting	
	2013	2014	2013	2014	2013	2014
Propagule length (cm)						
30	2.45	3.67	3.15	3.99	3.64	4.35
40	2.05	4.83	2.93	3.51	3.17	3.79
50	2.05	2.97	2.84	3.49	3.23	3.87
LSD	0.379	ns	ns	ns	ns	ns
Cattle dung (kg N ha^{-1})						
0	1.67	4.73	2.83	3.55	3.27	3.78
225	2.60	3.55	3.14	3.74	3.48	4.18
450	2.28	3.20	2.94	3.69	3.28	4.03
LSD	0.379	ns	Ns	ns	ns	ns
Interaction	ns	ns	Ns	ns	ns	ns

ns - not significant at 5 % level of probability

At 4 WAT in 2013, internode length was significantly ($P < 0.05$) affected by propagule length (Table 6). Both propagule lengths of 40 and 50 cm had the same internode length but significantly ($P < 0.05$) lower than propagule length of 30 cm. Similarly, cattle dung application had significant effect on internode length at 4 WAP in 2013. The cattle dung application rates of 225 and 450 kg N ha^{-1} produced statistically the same internode length but significantly ($P < 0.05$) longer than those produced at 0 kg N ha^{-1}. There was no significant ($P > 0.05$) difference on internode length by the interaction of propagule length and cattle dung application rates

Sweet potato number of leaves and leaf area index

Results of the effect of propagule length and cattle dung application rate on the number of leaves are presented in Table 7. It revealed that the number of leaves were significantly ($P < 0.05$) affected by propagule length at 4 WAP in 2013 and 2014, 8 WAP in 2013 and at 12 WAP in 2014. At 4 WAP in 2013, the highest number of leaves (4.38) was observed in plants grown with propagule length of 40 cm. However, in 2014, propagule length of 50 cm had the highest number of leaves. This was repeated at 8 WAP in 2014. At 12 WAP in 2014, the propagule length of 50 cm significantly ($P < 0.05$) had higher number of leaves than those produced by propagule length of 30 cm plants. Number of leaves was significantly ($P < 0.05$) affected by different rates of cattle dung application throughout the period of measurement. The 225 and 450 kg N ha^{-1} rates of cattle dung application producing statistical the same number of leaves but significantly ($P < 0.05$) increased number of leaves more compared to control (0 kg N ha^{-1}) throughout the periods of measurement except at 4 and 12 WAP in 2014. At 4 and 12 WAP, the 450 kg N ha^{-1} fertilized plants had the highest number of leaves. The interaction of propagule length and cattle dung rate on number of leaves was not significant.

Leaf area index (LAI) was significantly ($P < 0.05$) higher plots planted with propagule length of 30 cm plants at 12 WAP in 2013 (Table 8). LAI increased significantly with increased rates of cattle dung application at all periods of measurement in both years except at 8 WAP in 2014. The cattle dung application rates of 225 and 450 kg N ha^{-1} resulted in statistically the same LAI but significantly ($P < 0.05$) higher compared with control (0 kg N ha^{-1}) except 8 and 12 WAP in 2013, in which 225 kg N ha^{-1} had the highest LAI. Propagule length and cattle dung application rates interaction effects were not significant ($P > 0.05$) in all the measurement periods in both years.

Sweet potato tuber yield and its components

Effect of propagule length and cattle dung application rates is presented in Table 9. Propagule length of 40 cm plants gave significant ($P < 0.05$) longer tubers in 2013. However, in 2014, propagule length had no significant ($P > 0.05$) effect on tuber length. Increase in the rates of cattle dung application also increase tuber length in 2013 and 2014. However, the cattle dung rates of 225 and 450 kg N ha^{-1} resulted in statistically similar tuber length but significantly ($P < 0.05$) higher compared

Table 7: Number of leaves of sweet potato as influenced by propagule length and cattle dung application rate

Treatment	4 weeks after planting		8 weeks after planting		12 weeks after planting	
	2013	2014	2013	2014	2013	2014
Propagule length (cm)						
30	3.89	5.22	9.78	12.44	12.11	18.44
40	4.89	5.33	9.22	13.67	10.89	19.44
50	3.89	6.33	10.67	13.22	11.67	20.44
LSD	0.950	0.608	1.073	ns	ns	1.703
Cattle dung (kg N ha^{-1})						
0	3.00	3.89	7.89	11.22	9.56	16.78
225	5.00	6.11	11.00	14.00	12.78	19.89
450	4.67	6.89	10.78	14.10	12.33	21.67
LSD	0.950	0.608	1.073	1.593	1.755	1.703
Interaction	ns	ns	ns	ns	ns	ns

ns - not significant at 5% level of probability

Table 8: Leaf area index of sweet potato as influenced by propagulelength and cattle dung application rate

Treatment	4 weeks after planting		8 weeks after planting		12 weeks after planting	
	2013	2014	2013	2014	2013	2014
Propagule length (cm)						
30	0.27	0.60	1.05	1.43	1.48	2.21
40	0.36	0.51	0.82	1.30	1.04	1.99
50	0.28	0.63	0.97	1.45	1.19	2.14
LSD	ns	ns	ns	ns	0.32	ns
Cattle dung (kg N ha^{-1})						
0	0.19	0.38	0.71	1.13	0.97	1.81
225	0.40	0.70	1.18	1.59	1.54	2.37
450	0.32	0.66	0.94	1.46	1.20	2.15
LSD	0.083	0.138	0.235	ns	0.320	0.455
Interaction	ns	ns	ns	ns	ns	ns

ns - not significant at 5 % level of probability with the control in both years. This performance pattern by the treatments was also reflected in the number of tuber per plant. Propagule length and cattle dung application rates had no significant effect on average tuber size in 2013 and 2014. The interaction effect of propagule length and cattle dung application rates on tuber length, number of tuber and tuber size were not significant (P > 0.05).

Tuber weight of propagule lengths of 30 and 40 cm plants were higher (P < 0.05) than the propagule length of 50 cm in 2013. The 225 and 450 kg N ha^{-1} cattle dung application rates had statistically the same tuber weight but significantly (P < 0.05) higher than control (0 kg N ha^{-1}) in both years. This performance pattern by the cattle treatments was also repeated in tuber yield in 2013 and 2014. The highest tuber yield was produced by the propagule length of 40 cm in 2013. However, in 2014, all propagule lengths had similar tuber yield.

The results of correlation analysis showed that tuber weight is significantly correlated with numbers of leaves, nodes, tubers, and tuber length (0.351, 0.288, 0377 and 0.475, respectively) (Table 10). Tuber yield per plant was significantly positively correlated with number of tuber (r = 0.388), tuber length (r = 0.405), tuber weight (r = 0.337) and tuber yield per plant (r = 0.609).

The total variable cost increased as the rate of cattle dung application and propagule length increased up to the longest length (Table 11). Revenue, gross margin and return per naira invested increased as cattle dung application rate increased up to 450 kg N ha^{-1}. Returned per naira invested was highest at propagule length of 40 cm and 225 kg N ha^{-1} cattle dung with 2.47 and 2.03, respectively.

Table 9: Sweet potato tuber yield and is components as influenced by propagule length and cattle dung application rates

Treatment	Tuber length (g)		Number of tubers		Tuber size (g)		Tuber weight (g plant^{-1})		Tuber yield	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Propagule length (cm)										
30	6.33	5.88	1.56	1.67	85.00	44.90	181.00	74.00	17.00	7.00
40	11.67	7.64	3.07	1.82	131.00	42.00	212.00	70.00	42.40	9.70
50	6.31	5.23	1.74	1.67	85.00	40.60	90.00	70.20	18.00	7.30
LSD	2.290	ns	0.653	ns	ns	ns	18.650	ns	16.270	ns
Cattle dung (kg N ha^{-1})										
0	6.03	4.08	1.11	1.01	86.00	43.70	151.00	39.20	13.70	3.90
225	9.98	6.93	2.78	2.07	122.00	43.90	161.00	82.30	30.10	10.40
450	8.30	7.75	2.48	2.07	112.00	48.90	171.00	92.80	34.10	10.00
LSD	2.290	2.712	0.653	0.756	ns	ns	18.65	42.970	16.270	5.820
Interaction	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

ns - not significant at 5% level of probability

Table 10: Correlation analysis of different variables of sweet potato (*I. batatas*)

Variable	Internode length	Leaf area index	Number of leaves	Number of nodes	Number of tubers	Number of vines	Tuber length	Tuber size	Tuber yield	Tuber weight	Vine length	Vine girth
Internode length	1.00											
Leaf area index	0.626*	1.00										
Number of leaves	0.496*	0.798*	1.00									
Number of nodes	0.171	-0.112	0.086	1.00								
number of tubers	0.178	-0.006	-0.040	0.313*	1.00							
Number of vines	0.195	0.471*	0.576*	0.127	0.300*	1.00						
Tuber length	-0.048	0.102	-0.017	0.166	0.749*	0.382*	1.00					
tuber size	-0.113	-0.254	0.351*	0.288*	0.377*	0.015	0.475*	1.00				
Tuber yield	-0.075	-0.205	0.337*	0.090	0.281*	0.005	0.365*	0.652*	1.00			
Tuber weight	0.013	0.183	0.068	-0.002	0.388*	0.179	0.405*	0.337*	0.609*	1.00		
Vine length	0.407*	0.422*	0.393*	0.457	0.120	-0.394	0.259	0.072	-0.131	0.034	1.00	
Vine girth	0.324*	0.261	0.400*	0.208	0.211	0.427*	0.100	-0.088	-0.113	-0.075	0.244	1.00

*significant at 5% level of probability

Table 11: economic analysis of sweet potato as influenced by propagule length and cattle dung application rate

Item (₦ ha^{-1})	Propagule length (cm)			Cattle dung (kg N ha^{-1})		
	30	40	50	0	225	450
Total variable cost	300500	317500	334500	285500	300500	325500
Output (t ha^{-1})	21.60	26.10	12.70	18.10	20.30	22.00
Revenue	648000	783000	381000	543000	609000	660000
Gross margin	247500	465000	46500	257500	308500	334500
Return per naira invested	2.16	2.47	1.14	1.90	2.03	2.02

Exchange rate ₦197 = $1

DISCUSSION

This study had demonstrated that sweet potato growth and yield can be increased through increase in propagule length and cattle dung application rates of 225 and 450 kg N ha^{-1}. However, both factors acted independently as the interaction between the propagule length and cattle dung application rate was not significant (p = > 0.05). The number of vines per plant significantly increased with increase in the propagule length. This could probably be due to higher number of nodes associated with longer propagule lengths than shorter propagule lengths. The longer propagule lengths have more nodes than the shorter ones. These nodes serve as points of emergent of vines. Longer propagule lengths had higher amount of assimilates which probably favoured larger vine production. Larger vines are a precursor to higher number of leaves as indicated through positive correlation between vine girth and number of leaves. This is an indication of higher amount of assimilates for node and leaf production. The positive correlation between number of vines and girth is an indication that the number of vines increased with increase vine girth. The shorter propagule lengths tend to more efficiently utilize the available resources to nourish the fewer vines per plant than the longer propagule lengths with more vines per plant. This resulted in the production of longer vines by by negative correlation between the number of vines and vine length (r = -0.394).

The number of nodes was higher with shorter propagule lengths plant and there existed a positive correlation between vine length and number of nodes which indicated that higher number of nodes are associated with shorter propagule lengths which had longer vines due to fewer of vines unlike the longerpropagule lengths that gave rise to shorter vines due to higher number of vines.

Increased in vine girth with cattle dung application resulted in the retention of appreciable amount of assimilates in the vine for node and leaf production couple with longer vines. The significant increase in vine length with cattle dung application is a reflection of enhancement of nutrients, N, P and K. The non-cattle dung treated plants had shorter and thinner vines due to low native soil fertility resulting from insufficient absorption of nutrients by the plants. Since leaf is an organ of photosynthesis, any changes in the number of leaves is bound to affect the overall performance of the crop. Increase in the number of leaves and vines to a certain limit are precursor to greater amount of assimilates and thus allowing more translocation to the tuber. This was evidenced through significant correlation between number of leaves and tuber yield per hectare (0.337). This indicated the intensification of the bulking ability of the plant as number of leaves increases with longer vine plants. This observation is in agreement with Law-Ogbomo and Remison (2007) who reported that tuber yield in yam is dependent on the amount; rate and duration of assimilates translocated to it.

In this study, increase in propagule length significantly increased tuber yield. Propagule lengths of 50 cm resulted in lowest tuber yield. Apparently, propagule lengths of 50 cm had more vegetative growth as evidenced by number of leaves, vines, shorter internodes and thicker vines resulted at the expense of tuberization. Earlier Brobbey (2015) reported that tuber yield tend to increase with increase in the propagule length used and a length of about 30 cm is recommended. Propagule lengths greater than this tend to be wasteful of planting material, while propagule lengths shorter than 30 cm establish slowly, and give poorer yields. In this present study, propagule lengths of 40 cm gave tuber yield greater than African average and propagule lengths of 40 cm were the optimum. This observation was in agreement with Prasad (1989) who reported propagule lengths of 40 cm as the most appropriate. Propagule lengths of 40 cm is most appropriate for commercial propagation as evidenced through longest tubers, highest number of tuber per plant and heaviest tubers.

The soils of the experimental site were sandy loam, moderately acidic and deficient in available phosphorus. However, the soil of the experimental site in 2014 was deficient in organic carbon, exchangeable calcium, potassium and magnesium. Since Ca/Mg is less 3 and the effective cation exchange capacity is less than 10 cmol kg^{-1} indicating that the soil is a typical ultisol. This observation is in agreement with Ezekiel *et al* (2009) who reported that the ultisols of Southeastern Nigeria are low in exchangeable Ca, K and Mg. The deficiency of these nutrients in the soil necessitated the use of external fertilizer input. Ali *et al* (2009) reported that the application of fertilizer is one of the most important inputs for increasing the productivity of crops.

The cattle dung was relatively high in organic carbon and fair in amount of plant nutrients. Organic carbon is a store room of plant nutrients and increase soil microbial activities by creating conducive environment for their multiplication. The cattle dung with high quantity of organic carbon can improve the soil physical properties through the stabilization of the soil structure which in turn will reduced the bulk density and improved soil porosity and water retention capacity (Vanlauwe, 2000). Organic carbon when decomposed and mineralized, nutrients are release to the soil for plant uptake.

This present study showed that cattle dung application increased tuber yield. This is a confirmation of the fact that fertilization for efficient nutrient use by plants has been identified as a necessary cultural input for improving growth and yield of the crop. The application cattle dung to sweet potato had positive effects on the performance of the crop in both years.

The superiority of the cattle dung treated plants over the non fertilized plants in terms of growth (number of vines, nodes and leaves, vine girth, vine length and leaf area index) indicated that the plants benefited from the applied cattle dung.

All fertilized plants exhibited higher number of vines per plant, thicker vines and longer vines resulting in higher number of leaves and LAI. As a consequence, high amount of radiation was intercepted contributing to an increase in tuber yield over unfertilized plant. The unfertilized plants had lower LAI due to lower number of leaves resulting from less number of vines per plants, thinner vines and shorter vines leading to reduction in tuber yield in comparison to fertilized plants. The present study revealed tuber yield of the fertilized plants was accounted for significantly by nutrient availability (Udo *et al*., 2005). Low yield observed among the unfertilized plants could probably be due to poor availability of soil nutrients for the crop to utilize.

The higher tuber yield in 2013 over 2014 was probably due to better soil conditions of 2013 experimental site over 2014 site leading to better growth of 2013 plants over 2014. This probably resulted in higher yields in 2013 than 2014.

This study clearly showed that sweet potato productivity can be increased in humid Ultisols through cattle manure application and increase in propagule lengths up to 40 cm. This can further be proven by economic analysis of the study. Despite the high cost of production associated with the application of cattle manure and the use of longer propagule length due to additional use of fertilizer inputs and additional quantity of planting material, sweet potato production in the humid Ultisols is viable. There is positive relationship between tuber yield improvement and economic viability in sweet potato production. Return per naira invested is an indication of viability and the optimum yield was obtained from propagule lengths of 40 cm and 225 kg N ha^{-1} which had the highest return per naira invested. On the part of fertilizer application, it implies that maximum yield does not connote maximum profit per amount of money invested (Erhabor, 2005). The maximum return per naira invested indicated the point of profit maximization and beyond that point, diminishing return set in.

CONCLUSION

This study showed that tuber yield was increased through the use of propagule lengths of 40 cm and increased application rates of cattle dung. Though additional cost was incur through the use of cattle manure input and more quantity of planting material, the enterprise was profitable. Based on this fact, the farmers should adopt propagule length of 40 cm and cattle dung application rate of 225 kg N for optimum production of sweet potato in the humid Ultisol. For future study, cattle manure should be compared with other organic fertilizers (such as poultry manure, compost, swine manure, etc.) for the production of sweet potato.

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